

**DEVELOPMENT OF A SMARTPHONE APP-
BASED INTERVENTION TO PROMOTE
PHYSICAL ACTIVITY AMONG PEOPLE
LIVING WITH AND BEYOND CANCER**

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University College London

Declaration

I, Anna Louise Roberts, confirm that the work presented in the thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Acknowledgements

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I feel incredibly lucky to have been able to study in the Department of Behavioural Science & Health, surrounded by the most inspiring, caring and friendly colleagues, who have made it a joy to come to work. I am particularly grateful to all of those who I've shared the PhD room with at some point or another – for the friendship, fun, advice...and cake. I would also like to thank the many other colleagues who I've had the pleasure of working alongside. Special thanks to Dr Rebecca Beeken, Dr Clare Llewelyn and Dr Helen Croker, who have always provided such constructive and insightful feedback on my work, and to Dr Dimitrios Koutoukidis and Claire Stevens for their assistance in analysing the qualitative studies in this thesis.

I would like to gratefully acknowledge the Medical Research Council, who funded this work, and the opportunities to meet colleagues and friends working in this field across the world. I am also extremely grateful to the participants who took the time to take part in each of the studies included in this thesis.

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Lastly, I would like to dedicate this thesis to the memory of Lynne Crisford, who died of metastatic breast cancer in 2003. Her strength, love and ability to enjoy life was remarkable and she has been a huge source of inspiration for this work.

Abstract

With increasing numbers of people being diagnosed with cancer, and living for many years after diagnosis, it is important that cancer survivors are supported to live well, for as long as possible. Physical activity improves quality of life and many treatment side effects after cancer. Physical activity is important in reducing the risk of other common comorbid conditions and may prolong survival in cancer survivors. However, many cancer survivors do not meet recommended levels of physical activity and evidence-based interventions that are accessible and that could be implemented at scale are needed. The rising use of the internet, smartphones and mobile technology mean that digital interventions could reach large proportions of the population in a way that could be more cost-effective and scalable. This thesis used mixed-methods to conduct a series of studies with the aim of developing a smartphone-app based intervention to promote physical activity in breast, prostate and colorectal cancer survivors. Study 1 showed that digital interventions have the potential to increase cancer survivors' moderate-vigorous physical activity by 41 minutes per week, however high-quality studies are lacking. Study 2 found that 38% and 24% of breast, prostate and colorectal cancer survivors respectively are interested in internet-based and app-based health behaviour interventions. Interest is related to several sociodemographic and participant characteristics. Study 3 found that physical activity apps must acknowledge the varying needs and physical activity preferences of cancer survivors. Apps that promote walking and are recommended to them by members of their clinical team (particularly Clinical Nurse Specialists) are favoured. Study 4 provided insight into Clinical Nurse Specialists' perceptions of their role in physical activity promotion and showed that they are generally positive about the use of apps to complement existing physical activity promotion in cancer care. Together, these studies led to the development of an app-based physical activity intervention for cancer survivors.

Impact Statement

The research reported in this thesis has potential for impact both inside and outside of academia. It is important that people affected by cancer are supported to live as long and as well as possible in the years after they are diagnosed. Effective physical activity promotion in cancer care has the potential to improve a range of patient and public benefit outcomes. Even small increases in physical activity after a cancer diagnosis may prolong survival and reduce the risk of second primary cancers/cancer recurrence, while also substantially reducing the risk of other long-term conditions (e.g. cardiovascular disease, diabetes). Physical activity also improves quality of life and other common cancer-related side effects (including sleep quality, fatigue, pain, anxiety and depression). There are also potential economic benefits of effective physical activity promotion in cancer care, including increased rates of returning to work and reduced health and social care service use. It is therefore important that cancer survivors are supported to increase their physical activity after diagnosis with interventions that are evidence-based, accessible and have the feasibility to be rolled out across cancer care.

The formative work presented in this thesis has led to the development of an app-based intervention that could be evaluated to determine whether it increases physical activity participation or improves outcomes such as quality of life, fatigue and sleep. As co-Principal Investigators, my primary supervisor (Dr Abi Fisher) and I, submitted a successful funding application to Yorkshire Cancer Research (£620,418) to conduct the next stage of the research, which will be a direct continuation of the studies reported in this thesis. This project will evaluate a smartphone app-based physical activity intervention that could be delivered as part of routine cancer care. If successful, this intervention could be rolled out nationally across the health service for any health professional that works with cancer patients. This work is due to start in Autumn 2019.

With regards to dissemination of the work included in this thesis, two of the four studies have been published in peer-reviewed journals, and a third has been submitted for peer-review. The studies have also been presented, as oral and poster presentations, at several international academic conferences.

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Abbreviations

Abbreviation	Meaning
ADT	androgen deprivation therapy
ASCOT	Advancing Survivorship after Cancer: Outcomes Trial
BCT(s)	behaviour change technique(s)
BMI	body mass index
CCG	Clinical Commissioning Group
CI	confidence interval
CIPN	chemotherapy-induced peripheral neuropathy
CNS(s)	Clinical Nurse Specialist(s)
COM-B	Capability Opportunity Motivation - Behaviour
CRF	cancer-related fatigue
CRN	Clinical Research Network
CRP	C-reactive protein
CT	computerised tomography
CVD	cardiovascular disease
DHBCI(s)	digital health behaviour change intervention(s)
EMR	electronic medical record
EORTC QLQC30	European Organisation for Research and Treatment of Cancer Quality of Life Questionnaire-core 30
F&V	fruit and vegetable
FACT-G	Functional Assessment of Cancer Therapy-General
GLTEQ	Godin Leisure-Time Exercise Questionnaire
GP(s)	General Practitioner(s)
HbA1c	average blood glucose levels
HES	Hospital Episode Statistics
HR	hazard ratio
HRQoL	health-related quality of life
ID	identification
IGF	insulin-like growth factor
IGFBP	insulin-like growth factor binding protein
IL	interleukin
IMAT	intra-muscular adipose tissue
IT	information technology
J&J	The Johnson & Johnson Official 7 Minute Workout
MAR	missing at random
MCAR	missing completely at random
MD	mean difference
MET	metabolic equivalent of task
MNAR	missing not at random
MWT	minute walk test
NCRAS	National Cancer Registration and Analysis Service
NCSI	National Cancer Survivorship Initiative
NHS	National Health Service
NICE	The National Institute for Health and Care Excellence
NS	non-significant
NSCLC	non-small-cell lung cancer
OE	outcome expectancy
OR	odds ratio
OT	Occupational Therapist
PA	physical activity

PSQI	Pittsburgh Sleep Quality Index
QoL	quality of life
RCT(s)	randomised controlled trial(s)
RR	relative risk
SB	Sedentary behaviour
SCT	Social Cognitive Theory
SD	standard deviation
SE	self-efficacy
SEP	socioeconomic position
SF-36	Short-Form (36) Health Survey
SMART	specific, measurable, attainable, realistic, timely
SMD(s)	standardised mean difference(s)
TNF	tumour necrosis factor
TTM	Transtheoretical Model
UK	United Kingdom
USA	United States of America
VO ₂ ^{max}	maximum rate of oxygen consumption
WES	weighted effect size
WMD	weighted mean difference

Publications

The following peer-reviewed publications and conference presentations have resulted from the work presented in this thesis:

Peer-reviewed publications:

Roberts, A. L., Fisher, A., Smith, L., Heinrich, M., & Potts, H. W. W. (2017). Digital health behaviour change interventions targeting physical activity and diet in cancer survivors: a systematic review and meta-analysis. *J Cancer Surviv*, 11 (6), 704-719. doi: 10.1007/s11764-017-0632-1.

Roberts, A. L., Potts, H. W. W., Koutoukidis, D. A., Smith, L., & Fisher, A. (2019). Breast, Prostate, and Colorectal Cancer Survivors' Experiences of Using Publicly Available Physical Activity Mobile Apps: Qualitative Study. *JMIR Mhealth Uhealth*, 7 (1), e10918. doi: 10.2196/10918.

Oral conference presentations:

Roberts, A. L., Potts, H. W. W., Smith, L., Heinrich, M., & Fisher, A. Cancer survivors' experiences of using publicly available physical activity mobile apps: a qualitative analysis. February 2017. 2nd Behaviour Change Conference: Digital Health & Wellbeing. London, United Kingdom.

Roberts, A. L., Potts, H. W. W., Koutoukidis, D. A., Smith, L., & Fisher, A. Cancer survivors' experiences of using publicly available physical activity mobile apps: a qualitative study. June 2018. International Society of Behavioural Nutrition & Physical Activity Annual Meeting. Hong Kong.

Roberts, A. L., Potts, H. W. W., Stevens, C., Smith, L., & Fisher, A. Breast, prostate and colorectal cancer specialist nurses' perspectives of physical activity promotion and the potential role of smartphone-based physical activity interventions in cancer care: a qualitative study. June 2019. International Society of Behavioural Nutrition & Physical Activity Annual Meeting. Prague, Czech Republic.

Poster conference presentations:

Roberts, A. L., Potts, H. W. W., Smith, L., Heinrich, M., & Fisher, A. Cancer survivors' experiences of using publicly available physical activity mobile apps: a qualitative analysis. May 2017. GetAMoveOn 1st Annual Symposium. London, United Kingdom.

Roberts, A. L., Fisher, A., Smith, L., Heinrich, M., & Potts, H. W. W. Digital health behaviour change interventions in cancer survivors: a systematic review and meta-analysis. June 2017. International Society of Behavioural Nutrition & Physical Activity Annual Meeting. Victoria, Canada.

Roberts, A. L., Lally, P., Potts, H. W. W., Beeken, R. J., Croker, H., Smith, L., & Fisher, A. Interest in digital interventions among breast, prostate and colorectal cancer survivors in the United Kingdom: a cross-sectional study. June 2018. International Society of Behavioural Nutrition & Physical Activity Annual Meeting. Hong Kong.

The following peer-reviewed publications and conference presentations highlight other work I have been involved in throughout, but are not directly reported in this thesis:

Peer-reviewed publications:

Puskiewicz, P.*, **Roberts, A. L.***, Smith, L., Wardle, J., & Fisher, A. Assessment of cancer survivors' experiences of using a publicly available physical activity mobile application. (2016). *JMIR Cancer*, 2 (1), e7. doi: 10.2196/cancer.5380. (* joint first author)

Poster conference presentations:

Crocker, H., Lally, P., **Roberts, A. L.**, Fisher, A., & Beeken, R. J. Perceptions of the importance of weight and dietary factors as causal factors for cancer and for preventing recurrence in patients with breast, colorectal and prostate cancer. May 2018. 25th European Congress on Obesity. Vienna, Austria.

Lally, P., **Roberts, A. L.**, Crocker, H., Beeken, R. J., & Fisher, A. Interest in Advancing Survivorship Cancer Outcomes Trial (ASCOT): characterising cancer survivors who were interested in participating in a trial of a lifestyle intervention. June 2018. International Society of Behavioural Nutrition & Physical Activity Annual Meeting. Hong Kong.

Beeken, R. J., Williams, K., **Roberts, A. L.**, Lally, P., Crocker, H., & Fisher, A. Perceptions of physical activity and diet among UK adults diagnosed with breast, prostate or colorectal cancer. June 2018. International Society of Behavioural Nutrition & Physical Activity Annual Meeting. Hong Kong.

Chavez-Ugalde, Y., Lally, P., **Roberts, A. L.**, Crocker, H., Beeken, R. J., & Fisher, A. Associations between loneliness and health behaviours in breast, prostate and colorectal cancer survivors in the United Kingdom: a cross-sectional study. June 2018. International Society of Behavioural Nutrition & Physical Activity Annual Meeting. Hong Kong.

Contributions to the work reported in this thesis

I designed and carried out the studies reported in this thesis, together with my supervisors Dr Abigail Fisher, Dr Henry Potts, Dr Lee Smith and Dr Phillippa Lally.

For Study 1 (Chapter 3), I prepared and registered the systematic review protocol, developed and refined the search strategy, and screened titles, abstracts and full-text articles for study selection (with a sub-sample reviewed for reliability by Dr Abi Fisher). I carried out data extraction and data preparation for the meta-analyses, which I conducted with support from Dr Henry Potts. I prepared the study manuscript, submitted it to the Journal of Cancer Survivorship (where it is now published) and addressed comments provided during peer-review.

The analyses reported in Study 2 (Chapter 4) are part of a larger programme of work funded by Cancer Research UK. I was involved in data entry of survey data, which was outsourced to a third party company due to the volume of surveys returned. I oversaw the outsourcing of data entry, which included obtaining and negotiating quotes, liaising with UCL Research Contracts to develop appropriate service agreements, ensuring that appropriate data security, information governance and risk assessment procedures were in place. I also organised collection and delivery of questionnaires and was responsible for quality assurance. Dr Phillippa Lally and I cleaned all of the returned questionnaire data. I developed the research question, prepared the analysis plan and conducted the analyses for the study reported in this thesis.

For Study 3, I developed the research question, designed the study protocol, submitted the appropriate applications required for data protection and ethical approvals, and recruited and enrolled participants to the study. I carried out data collection and analysis, and developed the coding framework with Dr Dimitrios Koutoukidis, who analysed a sub-sample of interviews. I prepared the study manuscript, which was submitted to the Journal of Medical Internet Research. I addressed comments provided during peer review and this study is now published in the sister journal JMIR Mhealth Uhealth.

For Study 4, I developed the research question, designed the study protocol, submitted the appropriate applications required for data protection and ethical approvals, and recruited and enrolled participants to the study. I carried out data collection and analysis, and developed the coding framework with Ms Claire Stevens, who analysed a sub-sample of interviews.

Chapter 1: An Introduction to Cancer Survivorship and Physical Activity

1.1 Cancer Survivorship

1.1.1 The growing prevalence of cancer survivors

Over 14 million people worldwide are diagnosed with cancer each year and this is expected to rise to 22 million over the next two decades (Ferlay et al., 2015). In the United Kingdom (UK), it is estimated that 1 in 2 people born after 1960 will be diagnosed with cancer (excluding non-melanoma skin cancer) at some point in their lifetime (Ahmad, Ormiston-Smith, & Sasieni, 2015). There were almost 360,000 new cancer diagnoses in the UK in 2015 and cancer incidence has risen by 13% between 1993-1995 and 2013-2015 (3% among men and by 16% among women) (Cancer Research UK). Breast, prostate, lung and bowel cancers account for over half (53%) of all new cancers diagnosed in the UK (Cancer Research UK).

Despite the increasing cancer incidence, improvements in early diagnosis and treatments mean that cancer survival is also improving and more people are living with and beyond the disease for many years. In 2012, there were 32 million people worldwide living beyond 5 years of a cancer diagnosis (Ferlay et al., 2015) and in the UK, half of people diagnosed with cancer will survive more than 10 years (Quaresma, Coleman, & Rachet, 2015). In 2015, it was estimated that there were over 2.5 million people living after a diagnosis of cancer in the UK, and this is expected to increase by 3% each year (Maddams, Utley, & Moller, 2012). By 2030, it is expected that the number of people living with or beyond cancer in the UK will be almost 4 million (Maddams et al., 2012).

1.1.2 Defining cancer survivorship

Several terms are used to describe people diagnosed with cancer within academic literature and by various health and cancer support organisations (e.g. cancer charities). Some have adopted the use of people-first language and use terms such as “people living with and beyond cancer” or “people affected by cancer”. For the purposes of this thesis, the term “cancer survivor” will be used, which reflects the definition used by the National Cancer Institute, where “a person is considered to be a survivor from the time of diagnosis until the end of life” (National Cancer Institute). The growing number of cancer survivors has increased the attention on cancer

survivorship, which “focuses on the health and life of a person with cancer, post treatment until the end of life. It covers the physical, psychosocial, and economic issues of cancer, beyond the diagnosis and treatment phases” (National Cancer Institute).

1.1.3 Consequences of cancer survivorship

As described in the following sections, even when an individual survives, the consequences of a cancer diagnosis, treatment and side effects are common, can be debilitating and often long-lasting. As such, they can have a profound impact on cancer survivors' health, wellbeing and quality of life.

1.1.3.1 Physical consequences

Fatigue, pain, chemotherapy-induced peripheral neuropathy, sleep disturbance/insomnia, lymphoedema and changes in body weight and composition are some of the most common physical side effects of cancer and associated treatments, often with a detrimental impact on health and wellbeing.

1.1.3.1.1 Fatigue

Cancer-related fatigue (CRF) can be defined as a “persistent, subjective sense of tiredness related to cancer and cancer treatment that interferes with usual functioning” (Mock et al., 2000). CRF is the most commonly reported symptom for those who have undergone cancer treatment (Morrow, Andrews, Hickok, Roscoe, & Matteson, 2002; Wagner & Cella, 2004). Prevalence estimates range between 59-100% (Weis, 2011), depending on cancer type, the type(s) of treatment(s) experienced and varying approaches to measuring CRF (Jacobsen, 2004). In a narrative review of the prevalence of CRF, Hofman et al. report that up to 90% of cancer patients treated with radiotherapy and up to 80% of those treated with chemotherapy experience CRF (Hofman, Ryan, Figueroa-Moseley, Jean-Pierre, & Morrow, 2007).

Furthermore, fatigue can persist many years after the completion of treatment. An observational longitudinal study of 763 breast cancer survivors reported that 35% of the sample were classified as fatigued 1-5 years after diagnosis and 34% were classified as fatigued 5-10 years post-diagnosis (Bower et al., 2006). Approximately a fifth of the sample (21%) were classified as fatigued at both assessment points, illustrating the persistence of fatigue. In this study, women treated with a combination of radiotherapy and chemotherapy were more likely to be fatigued

compared to women treated with either radiotherapy or chemotherapy alone (Bower et al., 2006). Depression and cardiovascular problems (e.g. hypertension) were also longitudinal predictors of fatigue (Bower et al., 2006). Almost a third of recurrence-free prostate cancer survivors reported fatigue in a sample of 416 participants surveyed >1 year after radiotherapy or radical prostatectomy (Storey et al., 2012). A more recent cross-sectional study compared fatigue among 6011 long-term endometrial, colorectal, thyroid, Hodgkin lymphoma, non-Hodgkin lymphoma and multiple myeloma cancer survivors from the Netherlands with a representative age- and gender-matched normative population (Husson et al., 2015). Husson and colleagues reported significantly higher fatigue among the cancer survivor group (varying between 39% among endometrial and colorectal cancer survivors to 51% of the multiple myeloma survivors) compared with 21% of the age- and gender-matched normative population (Husson et al., 2015). Fatigue was higher for short-term survivors (<5 years post-diagnosis), younger participants, females, those who had undergone chemotherapy treatment, with a greater number of comorbidities, lower educational level and without a partner (Husson et al., 2015).

1.1.3.1.2 Pain

Cancer and its treatment can cause acute or chronic pain via damage to body tissue and the nervous system as a result of the cancer site, surgery, chemotherapy and/or radiotherapy. In a meta-analysis of 117 studies reporting the prevalence of pain among adult cancer survivors, van den Beuken-van Everdingen et al. reported that the prevalence of pain was 39% after curative treatment (29 studies, n = 18,832), 55% during cancer treatment (29 studies, n = 6,904), 66% in those with advanced, metastatic or terminal cancer (24 studies, n = 9,653) and 51% in studies that included all cancer stages (18 studies, n = 17,682) (van den Beuken-van Everdingen, Hochstenbach, Joosten, Tjan-Heijnen, & Janssen, 2016). Moderate-severe pain was reported by 38% of participants across the 52 studies included that reported pain severity (van den Beuken-van Everdingen et al., 2016).

1.1.3.1.3 Chemotherapy-induced Peripheral Neuropathy (CIPN)

Nerve damage, such as peripheral neuropathy, is estimated to affect 30-40% of patients receiving chemotherapy (Wolf, Barton, Kottschade, Grothey, & Loprinzi, 2008) and can cause neuropathic pain, sensitivity, numbness, tingling or weakness in the hands, feet and arms and loss of balance and co-ordination. A cross-sectional study of 296 long-term breast cancer survivors, who had been treated with taxane-based chemotherapy, found that 58% of women reported

chemotherapy-induced peripheral neuropathy (CIPN) symptoms such as tingling/numbness in the hands and/or feet (Bao et al., 2016). Almost half (47%) of a sample of 512 female cancer survivors reported CIPN symptoms after an average of 6 years post-treatment (Winters-Stone et al., 2017). A French study of 1805 cancer patients found that 21% of patients with chronic pain had neuropathic characteristics and that pain intensity and interference was higher in those with neuropathic characteristics (Bouhassira, Luporsi, & Krakowski, 2017). A prospective study of 3106 breast, prostate, colorectal and lung cancer outpatients reported significantly higher moderate-to-severe numbness/tingling in colorectal cancer patients (26%) compared with the breast, prostate and lung cancer patients (17%) (Lewis et al., 2015). A meta-analysis of 29 observational prospective studies reported that the prevalence of neuropathic cancer pain was 31% (Roberto et al., 2016). A further systematic review of 22 studies reported that the prevalence of neuropathic pain in cancer patients ranged between 19-39% (Bennett et al., 2012). However, many of the studies included in these reviews use patient self-report of CIPN symptoms as opposed to objective neurologic examination. Challenges in defining, assessing and accurately diagnosing neuropathic pain may mean the actual prevalence of CIPN/neuropathic pain is difficult to estimate and could explain the differences in prevalence estimates within the literature (Lema, Foley, & Hausheer, 2010).

1.1.3.1.4 Sleep disturbances

Sleep disturbances, such as trouble falling to sleep or remaining asleep, may arise as a result of psychological distress and worry, or as a consequence of some cancer treatments. A systematic review of 254 studies (both observational and intervention studies) was unable to report the prevalence of sleep disorders in cancer survivors, due to the lack of conceptualisation and operationalisation of poor sleep (Otte et al., 2015). Many of the studies included in the review focused on measuring symptoms of poor sleep, including sleep duration (hours of sleep), sleep latency (time taken to fall asleep), sleep disruption (waking during the night) and daytime dysfunction (unable to function during the day without napping), as opposed to the underlying sleep disorders (Otte et al., 2015). However, the authors note that much of the literature has shown that poor sleep is problematic for many cancer survivors, throughout the cancer trajectory (Otte et al., 2015). A cross-sectional analysis of breast cancer survivors approximately 5 years after completion of cancer treatment showed 65% suffered from sleep-wake disturbances compared to 55% of a sample of age-matched women without breast cancer (Otte, Carpenter,

Russell, Bigatti, & Champion, 2010). Breast cancer survivors also had significantly lower quality sleep than age-matched women without breast cancer as indicated on the Pittsburgh Sleep Quality Index (PSQI) scale (Otte et al., 2010). A prospective study of 962 non-metastatic cancer patients (mixed cancer sites) completed an insomnia diagnostic interview on the day of their preoperative visit and at 2, 6, 10, 14, and 18 months after surgery (Savard, Ivers, Villa, Caplette-Gingras, & Morin, 2011). Savard and colleagues found that 59% of the sample reported insomnia symptoms at baseline, which included 28% with an insomnia syndrome. Prevalence of insomnia declined throughout the study period to 36% at 18 months, which included 21% with an insomnia syndrome. Prevalence of insomnia was highest in breast (42-69%) and gynaecologic (33-68%) cancer patients and lowest in prostate cancer patients (25-39%). Over a third (38%) of patients had an insomnia syndrome at each measurement point throughout the 18-month study (Savard et al., 2011). In a cross-sectional survey of 300 women treated for breast cancer with radiotherapy, 48% (n=145) reported current sleep difficulties and 19% (n=56) met diagnostic criteria for an insomnia syndrome or disorder (Savard, Simard, Blanchet, Ivers, & Morin, 2001). A similar prevalence of sleep disturbance symptoms were reported in a German population-based cohort of 439 colorectal cancer survivors who were assessed 1 year post-diagnosis, where 55% reported insomnia-related symptoms (Arndt, Merx, Stegmaier, Ziegler, & Brenner, 2004).

1.1.3.1.5 Lymphoedema

Lymphoedema is caused by dysfunction within the lymphatic system causing a build-up of excess fluid and chronic swelling, usually in the arms or legs. Lymphoedema is most commonly associated with breast cancer as it is more common when lymph nodes have been removed via surgery, the cancer has spread to the lymph nodes or if the lymph nodes have been targeted by radiotherapy. The proximity of lymph nodes to the breast region makes this more likely in breast cancer. A prospective study assessed lymphoedema among 287 Australian women recently diagnosed with breast cancer, from 6 to 18 months post-surgery at 3-monthly intervals. A third of the women (33%) showed evidence of lymphoedema at one or more of the testing intervals, and of these, approximately 40% had lymphoedema for more than 3 months (Hayes, Janda, Cornish, Battistutta, & Newman, 2008). A further study also assessed incidence of lymphoedema prospectively in a larger sample of 631 breast cancer survivors diagnosed between 1999 and 2001 for a longer period of follow-up (5 years) (Norman et al., 2009). Norman and colleagues reported that the five-year cumulative incidence for lymphoedema was 42 per 100 women. Of the

238 women who developed lymphoedema during the study, 80% were affected within 2 years of diagnosis and 89% were affected within 3 years of diagnosis (Norman et al., 2009).

1.1.3.1.6 Body weight and body composition

Changes in body weight and body composition are common both during and after cancer treatment and can affect survival outcomes.

1.1.3.1.6.1 Weight gain

In breast cancer, weight gain is common, particularly among younger, pre-menopausal women and those treated with chemotherapy (Caan et al., 2008; Vance, Mourtzakis, McCargar, & Hanning, 2011). An observational Dutch study assessed weight change among 485 stage II/III colorectal cancer patients diagnosed between 2007-2012 during the period of surgery, chemotherapy and oncological follow-up (Winkels, Snetselaar, et al., 2016). Weight data and details of treatment was obtained from medical records and therefore did not rely on patient self-report. Winkels and colleagues found that, on average, patients lost 1.9kg during the period of surgery but gained 2.9kg, and 2.2kg, during and after chemotherapy, respectively (Winkels, Snetselaar, et al., 2016). Some evidence suggests that increased weight further exacerbates other cancer-related side effects, such as fatigue. A longitudinal study of breast cancer survivors found that obesity (body mass index (BMI) >30) at 6-months post-treatment was significantly predictive of cancer-related fatigue at 42 months (Andrykowski, Donovan, Laronga, & Jacobsen, 2010). This study obtained BMI from medical records, and therefore did not rely on participant self-report. A cross-sectional study of 229 men treated with androgen deprivation therapy (ADT) for prostate cancer also reported that fat mass was significantly higher in men experiencing fatigue compared with men who were not (Newton, Jeffery, et al., 2018). Furthermore, increased weight has been associated with increases in cardiovascular risk (Poirier et al., 2006), distress (Casey, Corcoran, & Goldenberg, 2012; Helms, O'Hea, & Corso, 2008), and has been found to be associated with poorer survival outcomes in two large systematic reviews and meta-analyses of breast cancer survivors (Chan et al., 2014; Playdon et al., 2015). The first included 82 observational studies, including 213,075 breast cancer survivors, and found that obesity was associated with poorer all-cause and breast cancer-specific mortality outcomes regardless of whether BMI was measured before, <12 months or \geq 12 months after diagnosis (Chan et al., 2014). However, the association between BMI and cancer survival is not consistent across cancer types and stages (Greenlee, Unger, LeBlanc, Ramsey, & Hershman, 2017). The second meta-

analysis specifically assessed the impact of post-diagnosis weight gain on all-cause and breast cancer-specific mortality in 12 observational studies, including 23,832 breast cancer survivors (Playdon et al., 2015). Playdon and colleagues found that, compared with weight maintenance ($\pm 5\%$), post-diagnosis weight gain ($\geq 10\%$ body weight) was significantly associated with increased risk of all-cause mortality (hazard ratio (HR)=1.23; 95% confidence interval (CI): 1.09-1.39) and non-significantly associated with breast cancer-specific mortality (HR=1.17; 95% CI: 1.00-1.38). Compared with weight maintenance, weight gain ($\geq 5\%$) was also significantly associated with all-cause mortality (HR=1.12; 95% CI: 1.03-1.22) (Playdon et al., 2015).

1.1.3.1.6.2 Weight loss

Cancer survivors are also at risk of rapid and extensive weight loss, including the loss of muscle mass. This can be a result of cachexia and/or sarcopenia. Cachexia has been described as “a multifactorial syndrome defined by loss of skeletal muscle mass with or without fat wasting that cannot be reversed by nutrition support in the context of chronic systemic inflammation and metabolic alterations” (Peterson & Mozer, 2017). The systemic inflammation and metabolic alterations in cancer leads to a negative protein and energy balance (Vanhoutte et al., 2016) and subsequent loss of muscle/fat mass. Two narrative reviews report that cachexia can affect between 25-80% of cancer survivors, and is particularly prevalent among those with advanced disease (Peterson & Mozer, 2017; von Haehling, Anker, & Anker, 2016). As a result, weight loss also appears to be associated with poorer survival outcomes. A systematic review of 5 observational studies that assessed the association between weight loss and mortality in overweight/obese cancer survivors found that 4 of the 5 included studies reported a positive association between weight loss and mortality and the remaining study reported no association (Jackson, Heinrich, Beeken, & Wardle, 2017). None of these studies reported whether the weight loss was intentional or not, but the authors suggest that the results are likely to reflect the consequences of disease-related weight loss indicative of advanced disease and therefore poorer survival outcomes, as opposed to intentional weight loss (Jackson et al., 2017). A large prospective cohort study of 12,590 stage I-III breast cancer survivors, who had weight measured by medical assistants within 3-months of diagnosis and 18-months post-diagnosis, reported that while most women maintained their body weight ($\pm 5\%$ of diagnosis body weight), 19% of women lost weight and 19% gained weight (Feliciano, Kroenke, et al., 2017). Compared with weight maintenance, large weight loss ($\geq 10\%$) was associated with poorer all-cause mortality outcomes

both earlier (18-54 months) (HR=2.63; 95% CI: 2.12-3.26) and later (>54 months) (HR=1.60; 95% CI: 1.14-2.25) in follow-up. Modest weight loss (>5%-<10%) was associated with all-cause mortality earlier (HR=1.39; 95% CI: 1.11-1.74) but not later (HR=0.77; 95% CI: 0.54-1.11) in follow-up. The authors did not find an association between weight gain and survival (Feliciano, Kroenke, et al., 2017). Using the same methods as Feliciano et al. (2017), albeit with follow-up to 18 months only, a study of 2,781 stage I-III colorectal cancer survivors found that after completion of treatment, weight loss (>10% of baseline weight) was significantly associated with all-cause (HR=3.27; 95% CI: 2.56-4.18) and colorectal-cancer specific mortality (HR=3.20; 95% CI: 2.33-4.39) (Meyerhardt et al., 2017). No association was found between weight gain and all-cause or colorectal cancer-specific mortality.

1.1.3.1.6.3 Body composition

The evidence presented above illustrates the complex association between body weight, weight change and survival outcomes in various cancer types. It is possible that (change in) body composition, as opposed to body weight per se, could be a more informative indicator. Sarcopenia is defined as a loss of skeletal muscle or lean body mass (Cruz-Jentoft et al., 2010) and is primarily associated with ageing. Sarcopenic obesity occurs in individuals who have high BMI/fat mass but low muscle mass, and its prevalence is increasing due to the ageing population and the increasing proportion of the population with obesity (Batsis & Villareal, 2018). A cross-sectional survey of 2,914 women diagnosed with stage I-III breast cancer revealed that 40% of the sample had sarcopenia and 38% had low muscle radio-density (suggestive of muscle fat infiltration), assessed via computerised tomography (CT) scans (Feliciano, Caan, et al., 2017). Feliciano et al. also showed that the odds of sarcopenia and low muscle radio-density increased with age (per 5 years, odds ratio (OR)=1.33; 95% CI: 1.27-1.39 and OR=1.41; 95% CI: 1.35-1.47, respectively). The odds of sarcopenia decreased with greater BMI (OR=0.80; 95% CI: 0.78-0.82 per kg/m²), and the odds of low muscle radio-density (muscle fat infiltration) also increased with greater BMI (OR=1.03; 95% CI: 1.01-1.04 per kg/m²).

Cancer treatment can also affect body composition. A prospective study measured lean body mass among 252 men with prostate cancer receiving ADT at baseline, 12, 24 and 36 months (Smith et al., 2012). Mean lean body mass decreased significantly by 1.0% at 12 months, 2.1% at month 24 and by 2.4% at month 36. At the 36 month follow-up, older men (≥ 70 years) showed significantly greater changes in lean body mass (-2.8%) compared with younger (<70 years) men

(-0.9%) (Smith et al., 2012). Other research conducted by the same group has shown that ADT in prostate cancer reduces lean body mass, but also increases fat mass and increases body weight (Smith, 2004; Smith et al., 2002; Smith et al., 2008). A review of 36 studies (both observational and intervention trials) assessing body composition changes among breast cancer survivors found that tamoxifen had a negative impact on body composition, demonstrating that women had higher overall body fat when treated with tamoxifen (Sheehan, Hoskins, & Stolley, 2012).

Changes in body composition are important given that sarcopenia and muscle fat infiltration have been shown to influence survival outcomes. A prospective cohort study of 471 women with breast cancer, of whom 16% were classified as sarcopenic, were followed up for 9 years (Villasenor et al., 2012). After controlling for age, race-ethnicity, study site, treatment type, comorbidities, waist circumference and total body fat percentage, women with sarcopenia had a significantly higher risk of all-cause mortality than those without (HR=2.86, 95% CI: 1.67-4.89). They also had increased risk of breast cancer-specific mortality (HR=1.95; 95% CI: 0.87-4.35), although this was not statistically significant, which may be a result of the small number of women (N=46) who died of breast cancer during the follow-up period (Villasenor et al., 2012). A meta-analysis of 12 retrospective and prospective studies evaluating the impact of sarcopenia (determined by CT scan) in non-metastatic colorectal cancer survivors (N=5,337) found that sarcopenia was associated with a significantly longer hospital stay (weighted mean difference (WMD)=1.29; 95% CI: 0.50-2.08), higher total morbidity (OR=1.70; 95% CI: 1.07-2.70), mortality (OR=3.45; 95% CI: 1.69-7.02) and post-operative infection (OR=2.21; 95% CI: 1.50-3.25) than those without sarcopenia (Sun et al., 2018). In a retrospective study, 119 women with early stage breast cancer received CT scans to assess sarcopenia and muscle fat infiltration (intra-muscular adipose tissue areas (IMAT)) (Deluche et al., 2018). Deluche and colleagues reported that 49% and 52% of the sample, respectively, had sarcopenia and a high IMAT index. No sarcopenia was associated with both better disease-free survival (HR=0.3; 95% CI: 0.1-0.8) and overall survival (HR=0.3; 95% CI: 0.1-1.0). High IMAT index was associated with both poorer disease-free survival (HR=2.8; 95% CI: 1.0-7.8) and overall survival (HR=3.6; 95% CI: 1.2-10.8) (Deluche et al., 2018). Similar findings have also recently been reported in a study of 1,924 participants who had undergone surgical resection for stage I-III colorectal cancer. Using CT scans, Brown et al. found that compared to patients whose muscle mass remained stable over the 14 month follow-up, those

who experienced the largest deterioration in muscle mass and muscle radio-density had a significantly higher risk of all-cause mortality (HR=2.15; 95% CI: 1.59-2.92 and HR=1.61; 95% CI: 1.20-2.15, respectively) (Brown et al., 2018). These results are all obtained from observational studies and so causality cannot be assumed, however, one possible explanation for poorer survival outcomes among those with sarcopenia may be related to the fact that sarcopenia has been identified as an objective, independent predictor of completion of chemotherapy (Sabel, Conlon, Griffith, Englesbe, & Wang, 2012) and increased chemotherapy toxicity (Jung et al., 2015). Therefore, it is important that cancer survivors are supported to maintain/increase muscle mass during and after treatment.

1.1.3.2 Psychosocial consequences

The psychosocial impact of a cancer diagnosis, treatment and survivorship can be substantial. Anxiety and depression, fear of cancer recurrence and other sources of psychological distress are all frequently reported among cancer survivors.

1.1.3.2.1 Anxiety and Depression

A cancer diagnosis is an understandably emotional and distressing experience where a reaction of sadness and apprehension would be considered normal. Clinical depression is a serious psychiatric complication which is relatively common amongst cancer survivors, yet often overlooked (Chochinov, 2001). The complex combination of physical and psychological consequences of cancer can make recognising and diagnosing anxiety and depression in cancer survivors particularly difficult. A meta-analysis of 211 studies estimated that the prevalence of depression among cancer patients ranges between 8-24%, depending on the type of instrument used (diagnostic interviews vs. self-report instruments), the type of cancer and the treatment phase (Krebber et al., 2014). Krebber and colleagues found that depression was most prevalent during treatment (14% diagnostic interviews, 27% self-report), but declined during the first year after diagnosis (9% diagnostic interviews, 21% self-report) and beyond the first year post-diagnosis (8% diagnostic interviews, 15% self-report) (Krebber et al., 2014). Despite this, it remains unclear whether the prevalence of depression in cancer survivors is any higher than in the general population. A meta-analysis of 16 studies did not find a significant difference in the prevalence of depression in cancer survivors >2 years post-diagnosis (11.6%; N=51,381) compared with healthy controls (10.2%; N=217,630) (pooled relative risk (RR)=1.11; 95% CI: 0.96-1.27; $p = 0.17$) (Mitchell, Ferguson, Gill, Paul, & Symonds, 2013). However, the prevalence

of anxiety was significantly higher among cancer survivors (17.9%; N=48,964) compared to healthy controls (13.9%; N=226,467) (pooled RR=1.27; 95% CI: 1.08-1.50; $p = 0.004$) in a meta-analysis of 10 studies. However, the quality of the studies included in this review was variable. Twelve studies had excellent quality ratings but only 10 were deemed to have high quality matching of cancer survivors with healthy controls (Mitchell et al., 2013).

1.1.3.2.2 Cancer-related distress and fear of cancer recurrence

There are many sources of cancer-related distress among survivors, of which fear of cancer recurrence is the most prominent (Deimling, Bowman, Sterns, Wagner, & Kahana, 2006; Simard et al., 2013). In the LIVESTRONG surveys of 6,593 American cancer survivors within 5 years of diagnosis, approximately 80% reported fears of recurrence, which can result in a heightened awareness of vulnerability, mortality and hypervigilance about new or ongoing symptoms (Beckjord et al., 2014). This was the mostly highly-reported concern of all of the emotional, physical and practical issues in both the 2006 and 2010 LIVESTRONG surveys. In the same study, approximately half of the sample reported concerns around body image and approximately a third reported concerns about sexual dysfunction (Beckjord et al., 2014). Increased financial stress and increased financial strain due to cancer was reported among 49% and 32% of a sample of 654 Irish breast, prostate and lung cancer survivors who completed a cross-sectional survey >6 months post-diagnosis. Increased financial stress/strain were significantly associated with anxiety and depression, however given the cross-sectional nature of the survey, it is not possible to determine the direction of causality (Sharp, Carsin, & Timmons, 2013). The increased financial pressure after cancer may trigger additional distress caused by concerns relating to returning to employment after treatment (e.g. ability to work, employer expectations and access to appropriate support and adjustments) (Kennedy, Haslam, Munir, & Pryce, 2007; Main, Nowels, Cavender, Etschmaier, & Steiner, 2005).

1.1.3.3 Health-related quality of life

The physical and psychological consequences of a cancer diagnosis and treatment can have a profound impact on health-related quality of life (HRQoL). A pooled analysis of 25 randomised controlled trials (RCTs) using the European Organisation for Research and Treatment of Cancer Quality of Life Questionnaire-core 30 (EORTC QLQ-C30) measure of HRQoL demonstrated that cancer survivors have worse HRQoL when compared with the general population, although the

impairments in various domains of HRQoL varied with age (Quinten et al., 2015). Older cancer survivors suffered more from impaired physical functioning, whereas younger cancer survivors report poorer social functioning, insomnia and financial problems (Quinten et al., 2015). The diminished HRQoL is likely due to the combination of physical and psychosocial consequences of cancer and its treatment. For example, cancer survivors with peripheral neuropathy are more likely to suffer with insomnia, anxiety and depression (Bao et al., 2016) and increased financial stress and financial strain were both significantly associated with increased anxiety and depression (Sharp et al., 2013). Similarly, a cross-sectional survey of 1,957 breast cancer survivors showed that more severe fatigue was associated with significantly higher depression, pain and sleep disturbance, and that women who were more fatigued reported a lower quality of life (Bower et al., 2000). A study among Chinese breast cancer survivors undergoing treatment also supported the presence of a symptom cluster of fatigue, pain, anxiety and depression, the combination of which had a detrimental impact on quality of life (So et al., 2009).

The impact on HRQoL can also depend on the treatment decisions and any consequently associated side effects. A prospective cohort study of 1,139 men with low-risk prostate cancer completed pre-treatment interviews and were followed up 6-10 months post-diagnosis (Taylor et al., 2018). After adjustment for pre-treatment functioning, men who were under active surveillance had significantly better sexual, bowel, urinary and general physical function compared to those who had undergone active treatment (surgery or radiation). However, those under active surveillance reported significantly higher general anxiety and prostate-specific anxiety compared to men who had undergone active treatment (Taylor et al., 2018).

1.1.3.4 Comorbidities and cancer

Macmillan Cancer Support report that 70% of cancer survivors are living with at least one other long-term health condition, approximately a third of whom have at least three comorbid conditions (Macmillan Cancer Support, 2015). Some of the most common comorbidities include hypertension (42%), obesity (31%), mental health problems (21%) and chronic heart disease (19%). A prospective cohort study recruited 872 colorectal cancer survivors prior to surgery who were then followed up for 5 years (Cummings et al., 2018). At baseline, approximately a third had 1 comorbidity and 40% had ≥ 2 . The most commonly reported comorbidities were high blood pressure (43%), arthritis/rheumatism (32%) and anxiety/depression (18%) but this study did not

assess obesity. Of those who reported any comorbidities, over a third (37%) reported at least one that limited daily activities. Reporting any limiting comorbidities at baseline was associated with poorer global health/quality of life, worse symptoms, and poorer functioning over the 5 year follow-up (Cummings et al., 2018). Furthermore, the number and severity of comorbidities is positively linked to risk of death and recurrence among cancer survivors (Binder et al., 2016). Multimorbidity increases with age (Barnett et al., 2012) and the shared risk factors between cancer, obesity and cardiovascular disease (CVD) are a likely explanation for the high levels of comorbidity between these conditions (Koene, Prizment, Blaes, & Konety, 2016). However, there is also evidence to suggest that cancer treatment can leave survivors at greater risk for developing these common comorbid conditions (e.g. due to cardiovascular toxicity of cancer therapy; Johnson, Davis, Law & Sulpher, 2016).

1.1.3.4.1 Cardiovascular disease

In a cohort study of 4,410 breast cancer survivors, who had survived at least 10 years since diagnosis, with a median follow-up of 18 years, radiotherapy was associated with increased risk of CVD (e.g. myocardial infarction, congestive heart failure, valvular dysfunction) (Hoening et al., 2007). Further, women who were treated with radiotherapy and adjuvant chemotherapy had a higher risk of congestive heart failure than women treated with radiotherapy only (HR=1.85; 95% CI: 1.25-2.73; $p = 0.002$). In a UK study of 26,213 breast, prostate and colorectal cancer survivors, breast cancer survivors showed an increased incidence of heart failure (HR=1.95; 95% CI: 1.27-3.01) and coronary artery disease (HR=1.27; 95% CI: 1.11-1.44) compared to age-, sex- and general practice-matched non-cancer controls, but there were no differences for the other cancer sites (Khan, Mant, Carpenter, Forman, & Rose, 2011). In a cross-sectional study comparing 1,526 Canadian cancer survivors with 6,034 age- and sex-matched controls without a cancer diagnosis, cancer survivors had increased odds of having experienced a CVD event (myocardial infarction/stroke) versus controls, although this was not statistically significant (OR=1.3; 95% CI: 1.0–1.7) (Keats, Cui, Grandy, & Parker, 2017).

1.1.3.4.2 Type 2 diabetes

The incidence of many common cancer types is higher among those with diabetes (Giovannucci et al., 2010). In the aforementioned study by Keats et al., cancer survivors also had significantly higher odds of diabetes versus age- and sex-matched controls without a cancer diagnosis (OR=1.27; 95% CI: 1.03–1.16) (Keats et al., 2017). The incidence of type 2 diabetes was also

compared among 24,976 post-menopausal breast cancer survivors and 124,880 controls between 1996 and 2008 (Lipscombe et al., 2013). This study found that breast cancer survivors had a small but significantly increased risk of diabetes 2 years post-diagnosis (HR=1.07; 95% CI: 1.02-1.12) which increased at 10 years post-diagnosis (HR=1.21; 95% CI: 1.09-1.35). The risk was highest for those at 2 years post-diagnosis among patients who received adjuvant chemotherapy (HR=1.24; 95% CI: 1.12-1.38). A large Korean general population prospective cohort study followed-up 524,089 participants up to 10 years. Hwangbo et al. found that those who developed cancer during the follow-up period were at significantly higher risk of also developing diabetes versus those who did not have cancer (HR=1.35; 95% CI: 1.26-1.45), after adjusting for age, gender, pre-cancer diabetes risk factors, metabolic factors and comorbidities (Hwangbo et al., 2018). These studies give a possible indication that certain cancer treatments could affect subsequent diabetes risk, although given the observational nature of these findings, cause and effect cannot be inferred.

Prostate cancer incidence is lower among men with diabetes (Giovannucci et al., 2010), however diabetic men who are diagnosed with prostate cancer have poorer survival outcomes. A meta-analysis of 17 cohort studies (N=274,677) demonstrated that pre-existing diabetes was associated with a 29% increased risk of prostate cancer-specific mortality (RR=1.29; 95% CI: 1.22-1.38) and a 37% increase in all-cause mortality (RR=1.37; 95% CI: 1.29-1.45) (Lee, Giovannucci, & Jeon, 2016). A recent study found that prostate cancer patients with diabetes were significantly more likely to have higher-risk disease with lymph node metastases when compared to men without diabetes, independent of body weight (Lutz et al., 2018). There are several potential clinical mechanisms that could explain the poorer prognosis in men with prostate cancer and diabetes. These include the fact that men with diabetes have a higher failure rate of radiotherapy treatment and worse gastrointestinal and genitourinary complications (Chan, Latini, Cowan, DuChane, & Carroll, 2005; Herold, Hanlon, & Hanks, 1999). Furthermore, prostate cancer patients are often treated with ADT and low levels of androgens in prostate cancer patients with diabetes has been associated with insulin resistance and both prostate cancer-specific and all-cause mortality (Basaria, Muller, Carducci, Egan, & Dobs, 2006; Smith, Lee, & Nathan, 2006). ADT increases insulin resistance and hyperglycaemia, which also increase risk of cardiovascular diseases (Basaria et al., 2006; Smith et al., 2006). Men with higher blood glucose levels have also been found to have more aggressive forms of prostate cancer (Kim et al., 2010).

1.1.4 The cultural shift in survivorship

The UK Department of Health's 'Cancer Reform Strategy' (Department of Health, 2007) and 'Improving Outcomes Strategy for Cancer' (Department of Health, 2011) reports highlighted the needs of the growing number of people living with and beyond a cancer diagnosis as a key area of focus for improvement of cancer care within the UK. These reports emphasised the range of physical, psychological, social, financial and information needs of cancer survivors, many of which were discussed in section 1.1.3, and the need to better integrate cancer services to meet these needs. As a result, the National Cancer Survivorship Initiative (NCSI) was launched in 2007, involving a partnership between the UK government's Department of Health, the National Health Service (NHS) and the national cancer charity, Macmillan Cancer Support (Richards, Corner, & Maher, 2011). The NCSI made several recommendations to support the needs of cancer survivors and better integrate cancer care. These recommendations included five key shifts of focus to improve survivorship outcomes:

- A cultural shift in care and support to a focus on recovery, health and wellbeing after cancer treatment
- A shift towards individualised assessment, information provision and personalised care planning accounting for individual risks, needs and preferences
- A shift towards supported self-management with the appropriate clinical assessment, support and treatment
- A shift from a single model of clinical follow-up to tailored support that enables early recognition of, and preparation for, the consequences of treatment as well early recognition of signs of recurrence or secondary cancers
- A shift to routine use of Patient Reported Outcome Measures in aftercare services to measure experience and outcomes for cancer survivors

(Department of Health, Macmillan Cancer Support & NHS Improvement, 2010)

The formation of this partnership between the government, policy makers, the NHS and third sector organisations in the UK reflects the cultural shift in cancer care from a previously inevitably life-threatening disease to a long-term, 'chronic' condition where aftercare focuses on recovery and self-management, and promotes the return to a healthy and active life as possible.

The Recovery Package¹, which was developed and tested by the NCSI, is one of the key products of the collaboration. It combines a holistic needs assessment, treatment summary, cancer care review and health and wellbeing event to form an overall support package to help manage consequences of treatment, promote self-management and meet survivors' unmet needs. The Independent Cancer Taskforce report (Independent Cancer Taskforce, 2015) recommended that everyone with cancer should have access to the elements of the Recovery Package, including advice on healthy lifestyle and physical activity, by 2020 and that stratified pathways of follow-up care should be in place for 3 of the most common cancers in the UK (breast, prostate, colorectal). This was upheld in the recently published NHS Long Term Plan which stated that "By 2021, where appropriate every person diagnosed with cancer will have access to personalised care, including needs assessment, a care plan and health and wellbeing information and support...for their wider health and wellbeing" (NHS England, 2019) (p.61). The Long Term Plan also indicated that "this will empower people to manage their care and the impact of their cancer, and maximise the potential of digital and community-based support" (NHS England, 2019) (p.61). Physical activity promotion is a major component of the health and wellbeing part of the Recovery Package, due to the evidence illustrating the benefits of physical activity after cancer, which will be discussed in the following section (1.2).

1.2 Physical activity and cancer

Physical activity is defined as energy expenditure resulting from any bodily movement created by skeletal muscle (Caspersen, Powell, & Christenson, 1985). Broadly, physical activity can be separated into 4 domains: occupational, household, transport and recreational activities (Sallis et al., 2006). Different types of physical activity are performed at varying levels of intensity (Ainsworth et al., 2011). For instance, light intensity physical activity includes easy walking, stretching, and light housework. Moderate intensity physical activity includes brisk walking, golf, gardening, housework, weight lifting, cycling, easy swimming and leads to an increase in heart rate, beginning to feel out of breath and breaking out into a light/moderate sweat. Vigorous/strenuous intensity physical activity includes running, jogging, fast cycling, fast swimming, and most competitive sports and leads to a rapid increase in heart rate, heavier and

¹<https://www.macmillan.org.uk/about-us/health-professionals/programmes-and-services/recovery-package#297615>

faster breathing and sweating. The health benefits of sufficient physical activity are well established in the general population (Haskell et al., 2007; Penedo & Dahn, 2005; Warburton, Nicol, & Bredin, 2006). In light of these benefits, physical activity guidelines for the UK have been published which recommend participation in daily physical activity which result in an accumulation of either ≥ 150 minutes of moderate activity, ≥ 75 minutes of vigorous activity (or a combination) per week (Bull and the Expert Working Groups, 2010). Participating in muscle-strengthening activities (e.g. exercising with weights, carrying shopping bags) are also recommended twice weekly along with reducing the amount of sedentary time. Older adults (≥ 65 years old) are recommended to meet the same physical activity guidelines but are also recommended to participate in co-ordination, flexibility and balance improving activities to reduce risk of falls (e.g. dancing, Tai Chi, yoga) (Bull and the Expert Working Groups, 2010).

The evidence-base surrounding the benefits of physical activity among cancer survivors is growing. Research suggests that physical activity may prolong survival and reduce recurrence, and helps to combat many of the consequences of diagnosis and treatment described in section 1.1.3. An overview of this research is provided in the following sections.

1.2.1 Effects of physical activity after cancer and on consequences of treatment

1.2.1.1 Mortality, survival and cancer recurrence

There is a large body of observational data suggesting that greater physical activity participation may improve survival outcomes for cancer survivors diagnosed with solid tumours. A meta-analysis of 22 prospective cohort studies of breast cancer survivors ($n=123,574$) showed that greater physical activity participation reduced both all-cause (HR=0.52; 95% CI: 0.43-0.64) and breast-cancer specific mortality (HR=0.59; 95% CI: 0.45-0.78), breast cancer progression, second primary cancers and recurrence (HR=0.79; 95% CI: 0.63-0.98) (Lahart, Metsios, Nevill, & Carmichael, 2015). A meta-analysis of 7 prospective studies of colorectal cancer survivors reported similar conclusions and showed that pre-diagnosis physical activity was associated with lower all-cause (summary RR=0.74; 95% CI: 0.63-0.86) and colorectal cancer mortality (summary RR=0.75; 95% CI: 0.62-0.91). An effect was also observed for post-diagnosis physical activity on both all-cause (summary RR=0.58; 95% CI: 0.48-0.70) and colorectal cancer-specific mortality (summary RR=0.61; 95% CI: 0.40-0.92) (Schmid & Leitzmann, 2014). A more recent meta-analysis of 11 studies including 17,295 colorectal cancer survivors that were followed-up for

between 4-12 years demonstrated that pre-diagnosis physical activity was associated with lower all-cause (RR=0.81; 95% CI: 0.72-0.91) and colorectal cancer-specific mortality (RR=0.79; 95% CI: 0.71-0.89) (Wu et al., 2016). This study also demonstrated a significant effect of post-diagnosis physical activity on lower all-cause (RR=0.77; 95% CI: 0.63-0.94) and colorectal cancer-specific mortality (RR=0.71; 95% CI: 0.63-0.81) (Wu et al., 2016). Schmid & Leitzmann estimated that meeting the current recommendations of 150 minutes per week of at least moderate intensity physical activity was associated with a 24% (95% CI: 11-36%) and 28% (95% CI: 20-35%) decrease in total mortality risk, among breast and colorectal cancer survivors respectively (Schmid & Leitzmann, 2014). Evidence from a prospective study of 832 colorectal cancer survivors also suggests that physical activity reduces the risk of cancer recurrence (Meyerhardt et al., 2006). A meta-analysis that aimed to investigate the dose-response relationship between physical activity and cancer mortality in studies conducted among both breast and colorectal cancer survivors revealed that cancer mortality decreased by 21% at 15 metabolic equivalent of task (MET)-hours/week of pre-diagnosis physical activity compared to a decrease of 35% among those who participated in 15 MET-hours/week post-diagnosis (Li et al., 2016).

There have been fewer studies assessing physical activity and mortality and recurrence among prostate cancer survivors. A prospective study of 1,455 men with localised prostate cancer showed that men who walked briskly for at least 3 hours per week had a 57% lower rate of progression compared to men who walked at a gentle pace (HR=0.43; 95% CI: 0.21-0.91) (Richman et al., 2011). Importantly, walking pace was associated with risk of progression, independently of walking duration, indicating the importance of the intensity of physical activity (Richman et al., 2011). A more recent study demonstrated that, among 830 stage II-IV prostate cancer survivors diagnosed between 1997 and 2000 and followed-up to 2014, post-diagnosis total physical activity (>119 vs <42 MET-hours/week per year) was associated with significantly lower all-cause mortality (HR=0.58; 95% CI: 0.42-0.79) (Friedenreich et al., 2016). Post-diagnosis recreational physical activity (>26 vs. <4 MET-hours/week per year) was significantly associated with lower prostate-cancer specific mortality (HR=0.56; 95% CI: 0.35-0.90) (Friedenreich et al., 2016). A larger prospective cohort study conducted among 5,319 men diagnosed with non-metastatic prostate cancer in the USA also found that post-diagnosis physical activity (\geq 17.5 MET-hours/week vs. 3.5-<8.75 MET-hours/week) was inversely associated with all-cause

mortality (HR=0.86; 95% CI: 0.75-0.98) and prostate cancer-specific mortality (HR=0.69; 95% CI: 0.49-0.95) (Wang et al., 2017).

As detailed above, the majority of the evidence for the link between physical activity and mortality, survival and recurrence outcomes comes primarily from research of breast, colorectal and prostate cancer survivors. However, evidence is also beginning to emerge for the benefits of physical activity for other cancer types. Two studies have conducted similar analyses in cancer survivors of any cancer type. Lee et al. conducted a prospective cohort study of 1,021 men diagnosed with prostate (30%), colon (16%), bladder (8%), melanoma (6%) and lymphoma (5%) cancers, as well as a smaller number of men diagnosed with other cancer types (Lee, Wolin, Freeman, Sattlemair, & Sesso, 2014). Compared with the least active men, the most active men had significantly reduced risk of all-cause mortality (RR=0.52; 95% CI: 0.42-0.65), cancer-specific mortality (RR=0.62; 95% CI: 0.44-0.87), cardiovascular mortality (RR=0.51; 95% CI: 0.33-0.79) and non-cancer/non-cardiovascular mortality (RR=0.41; 95% CI: 0.27-0.62) (Lee, Wolin, et al., 2014). Inoue-Choi et al. report the results of a further prospective cohort study of 2,017 female participants from the Iowa Women's Health Study who had been diagnosed with breast (46.5%), colorectal (18.8%), gynaecologic (13.0%) cancers, as well as women diagnosed with any other cancer type (21.7%) (Inoue-Choi, Robien, & Lazovich, 2013). The authors found meeting physical activity recommendations was associated with lower risk of all-cause mortality (HR=0.62; 95% CI: 0.47-0.83, $p < .0001$), cancer-specific mortality (HR=0.72; 95% CI: 0.47-1.10, $p = 0.04$) and cardiovascular disease-specific mortality (HR=0.60; 95% CI: 0.35-1.03, $p = 0.03$), after controlling for adherence to dietary and body weight recommendations (Inoue-Choi et al., 2013). In an observational cohort study of endometrial cancer survivors, higher pre-diagnosis physical activity participation (>7 hours per week) was associated with lower all-cause 5-year mortality compared to those who were never or rarely physically active (HR=0.57; 95% CI: 0.33-0.98), however the effect was attenuated after controlling for pre-diagnosis BMI (HR=0.64; 95% CI: 0.37-1.12) (Arem et al., 2013). The authors were not able to report the impact of post-diagnosis physical activity, as this was not assessed. None of the 9 RCTs identified in a systematic review of haematological cancer survivors assessed overall survival, however 3 did report the number of deceased participants within the duration of the study or the first 100 days following its completion (Bergenthal et al., 2014). Pooled analyses of these 3 RCTs ($n=269$) revealed no difference between the PA intervention and control groups (RR=0.93; 95% CI: 0.59-1.47; $p = 0.75$), however

it is likely that follow-up is required to be longer than 100 days to detect differences in overall survival.

Despite promising evidence of physical activity reducing mortality and recurrence and improving survival among cancer survivors, it is important to highlight that the vast majority of these studies rely entirely on self-reported physical activity data. Given the large number of participants involved in these studies, validated self-reported measures are often the only feasible way to assess physical activity in such large populations as they are easy to administer and inexpensive. However, self-reported measures are often extremely inaccurate and therefore prone to bias (Prince et al., 2008). Objective approaches to data collection, such as accelerometry, would increase the reliability and validity of the conclusions of this evidence considerably. Furthermore, the evidence presented here is all as a result of observational data. Therefore it is not possible to infer causality. A further possible explanation for the pattern of results is that cancer survivors who have a poorer prognosis (e.g. advanced or aggressive disease) are less active. Therefore randomised controlled trials (RCTs) are required to confirm the impact of physical activity on mortality, recurrence and survival. There are very few ongoing RCTs that assess survival as an outcome of physical activity intervention studies. The Colon Health and Life-Long Exercise Change trial is one such RCT, which aims to assess survival of people diagnosed with high-risk stage II or III colon cancer who have completed adjuvant chemotherapy following a 3-year structured physical activity intervention (Courneya et al., 2008). Survival is to be measured every 6 months for the first 3 years and annually from years 4-10, however no survival outcomes from this trial have been published. One year feasibility results showed a significant improvement in recreational physical activity participation and various tests of functional capacity (maximum rate of oxygen consumption (VO_2^{max}), 6-minute walk, 30-second chair stand, 8-foot up-and-go, sit-and-reach tests) in the intervention group versus control (Courneya et al., 2016).

1.2.1.2 Fatigue

As one of the most prevalent and debilitating consequences of cancer and treatment, it is encouraging that strong evidence from RCTs shows that physical activity can alleviate fatigue. The Cochrane Collaboration has published two large meta-analyses, both conducted by Mishra and colleagues, to assess the impact of physical activity on a range of physical, psychological and HRQoL outcomes (including fatigue) among survivors who have completed treatment

(Mishra, Scherer, Geigle, et al., 2012) or who were undergoing active treatment (Mishra, Scherer, Snyder, et al., 2012). For those undergoing active treatment, the meta-analysis of 12 RCTs ($n=971$) found that there was a significantly greater reduction in fatigue scores from baseline to 12 weeks of follow-up among those allocated to the exercise interventions compared to control groups (standardised mean difference (SMD)=-0.73; 95% CI: -1.14,-0.31) (Mishra, Scherer, Snyder, et al., 2012). However, the methodological quality of these studies was deemed to be very low, namely due to lack of blinding among participants or those administering treatment, moderate-high statistical heterogeneity and unclear allocation concealment in more than half of the trials. A comparable pattern of results was reported in the meta-analysis of cancer survivors who had completed treatment (10 studies; $n=745$; SMD=-0.82; 95% CI:-1.50,-0.14), where the quality of evidence was better and deemed to be moderate (Mishra, Scherer, Geigle, et al., 2012). The main limitation in these studies was that it was not possible to blind study participants or those administering treatment. A more recent meta-analysis of 11 RCTs found a large effect size for the effect of exercise on cancer-related fatigue (Cohen's $d = 0.61$; 95% CI: 0.24-0.98) and no significant differences between cancer types (Kessels, Husson, & van der Feltz-Cornelis, 2018). Kessels and colleagues also found that improvement in fatigue was significantly greater for aerobic exercise as opposed to a combination of aerobic and resistance exercises. Six of the 11 studies included in this review were deemed to have a low risk of bias (Kessels et al., 2018). A meta-analysis of 113 studies demonstrated that exercise (weighted effect size (WES)=0.30; 95% CI: 0.25-0.36; $p < .001$), psychological (WES=0.27; 95% CI: 0.21-0.33; $p < .001$), and exercise plus psychological (WES=0.26; 95% CI: 0.13-0.38; $p < .001$) interventions were all superior to pharmaceutical interventions (WES=0.09; 95% CI: 0.00-0.19; $p < .05$) in targeting fatigue (Mustian et al., 2017). As a result, the authors suggest that clinicians should prescribe exercise and psychological interventions as first-line therapy for patients with CRF.

A recent study published 4-year follow-up results of an 18-week exercise program delivered during adjuvant treatment on levels of fatigue and physical activity in an RCT of 128 breast and colorectal cancer survivors (Witlox et al., 2018). In intention-to-treat analyses, Witlox et al. found that moderate-vigorous physical activity (MVPA) was significantly higher in the intervention group (141 minutes/week; 95% CI: 1-282, effect size = 0.22) versus control at 4 years. Intervention group participants also reported less physical fatigue at 4 years versus control (mean difference (MD)=-1.13; 95% CI: -2.45-0.20; effect size = 0.22), although this was not statistically significant

(Witlox et al., 2018). Witlox and colleagues propose that this may be due to insufficient power and while this study suggests that positive effects of physical activity interventions can be observed in the longer term, more studies with long-term follow-up are required to corroborate findings. A prospective cohort study of 1,928 disease-free breast cancer survivors also found that low levels of physical activity and obesity were significantly associated with persisting physical fatigue at follow-up (median 6.3 years post-diagnosis) (Schmidt et al., 2015).

A qualitative study of 23 cancer survivors participating in a 6-week exercise programme found that physical activity was associated with feelings of increased strength, physical capacity, and wellbeing (Adamsen et al., 2004). The participants identified that 'exercise-induced fatigue' was in contrast to the widely reported feeling of chemotherapy-induced fatigue which was characterised as 'physical discomfort and uncontrollable exhaustion'. The participants reported that participating in physical activity gave them a sense of energy, even if it made them feel physically tired, allowing them to differentiate between feelings of CRF and exercise-induced fatigue, which helped to provide a strategy to help manage their symptoms and feel more in control of their bodies.

As with the evidence for mortality, survival and recurrence outcomes, the majority of the existing evidence is formed from research involving breast, prostate and colorectal cancer survivors, however the evidence-base is growing for other cancer types. An RCT of 33 gynaecological cancer survivors found a significant improvement in fatigue at 12 weeks (MD=-11.06; 95% CI: -21.89, -0.23; $d=0.13$) and 6-month (MD=-19.48; 95% CI: -19.67, -19.15; $d=0.20$) follow-up between physical activity intervention and control groups (Donnelly et al., 2011). Among haematological cancer survivors, a meta-analysis of 7 RCTs ($n=692$) revealed a significant improvement in fatigue in physical activity intervention groups compared to controls (SMD=0.24; 95% CI: 0.08-0.40) (Bergenthal et al., 2014). While meta-analysis was not possible in a systematic review of 3 studies of head and neck cancer survivors, Capozzi et al. concluded that physical activity interventions show evidence of improvements in fatigue (Capozzi, Nishimura, McNeely, Lau, & Culos-Reed, 2016).

1.2.1.3 Pain

Mishra and colleagues conducted a Cochrane review which included a meta-analysis of 4 studies ($n=289$) that assessed the impact of physical activity interventions on scores on the pain subscale

of the EORTC QLQ-C30 measure of HRQoL in cancer survivors who had completed treatment (Mishra, Scherer, Geigle, et al., 2012). They reported a significant reduction in pain scores as a result of participation in physical activity interventions among cancer survivors at up to 12 weeks of follow-up (SMD=-0.29; 95% CI:-0.55,-0.04). The methodological quality of the studies was moderate, mostly due to the lack of blinding and small sample sizes (Mishra, Scherer, Geigle, et al., 2012). Galiano-Castillo et al. report the results of an RCT evaluating the impact of a tailored internet-based remote rehabilitation exercise programme, where intervention participants completed three 90 minute sessions per week including a warm-up, resistance and aerobic training, and cool-down (Galiano-Castillo et al., 2016). The trial randomised 81 stage I-III breast cancer survivors and found that intervention participants reported significantly improved pain severity and pain interference in daily activities when compared with control participants (Galiano-Castillo et al., 2016). A more recent meta-analysis of 10 RCTs of exercise interventions revealed significantly lower reported pain in intervention participants versus control (SMD = -0.17; 95% CI: -0.32, -0.03) (Nakano et al., 2018).

1.2.1.4 Chemotherapy-induced Peripheral Neuropathy

A cross-sectional study of 1,648 colorectal cancer survivors diagnosed in the Netherlands between 2000-2009 showed that those who were treated with chemotherapy and were not meeting the national guideline of 150 minutes of MVPA per week reported more symptoms of CIPN such as sensory, motor and autonomic symptoms (Mols et al., 2015). Interestingly, those who were not treated with chemotherapy were also more likely to report CIPN-like symptoms when not meeting national physical activity guidelines (Mols et al., 2015). Wonders and colleagues have conducted two pre-post studies of a structured exercise programme, one home-based and one supervised, over 10 and 12 weeks, respectively. They reported that exercise training reduced CIPN symptoms, including unpleasant skin sensations, sensitivity to neuropathic pain and symptoms coming on suddenly in bursts for no apparent reason (Wonders, 2014; Wonders et al., 2013). While these are promising findings, these studies lack a control group and are conducted in small samples. An RCT conducted among 30 colorectal cancer survivors with metastatic disease found that while intervention participants who received an 8 week structured exercise programme (involving twice-weekly 60 minute sessions incorporating endurance, resistance and balance training) had stable neuropathic symptoms across the 4-week follow-up, symptoms in the control group significantly deteriorated (Zimmer et al., 2018). Intervention

participants also improved their strength and balance function, however this study had a very small sample size. A larger trial randomised 355 breast cancer survivors receiving taxane-, platinum-, or vinca alkaloid-based chemotherapy to an individualised, home-based exercise programme or control (Kleckner et al., 2018). The intervention attenuated increases in CIPN symptom (hot/coldness in hands/feet and numbness and tingling) severity versus control group participants. However, symptoms were assessed using single-item measures. Larger, high-quality RCTs are required to make reliable conclusions about the benefits of physical activity with regards to CIPN but early evidence appears promising.

1.2.1.5 Sleep

As reported in section 1.1.3.1.4, many cancer survivors' sleep quality suffers both during and after treatment and often for a variety of reasons. In Mishra et al.'s meta-analysis of cancer survivors who had completed treatment, overall sleep disturbance was reduced for those allocated to the physical activity intervention groups compared to controls (8 studies; n=438; SMD=-0.46; 95% CI: -0.72, -0.20) at 12-weeks follow-up (Mishra, Scherer, Geigle, et al., 2012). Study quality was moderate with the most common source of potential bias arising from the inability to blind participants and/or those administering treatment. The effect was similar for cancer survivors undergoing active treatment albeit with a much smaller pooled sample size (3 studies; n=60; SMD=0.40; 95% CI: -0.67, -0.14) (Mishra, Scherer, Snyder, et al., 2012). Subgroup analyses here revealed that physical activity interventions showed a greater improvement in sleep disturbance for survivors of cancer types other than breast cancer and for those enrolled on MVPA interventions as opposed to light intensity physical activity interventions (Mishra, Scherer, Snyder, et al., 2012). A more recent meta-analysis of 9 RCTs found that sleep disturbance was significantly lower in the exercise intervention groups versus control (SMD=-0.28; 95% CI: -0.41, -0.15) with no significant difference between aerobic, resistance or mixed exercise programmes (Nakano et al., 2018).

1.2.1.6 Lymphoedema

Baumann and colleagues have recently published two systematic reviews with regards to the prevention and management of existing lymphoedema (Baumann, Reike, Hallek, Wiskemann, & Reimer, 2018; Baumann, Reike, Reimer, et al., 2018). With regards to prevention of lymphoedema, 8 RCTs were included in the review. Three of the studies specifically investigated

the effect of strength training, and the remaining 5 evaluated combined exercise therapy. Five studies specifically included participants without lymphoedema at the beginning of the study and the remaining 3 included participants with and without existing lymphoedema. Findings across the 8 included studies suggest that resistance training and combined exercise therapy (including physiotherapy, physical therapy, manual lymphatic drainage, stretching, massage, and/or kinesiotherapy) could have a potential effect on lymphoedema prevention. However, the authors acknowledge the differences between the interventions included in this review mean that it is difficult to make specific recommendations about exactly what should be advised to breast cancer survivors for lymphoedema prevention (Baumann, Reike, Hallek, et al., 2018). With regards to the management of existing breast-cancer related lymphoedema, 11 RCTs were included in the review. Interventions included aqua lymph training (hydrotherapy), swimming, resistance exercises, yoga, aerobic, and gravity-resistive exercise. Objective measures of lymphoedema (arm volume and/or arm circumference) were assessed in all 11 trials, four of which reported a significant improvement in arm volume. None of the studies demonstrate any negative effect of the interventions on breast-cancer related lymphoedema (Baumann, Reike, Reimer, et al., 2018).

1.2.1.7 Anxiety and Depression

Both of Mishra et al.'s meta-analyses assessed the impact of physical activity interventions for cancer survivors on anxiety and depression. For those who had completed treatment, evidence from 4 studies (n=455) showed a significant reduction in anxiety for those allocated to the physical activity intervention compared to control groups (SMD=-0.26; 95% CI: -0.44, -0.07) (Mishra, Scherer, Geigle, et al., 2012). Similar findings were reported for cancer survivors who were undergoing active treatment at 12 weeks of follow-up (12 studies; n=1,010; SMD=-0.46; 95% CI: -0.81, -0.11) and 6 months of follow-up (3 studies; n=286; SMD=-0.44; 95% CI: -0.71, -0.17) (Mishra, Scherer, Snyder, et al., 2012). Subgroup analyses showed the significant reduction in anxiety was more pronounced for those instructed to carry out MVPA compared to light intensity physical activity and for breast cancer survivors than for survivors of other cancer types, however the authors advise caution in interpreting these results due to the small number of trials assessing these outcomes. Meta-analysis was only conducted to assess the effect of physical activity interventions on depression among cancer survivors undergoing active treatment. There was an overall significant reduction in reporting of depression among those allocated to the physical activity intervention compared with control groups at both 12-weeks (15 studies; n=1,250; SMD=

-0.55; 95% CI: -0.87, -0.22) and 6-months follow-up (4 studies; n= 452; SMD=-0.29; 95% CI: -0.48, -0.09) (Mishra, Scherer, Geigle, et al., 2012). However, methodological quality was low or very low across all of the analyses as a result of lack of blinding, unclear allocation concealment and random sequence generation, statistical heterogeneity, small sample sizes in some of the cases, and self-reporting of physical activity. Patsou and colleagues have conducted a more recent meta-analysis of 14 RCTs, specifically looking at the impact of physical activity interventions on depressive symptoms of breast cancer survivors, with a combined sample size of 1,701 participants (Patsou, Alexias, Anagnostopoulos, & Karamouzis, 2017). Across all 14 studies, there was a small, non-significant effect size for a reduction in depressive symptoms among intervention participants ($g=-0.38$; 95% CI: -0.89, 0.13, $p = .14$). However, comparing between types of exercise interventions revealed that interventions focusing on aerobic physical activity ($g=-1.23$; 95% CI: -1.97, -0.49, $p = .001$) may have an improved effect on depressive symptoms when compared to resistance exercise interventions ($g=-0.37$; 95% CI: -4.15, 3.41, $p = .85$) or combined aerobic and resistance interventions ($g=-0.79$; 95% CI: -1.64, 0.07, $p = .07$).

1.2.1.8 Body weight and body composition

The role of physical activity in weight management and weight loss in the general population is well-established (Donnelly et al., 2009). Several studies have also demonstrated the positive impact of physical activity on body weight/body composition among cancer survivors. A meta-analysis including 60 RCTs evaluating the impact of physical activity among early stage breast cancer survivors reported that intervention group participants demonstrated significant reductions in weight (-1.36kg; 95% CI: -2.51, -0.21), BMI (-0.89kg/m²; 95% CI: -1.50, -0.28) and percent body fat (-1.6%; 95% CI: -2.31, -0.88) versus control group participants (Soares Falcetta et al., 2018). An RCT of a 12-month combined aerobic and resistance training intervention conducted among 121 breast cancer survivors taking aromatase inhibitors showed that, relative to usual care, intervention participants increased lean body mass (0.32 vs. -0.88kg, $p = .03$) and decreased percent body fat (-1.4% vs. 0.48%, $p = .03$) and BMI (-0.73 vs. 0.17 kg/m², $p = .03$) measured using dual-energy x-ray absorptiometry (Thomas et al., 2017). Dieli-Conwright et al. report the results of a further RCT that evaluated the impact of a 16-week intervention, incorporating supervised, combined aerobic and resistance exercise 3 times per week, specifically in 100 breast cancer survivors with overweight or obesity, 95% of whom presented with sarcopenic obesity. At the end of the 16-week intervention, intervention group participants showed significantly improved

BMI, weight, hip circumference, lean body mass, fat mass, percent body fat, trunk fat and sarcopenic obesity (appendicular skeletal muscle index) relative to control group participants. This study is particularly important given its focus on high-risk breast cancer survivors, demonstrating positive results (Dieli-Conwright et al., 2018). Similar results have been reported in an RCT of 97 men receiving ADT for localised prostate cancer. Wall and colleagues showed that in a 6-month combined aerobic and resistance exercise programme, intervention group participants showed significantly improved lean mass, total fat mass and trunk fat mass (Wall et al., 2017). Physical activity can also increase muscle strength, as well as muscle mass. This has been supported by a number of systematic review and meta-analyses (e.g. Capozzi et al., 2016; Speck, Courneya, Masse, Duval, & Schmitz, 2010; Strasser, Steindorf, Wiskemann, & Ulrich, 2013).

1.2.1.9 Quality of Life

Global HRQoL and some individual domains of HRQoL have been shown to improve as a result of participation in physical activity interventions after cancer. As discussed in section 1.1.3.3, it is likely that it is the co-occurrence of many of the consequences of cancer and treatment that have a profound impact on overall HRQoL. Given that the evidence outlined above demonstrates the impact of physical activity on many of these consequences such as fatigue, pain, anxiety and depression and sleep quality, it is likely that physical activity will also show an improvement in overall HRQoL. Global HRQoL (from the EORTC QLQ-C30 (Aaronson et al., 1993)) was the primary outcome of interest in both of Mishra et al.'s systematic reviews and meta-analyses of physical activity interventions during and after cancer treatment (Mishra, Scherer, Geigle, et al., 2012; Mishra, Scherer, Snyder, et al., 2012). For cancer survivors undergoing active treatment significant increases in HRQoL scores were observed at up to 12 weeks of follow-up for 11 studies assessing the difference in HRQoL change scores ($n=806$; $SMD=0.47$, 95% CI: 0.16-0.79) and 20 studies assessing the difference in HRQoL final values between groups post-intervention ($n=1,166$; $SMD=0.33$; 95% CI: 0.12-0.55) (Mishra, Scherer, Snyder, et al., 2012). However, the quality of the evidence was deemed to be very low due to lack of (or unfeasible) blinding among participants or investigators, high statistical heterogeneity and unclear allocation concealment. Among cancer survivors who had completed treatment, a similar pattern of results was found at both 12 weeks ($n=826$; $SMD=0.48$, 95% CI: 0.16-0.81) and 6 months ($n=115$; $SMD=0.46$, 95% CI: 0.09-0.84) follow-up, but whilst the quality of available evidence at 6 months was better

(moderate), this was only from 2 studies (n=115 participants) so caution should still be given to longer-term findings (Mishra, Scherer, Geigle, et al., 2012). In terms of individual domains of HRQoL, evidence from meta-analyses in both reviews found that social functioning was significantly improved as a result of physical activity interventions for cancer survivors undergoing and following completion of cancer treatment (Mishra, Scherer, Geigle, et al., 2012; Mishra, Scherer, Snyder, et al., 2012). However, improvements in physical and role functioning were only observed among those who were undergoing active treatment (Mishra, Scherer, Snyder, et al., 2012). Once again, the quality of these studies was deemed to be low to very low and it was unclear exactly whether physical activity improves individual HRQoL domains and in what circumstances.

A further meta-analysis, that included both RCTs and pre-post studies, reported that physical activity interventions were particularly successful among female participants (Ferrer, Huedo-Medina, Johnson, Ryan, & Pescatello, 2011). Similarly, a recent systematic review of 7 cross-sectional studies reported that the positive association between physical activity and long-term (≥ 5 years post-diagnosis) quality of life outcomes appeared to be stronger among female versus male colorectal cancer survivors (Eyl, Xie, Koch-Gallenkamp, Brenner, & Arndt, 2018). However, the authors do recommend that these results are interpreted with caution due to the small number of included studies that conducted subgroup analyses by gender. A cross-sectional analysis of 641 older (≥ 65 years), breast, prostate or colorectal cancer survivors with overweight or obesity (54% female) reported that, after adjusting for MVPA participation, light intensity physical activity was positively associated with domains of psychosocial quality of life (mental health, emotional role functioning, vitality and social role functioning from the Short-Form (36) Health Survey (SF-36) measure of quality of life) among female participants, but not males (Conroy, Wolin, Blair, & Demark-Wahnefried, 2017). However, MVPA was positively associated with psychosocial quality of life for male, but not female participants (Conroy et al., 2017). A systematic review of 36 RCTs specifically evaluating the impact of physical activity on quality of life in breast cancer survivors found that aerobic, resistance and combined aerobic/resistance interventions demonstrated positive results on quality of life outcomes, however the authors noted the large heterogeneity between included studies with regards to frequency, duration (of each session and intervention programmes), type of physical activity and quality of life outcome measures (Zhang, Li, & Liu, 2019). A meta-analysis of 7 RCTs (n=912) exploring the impact of exercise interventions on

prostate cancer-specific quality of life found no significant effect (SMD=0.13; 95% CI: -0.08, 0.34) (Bourke et al., 2016). However, this review also conducted sensitivity analyses with respect to risk of bias. Importantly, when the meta-analysis only included studies judged to be high quality (Bourke et al., 2014; Galvao, Taaffe, Spry, Joseph, & Newton, 2010; Segal et al., 2009), the results indicated a moderate positive effect (SMD=0.33; 95% CI: 0.08-0.58). Of these 3 studies, the one which demonstrated the largest effect on prostate cancer-specific quality of life specifically recruited inactive participants (<90 minutes moderate intensity physical activity/week), who may benefit the most from increasing levels of physical activity (Bourke et al., 2014).

Findings from these quantitative studies are supported by the results of a meta-synthesis of 40 qualitative studies (Burke et al., 2017). Themes identified demonstrated that cancer survivors perceived physical activity to have a positive impact on their quality of life and while the results were presented within four key dimensions of quality of life (physical, psychological/emotional, social and spiritual wellbeing), the authors emphasised that each of these themes/sub-themes were interconnected. Cancer survivors reported that physical activity: i) improved their physical and functional health and helped participants to manage the physical consequences of cancer and its treatment; ii) helped cancer survivors to focus on health as opposed to illness, exercise control and take action over their diagnosis, evoke positive self-perceptions, minimise negativity and gain a sense of normalcy; iii) helped cancer survivors to feel understood by others and foster social connectedness; and iv) (re)define their life purpose, live meaningfully and become more mindful (Burke et al., 2017). Taken together, both quantitative and qualitative research suggests that physical activity has a positive impact on global quality of life, as well as individual domains of quality of life in cancer survivors.

1.2.1.10 Comorbidities

Although additional trial evidence in cancer survivors is required, there is strong evidence from non-cancer populations that physical activity reduces the risk and improves self-management of many of the most common comorbidities reported in cancer survivors. This is described in detail below. As indicated in section 1.1.3.4, hypertension, obesity, mental health conditions, heart disease and diabetes are all common among cancer survivors. The positive impact of physical activity with regards to depression, anxiety, weight management, and cardiovascular disease risk in the general population is very well-established (Donnelly et al., 2009; Lear et al., 2017; Rebar et al., 2015). As described in sections 1.2.1.7 and 1.2.1.9, physical activity can also improve

mental health outcomes and psychological/emotional wellbeing in cancer survivors. Section 1.2.1.8 also described the positive impact that physical activity has on body weight and, potentially more importantly, body composition in cancer survivors. In an RCT evaluating the impact of a 16-week supervised, combined aerobic and resistance exercise intervention among 100 breast cancer survivors with overweight or obesity, Dieli-Conwright and colleagues found that intervention participants demonstrated significantly improved metabolic syndrome z-scores post-intervention versus usual care (-4.4; 95% CI: -5.9, -2.7) (Dieli-Conwright et al., 2018). The metabolic syndrome z-score was a composite outcome variable incorporating various objective measures indicative of metabolic syndrome (and therefore cardiovascular risk), including waist circumference, systolic blood pressure, diastolic blood pressure, high-density lipoprotein cholesterol, triglycerides and glucose. A further RCT of 50 men on long-term ADT for prostate cancer evaluated the impact of a combined supervised and home-based physical activity intervention with dietary on endothelial function, measured by flow-mediated dilatation of the brachial artery (Gilbert et al., 2016). At 12-week follow-up, Gilbert and colleagues reported a significant difference in mean relative flow-mediated dilatation of 2.2% (95% CI: 0.1-4.3; $p = .04$; Hedge's $g=0.60$) favouring the intervention group, however this was not sustained at 24-week follow-up (Gilbert et al., 2016). There were no significant changes in blood pressure or BMI.

Observational evidence also suggests that physical activity is important in comorbid conditions and markers of cardiovascular risk. In a cross-sectional study of 1,225 Korean cancer survivors (23% stomach; 15% cervical; 14% breast; 12% colorectal), those meeting aerobic physical activity guidelines had significantly lower metabolic disturbances, including lower fasting glucose levels, average blood glucose levels (HbA1c) and systolic blood pressure versus inactive cancer survivors (Kang et al., 2018). They also showed significantly reduced odds of common comorbidities including hypertension (OR=0.55; 95% CI: 0.32-0.93), diabetes (OR=0.64; 95% CI: 0.43-0.95) and arthritis (OR=0.64; 95% CI: 0.41-0.99). Cancer survivors meeting strength exercise guidelines also had significantly lower levels of fasting glucose, HbA1c and total cholesterol, and lower odds of arthritis (OR=0.42; 95% CI: 0.25-0.85) and back pain (OR=0.50; 95% CI: 0.30-0.83) (Kang et al., 2018). In a population-based Canadian study of 1,526 cancer survivors, those who were moderately active (OR=0.65; 95% CI: 0.48-0.88) and highly active (OR=0.55; 95% CI: 0.4-0.73) had significantly lower odds of having a CVD risk factor (hypertension/diabetes) versus the least active cancer survivors in this study (Keats et al., 2017).

This is particularly important given that the cancer survivors in this study had significantly increased odds of having ever experienced a CVD event (myocardial infarction/stroke) versus a control sample of 6,034 age-sex matched, non-cancer participants (OR=1.3; 95% CI: 1–1.7). As a result, cancer survivors with low levels of physical activity are at significantly higher risk of CVD-related comorbidity. However, both of these studies are cross-sectional and rely on self-reported physical activity and comorbidity data.

1.2.2 Mechanisms of action

As the evidence for the benefits of physical activity among cancer survivors accumulates, attention turns towards understanding the mechanisms that link physical activity and survival and recurrence, and other cancer-related side effects, such as fatigue, pain, sleep disturbance and anxiety/depression. Ballard-Barbash et al. (Ballard-Barbash et al., 2012) conducted a systematic review of observational studies and RCTs focused on physical activity, mortality and relevant cancer biomarkers to better understand the biological mechanisms underlying the link between physical activity and cancer outcomes. The review identified only one observational study, the Health, Eating, Activity and Lifestyle study, which assessed recreational physical activity and cancer-related biomarkers of insulin production (e.g. C-peptide), insulin-related metabolism, protein carriers, leptin, and inflammatory markers (i.e. C-reactive protein (CRP) and serum amyloid A) among breast cancer survivors. Across the publications resulting from this study, Irwin and colleagues found significant associations between increased physical activity and lower circulating levels of leptin, insulin-like growth factor (IGF)-1 and CRP (Irwin et al., 2005), but no significant associations for mammographic breast density, C-peptide, insulin-like growth factor binding protein (IGFBP)-3, the ratio of IGF-1 to IGFBP-3, or serum amyloid A (Irwin et al., 2006; Irwin et al., 2007; Irwin et al., 2005). More recently, a prospective study explored intraindividual and interindividual changes in objectively measured MVPA on CRP levels across five data collection points during the first year post-treatment for breast cancer. In intraindividual analyses, CRP concentration decreased in women who were more active compared to their average level of MVPA. Interindividual analyses also revealed that CRP was lower among more active women (Sabiston, Wrosch, Castonguay, & Sylvester, 2018). However, the observational nature of these studies, and lack of control group, means that it is not possible to infer causality from observational data alone.

Ballard-Barbash and colleagues' review also identified 11 RCTs which can provide a stronger evidence-base, 5 of which were conducted among breast cancer survivors. Four of these 5 studies assessed the impact of physical activity on the insulin pathway (Fairey et al., 2003; Fairey, Courneya, Field, Bell, Jones, & Mackey, 2005; Fairey, Courneya, Field, Bell, Jones, Martin, et al., 2005), all of which found a significant beneficial impact of physical activity on biomarkers of the insulin pathway (circulating insulin levels, IGF-1 or IGF-1 binding proteins), however this was not necessarily consistently significant across the studies or across insulin-related biomarkers. One RCT of breast cancer survivors also found that physical activity participation resulted in significantly higher immune function (Fairey, Courneya, Field, Bell, Jones, & Mackey, 2005). Only two of the studies assessed markers of inflammation among breast cancer survivors, one of which found a trend towards significance for lower levels of CRP among the physical activity group compared to a control (Fairey, Courneya, Field, Bell, Jones, Martin, et al., 2005), whereas the other found no significant difference among circulating levels of interleukin (IL)-6 between groups (Payne, Held, Thorpe, & Shaw, 2008). Ballard-Barbash et al.'s review also identified a study of prostate cancer survivors which assessed the impact of a physical activity intervention on circulating CRP, who found that CRP decreased in the physical activity group and increased in the control group, leaving a significant and clinical difference between groups at follow-up (Galvao et al., 2010). This study, and two other RCTs of prostate cancer survivors, found no impact of physical activity on testosterone or prostate-specific antigen (Segal et al., 2003; Segal et al., 2009).

As more evidence has emerged, Meneses-Echavez et al. (2016) were able to pool effects across 5 high-quality studies in a meta-analysis of the impact of a physical activity intervention on the IGF system among breast cancer survivors. They concluded that physical activity improved serum levels of IGF-1, IGF-2, IGFBP-1 and IGFBP-3. The IGF system is critical in mitosis, and is involved in regulating cell proliferation, differentiation and apoptosis (cell death). This is particularly important in cancer as malignant cancer cells are able to evade apoptosis. While this evidence suggests an important role for the IGF system in terms of linking physical activity and breast cancer prognosis, recurrence and survival, there is little high-quality research available for other cancer types or surrounding the specific mechanisms by which physical activity modulates the IGF system.

As discussed in section 1.2.1, there is also evidence to suggest that physical activity improves psychosocial outcomes such as fatigue, sleep quality, pain and anxiety and depression. Rogers et al. measured serum markers of inflammation (IL-6, IL-8, IL-10 and tumour necrosis factor (TNF)- α) among 42 breast cancer survivors involved in a physical activity intervention and found that inflammation and fatigue mediated and enhanced the effect of physical activity on sleep outcomes (Rogers et al., 2015). Kiecolt-Glaser and colleagues found that at 3-month follow-up, breast cancer survivors randomised to a yoga intervention reported significantly lower levels of fatigue, and had lower levels of IL-6 and IL-1 β production, but not TNF- α (Kiecolt-Glaser et al., 2014).

While the exact pathways underlying the biological mechanisms linking physical activity with improved survival and cancer-related side effects are still unclear, there is some evidence suggesting a role for reducing inflammation and biomarkers of the insulin system through its impact on cell division and apoptosis.

1.2.3 Physical activity guidelines for cancer survivors

As described in section 1.2.1, physical activity may reduce cancer-specific and all-cause mortality, cancer recurrence and can also alleviate negative consequences of the disease and treatments. There is insufficient data available to formulate cancer-specific physical activity guidelines with regards to the recommended frequency, intensity, timing and type of physical activity associated with the various cancer-specific benefits of physical activity and further research is required in this area. In lieu of cancer-specific guidelines, cancer survivors are advised to meet the same physical activity guidelines as the general adult population (Rock et al., 2012; Schmitz et al., 2010; US Department of Health and Human Services, 2008). These recommendations include a minimum of 150 minutes of at least moderate intensity physical activity and two instances of strength and resistance training per week, flexibility and balance exercises and reducing/breaking up sedentary time. Where this is not achievable, avoiding inactivity is recommended (Rock et al., 2012; Schmitz et al., 2010; US Department of Health and Human Services, 2008). Furthermore, a number of organisations have called for the inclusion of exercise within cancer care. The Clinical Oncology Society of Australia has called for: i) exercise to be embedded as part of standard practice in cancer care and to be viewed as an adjunct therapy that helps counteract the adverse effects of cancer and its treatment; ii) all members of the multidisciplinary cancer team to promote physical activity and recommend that people with cancer adhere to exercise guidelines; and iii) best

practice cancer care to include referral to an accredited exercise physiologist or physiotherapist with experience in cancer care (Cormie et al., 2018). Men with prostate cancer treated with long term ADT are recommended supervised aerobic and resistance exercise training as part of routine prostate cancer treatment by The National Institute for Health and Care Excellence (NICE) in the UK (NICE-CG175) (National Institute for Health and Care Excellence, 2014) and the European Association of Urology.

1.2.4 The ongoing need for physical activity interventions in cancer survivors

Despite the clear benefits of physical activity after cancer and the resulting physical activity guidelines for cancer survivors, adherence to lifestyle guidelines is remarkably poor (Blanchard, Courneya, Stein, & American Cancer Society's, 2008; Winkels, van Lee, et al., 2016). A cross-sectional survey of over 9,000 survivors of 6 types of cancer found that self-reported adherence to physical activity recommendations varied from 30% (uterine cancer) to 47% (skin melanoma) (Blanchard et al., 2008). While this study reported that 35% of breast cancer survivors were meeting guidelines, when physical activity is measured objectively using accelerometers, this is often much lower. For example, in a sample of 259 breast cancer survivors, only 16% met physical activity guidelines when measured objectively (Boyle, Vallance, Ransom, & Lynch, 2016). Additionally, data from the National Health and Nutrition Examination Survey, a representative population-based survey in the USA reported that only 8% of cancer survivors met physical activity recommendations when measured with accelerometers (Thraen-Borowski, Gennuso, & Cadmus-Bertram, 2017).

Typically, physical activity levels fall and sedentary behaviour rises as a result of a cancer diagnosis. In a survey of 629 cancer survivors, the majority of whom (80%) were still receiving some form of active treatment, 79% felt that their physical activity levels had decreased since their diagnosis (Romero et al., 2018). Data from the English Longitudinal Study of Ageing showed that for those who received a cancer diagnosis between waves of data collection (biennially), the proportion of respondents who were moderately-vigorously active at least once a week fell from 13.2% to 9.4% compared to a fall of 15.9% to 15.1% in the comparison group (Williams, Steptoe, & Wardle, 2013). The same study showed that sedentary behaviour rose from 5.1% to 8.6% in those who received a cancer diagnosis between data collection waves compared to a rise from 3.2% to 4.9% in the comparison group. Wang and colleagues also reported that cancer survivors were less likely to engage in physical activity compared to those without a cancer diagnosis

(adjusted OR=0.79, 95% CI: 0.67-0.93) using data from the nationally-representative Scottish Health Survey (Wang, McLoone, & Morrison, 2015). However, these studies all employed self-report measures of physical activity. In a nationally representative survey measuring physical activity objectively from the USA, Thraen-Borowski and colleagues found that when compared to age-matched individuals without a cancer diagnosis, cancer survivors performed significantly less light intensity physical activity, were more sedentary and took fewer breaks in sedentary time, but there were no significant differences in MVPA participation (Thraen-Borowski et al., 2017).

A mixed-methods systematic review, including 9 qualitative and 10 quantitative studies, concluded that persisting treatment-related side effects were the most commonly reported barrier to initiating/maintaining physical activity among cancer survivors (Clifford et al., 2018). These side effects differed by cancer site, as a result of the location of treatment. For instance, chronic diarrhoea and colostomy bags; lymphoedema and shoulder stiffness; and incontinence were reported as barriers to physical activity by colorectal, breast and prostate cancer survivors, respectively. Fatigue, a lack of information about what to do, what type/intensity of exercise is safe and effective and a lack of information from health professionals about physical activity were also commonly reported barriers (Clifford et al., 2018). In a cross-sectional study that assessed the association between fatigue, pain and decreased physical activity, cancer survivors who reported higher levels of fatigue (adjusted OR=4.01; 95% CI: 2.41-6.65) and pain (adjusted OR=1.89; 95% CI: 1.14-3.12) had increased odds of reporting that their physical activity had decreased since their diagnosis (Romero et al., 2018). Furthermore, those with highest levels of comorbidities were the least active in a study employing objective measures of physical activity (Boyle et al., 2016). This is particularly important given the high prevalence of comorbidities among cancer survivors, described in section 1.1.3.4 (Macmillan Cancer Support, 2015). Other non-cancer specific barriers are reported including lack of time, appropriate facilities, enjoyment and motivation (Clifford et al., 2018).

Very few cancer survivors meet physical activity recommendations and cancer survivors face unique challenges with regards to initiating, increasing or maintaining physical activity before, during or after treatment. As a result, tailored physical activity interventions that can alleviate the negative consequences of a cancer diagnosis and treatment, promote quality of life, and lead towards improved self-management and risk reduction of many common comorbid conditions are needed.

1.2.4.1 Approaches to delivery of physical activity interventions in cancer survivors

There is ongoing debate about the most appropriate, feasible and effective way to implement physical activity support within routine cancer care (Hardcastle & Cohen, 2017, 2018; Lopez, Jones, Alibhai, & Santa Mina, 2018; Newton, Taaffe, Chambers, Spry, & Galvao, 2018). There are considerable advantages and disadvantages to delivery of physical activity both within supervised settings and using distance-based approaches.

1.2.4.1.1 Supervised physical activity interventions for cancer survivors

A considerable proportion of the evidence-base surrounding physical activity and cancer described in this chapter draws upon findings of interventions which are delivered face-to-face, in groups or individually, and implemented in exercise facilities/clinical settings (e.g. gyms, community centres, universities or hospitals) by professional members of staff (e.g. exercise physiologists, physiotherapists, trained exercise professionals etc.). For example, colorectal cancer survivors enrolled in a physical activity intervention conducted by Bourke and colleagues, took part in group-based supervised exercise sessions of 30 minutes of aerobic exercise (e.g. treadmills, rowing and cycling machines) and 2-4 sets of 8-12 repetitions of resistance-based exercises in an exercise facility in a UK hospital led by an exercise physiologist (Bourke et al., 2011). Participants were required to meet 55-85% of age-predicted maximum heart rate within the sessions, which were delivered twice-weekly for the first 6 weeks and once per week for the last 6 weeks of the intervention. Participants were also encouraged to take part in one home-based session for the first 6 weeks and two home-based sessions for the last 6 weeks. Similarly, participants randomised to the intervention group in a trial conducted by Courneya et al. were required to attend exercise sessions 3 times per week using cycling machines at an intensity of 70-75% maximal oxygen consumption for 15 weeks. During weeks 1-3, participants used the machines for 15 minutes, which increased by 5 minutes per week to 35 minutes at weeks 13-15 (Courneya et al., 2003).

Interventions delivered by qualified exercise professionals can ensure that those who attend receive a personalised exercise prescription and supervision, which may be necessary for cancer survivors with particular comorbidities or specific requirements. As a result, some have criticised distance-based/independent exercise interventions. For instance, Newton, Taaffe, et al. (2018) state that cancer survivors with cachexia/sarcopenia require a more personalised assessment and exercise prescription than the generic recommendations for cancer survivors, as 150 minutes

of MVPA per week could exacerbate the muscle, fat, and bone loss as a result of the increasing energy deficit. Furthermore, they add that many cancer survivors are older, with several comorbid conditions, and supervision and personalisation of an exercise prescription is necessary to reduce the risk of adverse events (Newton, Taaffe, et al., 2018). Systematic review evidence also suggests that physical activity interventions demonstrate an improved effect on quality of life, muscular and aerobic fitness when they are delivered in supervised settings versus distance-based interventions (Segal et al., 2017).

However, these types of interventions are very time and resource-intensive and are therefore costly to implement and/or attend. Furthermore, supervised exercise interventions are likely to appeal to cancer survivors with high levels of motivation and self-regulation but may not be appealing to the vast majority of sedentary cancer survivors, resulting in limited uptake (Hardcastle & Cohen, 2017). For example, in the aforementioned RCT conducted by Bourke et al., 180 colorectal cancer patients were sent a recruitment letter endorsed by their surgeon (Bourke et al., 2011). No response was received from almost two thirds (63%) of the potential sample, a further 21% sent a “not interested” response and only 10% (n=18) were randomised to the intervention/usual care. Furthermore, in a study where trained recruiters approached breast cancer survivors during outpatient clinics for chemotherapy/radiotherapy, of 1,144 patients approached, 831 (73%) declined pre-screening to the study (Mutrie et al., 2007). The most common reasons were because of transport problems (n=425), not interested (n=79) and other health problems (n=63). A further 110 patients were excluded after pre-screening, 66 of whom declined to participate. Only 4 patients were excluded at pre-screening because they did not meet inclusion criteria. In total, 203 patients were randomised from the initial 1,144 patients approached (18%) (Mutrie et al., 2007). A qualitative study of 20 cancer survivors, who had cancelled their registration with or withdrawn from an exercise programme run by the Cancer Council Western Australia, revealed that issues with access, timing of classes and travel, cost of continuing facility-based exercise and a lack of motivation or confidence were the main reasons for withdrawal (Hardcastle et al., 2018). Other studies have demonstrated that barriers including low motivation, access, time and cost (Blaney, Lowe-Strong, Rankin-Watt, Campbell, & Gracey, 2013; Courneya et al., 2005; Hardcastle, Glassey, Salfinger, Tan, & Cohen, 2017; Hardcastle, Maxwell-Smith, et al., 2017; Ottenbacher et al., 2011; Rogers, Courneya, Shah, Dunnington, & Hopkins-Price, 2007) could explain the often reported poor attendance at and dropout from supervised physical activity

interventions among cancer survivors (Leach, Danyluk, Nishimura, & Culos-Reed, 2015). Indeed, a systematic review of 15 exercise RCTs in adult cancer survivors that evaluated outcomes related to factors predicting exercise adherence, reported that location of the rehabilitation centre, history of exercise, motivation for exercise and fewer exercise limitations predicted adherence to the intervention during cancer treatment. After completion of treatment, less extensive surgery, low alcohol consumption, high previous exercise adherence, family support, feedback by trainers and knowledge/skills of exercise predicted adherence (Ormel, van der Schoot, Sluiter, et al., 2018).

An additional issue is a lack of available and appropriate services and/or referral pathways to such services where they exist. A recent UK study found that, despite national guidelines recommending that prostate cancer survivors treated with ADT should receive 12 weeks of supervised exercise training, only 17% of NHS trusts are actually able to provide this (Bourke et al., 2018).

1.2.4.1.2 Physical activity interventions delivered remotely

Distance-based interventions (e.g. printed materials, telephone-based and digital interventions) could offer more accessible, broad-reaching and cost-effective delivery strategies. A systematic review of 41 quantitative and qualitative studies reported that cancer survivors have indicated preferences for home-based/independent physical activity interventions, with a preference for moderate intensity exercise, predominantly walking (Wong, McAuley, & Trinh, 2018). Goode and colleagues conducted a systematic review of 27 distance-based intervention studies, published up to 2013, and targeting physical activity, diet and/or weight control among cancer survivors. The majority of included studies evaluated telephone-based interventions (22 of 27), 3 studies evaluated web-based interventions, 2 interventions used mailed print materials, and the majority of trials focused on physical activity promotion (Goode, Lawler, Brakenridge, Reeves, & Eakin, 2015). Almost 75% of the studies included in Goode and colleagues' review were effective, leading them to conclude that distance-based approaches to intervention delivery could be used for health behaviour change. However, they highlighted the lack of studies utilizing more modern approaches to communication technologies (e.g. websites, text messaging). More recently, Groen and colleagues report the results of a systematic review and meta-analysis of 29 RCTs, evaluating the impact of physical activity interventions delivered remotely, published between 2013-2018 (i.e. since Goode et al.'s review) (Groen, van Harten, & Vallance, 2018). Their analysis

included 4,203 cancer survivors and revealed a significant, small effect of the intervention over control in the included studies (SMD=0.21; 95% CI: 0.11-0.32). However, the authors acknowledge that the majority of studies were over-represented by breast cancer survivors, and by married, Caucasian, relatively young and well-educated samples. As a result, the results of the review are unlikely to be representative of the wider population of cancer survivors. Furthermore, they identified major methodological limitations of the included studies, including a high proportion of the studies using self-report measures of physical activity, small sample sizes, lack of clarity with regards to the approach used to randomise/allocate participants to intervention and control groups, and the unfeasibility of study blinding (Groen et al., 2018).

1.2.4.1.3 The potential for digital physical activity interventions in the context of cancer

The widespread and rising use of the internet, smartphones and mobile technology mean that digital interventions have the benefit of being able to reach large proportions of the population in a way that could be more cost-effective and scalable.

The most recent Ofcom Communications Market report (OFCOM, 2018) reported that the proportion of UK households with an internet connection has risen from 64% in 2007 to 87% in 2018 and that personal smartphone ownership rose from 17% of adults in 2008 to 78% in 2018. During this period, laptop computer ownership rose from 44% in 2008 to 63% in 2018 (although ownership of a desktop computer fell from 69% to 28%) (OFCOM, 2018). However, it is important to acknowledge that there are differences in internet access and smartphone uptake between demographic groups. While overall internet access was 88% in 2017, it was 95% for 16-24 year olds compared to 78% of 65-74 year olds and 53% of those aged over 75 years (OFCOM, 2017). Furthermore, internet access was higher (94%) in households of higher socioeconomic position (SEP) (managerial, administrative, or professional qualifications) and lower (74%) in households of lower SEP (semi- or unskilled occupations or non-working households).

A similar pattern is shown for smartphone ownership. Despite 76% of all UK adults owning a smartphone in 2017, this was 96% for 16-24 year olds compared to 47% of those aged over 55 years. While older people are less likely to own a smartphone, this age group is where ownership is increasing most rapidly. Among people over the age of 55, smartphone ownership rose from just over a third (34%) in 2015 to just over half (51%) in 2018, compared to an increase from 90% to 95% for 16-24 year olds within the same time period (OFCOM, 2017, 2018). Almost half (48%)

of adults in the UK consider that their smartphone is the most important device for internet access and while there is a similar socioeconomic gradient with regards to smartphone ownership, smartphones appear to be a more affordable device for internet access among those in lower SEP households versus laptop/desktop computers. In the highest SEP households, 86% of adults own a smartphone, 81% own a laptop and 43% own a desktop computer. However, in the lowest SEP households, 65% own a smartphone but only 43% own a laptop and 17% own a desktop computer (OFCOM, 2017). Similar demographic patterns in internet access and smartphone ownership have been reported for older adults in the United States of America (USA) (Pew Research Center, 2017b, 2018).

As a result of increasing internet access and smartphone ownership, the popularity of digital interventions in a health context has also increased. Digital interventions have included the use of text-messaging, email, mobile applications (apps), video-conferencing (e.g. Skype), social media, websites and online patient portals to increase patient access to information, empower patients to promote self-management, connect patients with health services and deliver behaviour change interventions remotely. Digital health behaviour change interventions (DHBCIs) have been used in the promotion of medication adherence (Mistry et al., 2015), management of long-term conditions (Whitehead & Seaton, 2016), including diabetes (Su et al., 2016), inflammatory bowel disease (Jackson, Gray, Knowles, & De Cruz, 2016), cardiac rehabilitation (Rawstorn, Gant, Direito, Beckmann, & Maddison, 2016), in smoking cessation (Spohr et al., 2015), and in the promotion of physical activity and healthy eating in various populations (Hammersley, Jones, & Okely, 2016; Jahangiry, Farhangi, Shab-Bidar, Rezaei, & Pashaei, 2017; Mateo, Granado-Font, Ferre-Grau, & Montana-Carreras, 2015; Nour, Chen, & Allman-Farinelli, 2016). A systematic review of 224 studies reported that internet and mobile interventions improved diet, physical activity, obesity, tobacco and alcohol use up to 1 year (Afshin et al., 2016). With regards to physical activity specifically, a large systematic review and meta-analysis of 22 RCTs evaluating web-based interventions in 21,316 participants in the general population, found a significant positive effect of web-based interventions on walking, step-count and MVPA participation (Jahangiry et al., 2017). While 8 of the interventions included in Groen and colleagues' review evaluated digital approaches to physical activity intervention delivery among cancer survivors, the review also included interventions that employed print materials and telephone-based interventions that are likely to differ considerably to digital interventions given the level of human

contact required for telephone-based interventions and lack of interactivity in interventions using print materials. Less is known about the effectiveness of digital approaches to physical activity intervention delivery among cancer survivors.

1.3 Summary

As the number of people being diagnosed with cancer continues to increase each year, it is important to ensure that cancer survivors are supported to live as well as possible in the years after they are diagnosed. Cancer survivors are at risk of a range of physical and psychological effects of diagnosis and treatment, other late effects and comorbid conditions. Physical activity improves quality of life and many of the consequences of cancer and treatment (e.g. fatigue, pain, sleep, anxiety and depression). Physical activity is also important in reducing the risk of other common comorbid conditions (e.g. CVD, diabetes) and observational evidence shows that physical activity may reduce the risk of cancer recurrence, all-cause and cancer-specific mortality. The majority of cancer survivors do not meet recommended levels of physical activity and there is an urgent need for evidence-based interventions that are accessible, low-cost and have the feasibility to be rolled out to reach a large number of cancer survivors. Digital interventions, including smartphone apps, could be an effective way to increase physical activity in cancer survivors.

Chapter 2: Aims of the thesis

The evidence described in Chapter 1 illustrates the potential for physical activity in the management of many of the physical and psychological consequences of a cancer diagnosis and treatment and the need for evidence-based physical activity interventions that are easier to access, low-cost and have the acceptability and feasibility to be rolled out to reach a large number of cancer survivors. Therefore, the overall aim of this thesis was to develop a smartphone app-based intervention to promote physical activity among people living with and beyond cancer. Specifically, this PhD aimed to address the following research questions:

1. What is the evidence for digital interventions targeting physical activity in cancer survivors?
2. What proportion of breast, prostate and colorectal cancer survivors are interested in digital health behaviour change interventions and what factors are associated with interest in digital interventions?
3. What are breast, prostate and colorectal cancer survivors' perspectives of publicly available physical activity smartphone apps?
4. What are breast, prostate and colorectal cancer Clinical Nurse Specialists' perspectives on physical activity promotion and the role of smartphone app-based physical activity interventions within cancer care?

Firstly, Study 1 systematically reviewed and meta-analysed the available evidence of digital physical activity interventions in cancer survivors. Study 2 examined the proportion of breast, prostate and colorectal cancer survivors interested in lifestyle information/advice delivered using digital approaches to intervention delivery, and explored the association between interest in digital interventions with sociodemographic and clinical characteristics and factors related to physical activity in a cross-sectional survey. Studies 3 and 4 both used qualitative methods to explore breast, prostate and colorectal cancer survivors' experiences of using publicly available physical activity apps (Study 3) and breast, prostate and colorectal cancer Clinical Nurse Specialists' perspectives on physical activity promotion and the role of smartphone app-based physical activity interventions within cancer care (Study 4).

Chapter 3 (Study 1): Digital health behaviour change interventions targeting physical activity and diet in cancer survivors: a systematic review and meta-analysis²

3.1 Background

As discussed in Chapter 1, in 2015, Goode and colleagues published a systematic review of 27 studies evaluating physical activity, diet and/or weight management interventions for cancer survivors that were delivered using distance-based approaches (e.g. print materials, via telephone or digital technologies) (Goode et al., 2015). While these authors found that there was evidence that distance-based approaches can promote positive behaviour change in cancer survivors, they only identified 3 studies that used digital approaches to intervention delivery (via email, a website and social media) (Hatchett, Hallam, & Ford, 2013; Rabin, Dunsiger, Ness, & Marcus, 2011; Valle, Tate, Mayer, Allicock, & Cai, 2013), and highlighted this as a possible area for future research. A more recent review identified a further 8 studies that employed digital technology for intervention delivery (Groen et al., 2018). However, both reviews included all approaches to distance-based intervention delivery and neither focused on digital interventions specifically. Distinguishing between these intervention types is important as digital interventions are likely to differ considerably to print- or telephone-based interventions given the level of human contact involved in telephone-based interventions and lack of interactivity in interventions using print materials. Less is known about the effectiveness of digital approaches to physical activity intervention delivery among cancer survivors alone. 'Identifying the evidence-base' is a key component of the Medical Research Council guidance for developing and evaluating complex interventions (Craig et al., 2008). Therefore, the first study within this PhD thesis set out to identify and synthesise the current available evidence to provide a foundation to inform the rest of the studies within the thesis. Despite the focus on physical activity in this thesis, this review included interventions targeting physical activity and/or diet and/or sedentary behaviour among cancer survivors, since no such review/meta-analysis had been conducted in cancer survivors prior to

² A version of this chapter has been published (Appendix A).
Roberts AL, Fisher A, Smith L, Heinrich M, Potts HW. Digital health behaviour change interventions targeting physical activity and diet in cancer survivors: a systematic review and meta-analysis. *J Cancer Surviv* 2017 Dec;11(6):704-719. DOI: [10.1007/s11764-017-0632-1](https://doi.org/10.1007/s11764-017-0632-1)

this and this study therefore made a significant contribution to the field. The findings also allowed better understanding of the use of digital technologies in interventions targeting similar health behaviours in cancer survivors.

3.2 Aims

The primary aim of this study was to perform a systematic review and meta-analysis of health behaviour change interventions using digital technologies in cancer survivors in order to assess their efficacy in promoting physical activity, reducing sedentary behaviour and/or improving dietary quality. Secondary aims were to explore any effects of digital health behaviour change interventions (DHBCIs) on BMI/weight, other cancer-relevant outcomes and the theoretical underpinning of included studies.

3.3 Methods

3.3.1 Search strategy

A systematic literature search was conducted from database inception to November 8th 2016, of the following databases: Medline, EMBASE, PsycINFO and CINAHL. Full details of the search strategy/terms used can be found in Appendix B. Broadly, the search strategy combined synonyms for physical activity, diet and/or sedentary behaviour; with types of DHBCIs (e.g. website, mobile app, text messaging); with words for cancer survivor(ship). Limits included peer-reviewed, English language articles in human subjects. Forward and backward citing of included studies and hand-searching of relevant journals was also conducted to identify relevant articles. The protocol was registered in the PROSPERO database (CRD42016026956). After piloting of the search strategy, no new or relevant articles from other databases specified in the protocol (Cochrane Library, Web of Science, ACM Digital Library, or IEEE Xplore) were identified so these databases were excluded for the final search. As specified in the protocol, the Proquest database (grey literature) was searched, however this resulted in >60,000 search results. Results were sorted by relevance and the first 200 titles were reviewed. No additional, relevant papers which met criteria were identified throughout this process so grey literature was not included.

3.3.2 Study selection

Studies were selected in line with the search strategy shown in Figure 3.1. Eligible studies included DHBCIs delivered remotely and targeting at least one of the following health behaviours:

physical activity, diet and/or sedentary behaviour in adults (≥ 18 years) who had a cancer diagnosis of any type. As this is a new and emerging field of research, there were no restrictions on quantitative study designs, so RCTs, non-randomised controlled trials and one-arm pre-post comparison studies could be included. However qualitative studies and protocols were excluded. Studies must have measured at least one of the target health behaviours (physical activity, diet and/or sedentary behaviour) at baseline and follow-up, but there were no limits on length of follow-up for inclusion.

3.3.3 Data extraction and quality assessment

Two authors (myself and my primary supervisor, Dr Abi Fisher) independently reviewed 109 full-text articles screened for eligibility and extracted the data for included studies including author, country of study, study design, sample size, retention rate, population studied, age of participants, study duration, intervention type (i.e. type of DHBCI), description of intervention content (including incorporated behaviour change techniques (BCTs)), approaches to measurement of engagement/adherence to the intervention, control group treatment and outcomes measured. Any discrepancies were resolved through discussion. Michie et al.'s BCT Taxonomy (v1) (Michie, Atkins, & West, 2014; Michie et al., 2013) was used to code BCTs based on information provided in the included studies (and any supplementary material). The Cochrane Collaboration's tool for assessing risk of bias was used to evaluate methodological quality of included studies (Higgins & Green, 2011). Michie and Prestwich's Theory Coding Scheme was used to evaluate the theoretical basis of the included studies (Michie & Prestwich, 2010).

3.3.4 Statistical Methods

Where possible, findings from both RCTs and non-randomised pre-post studies were synthesised in random effects meta-analyses using Stata. Effect sizes for the intervention were calculated using the difference in final values between experimental and control groups in RCTs and the change in scores before and after the intervention in pre-post studies. It is not recommended to combine studies using a mixture of final values and change scores when using SMDs across studies using different measurement units/tools to assess an outcome (Higgins & Green, 2011). Therefore, outcomes using the same measurement unit were chosen wherever possible so non-standardised mean differences could be used and RCTs and pre-post studies could be combined in the meta-analyses (Higgins & Green, 2011). Where this was not possible (i.e. fatigue

outcomes), SMDs and their associated 95% CIs were calculated, and meta-analyses were conducted for the RCTs only (where the effect size reflects difference in final values between groups). As BMI is largely influenced by weight, the variability in reliability was judged to be similar for weight and BMI. Therefore, SMDs were used to pool the effect of BMI and weight across both the RCTs and pre-post studies reporting these outcomes. For physical activity outcomes, MVPA was chosen as the outcome measure of interest due to the American College of Sports Medicine's recommendation that cancer survivors follow the physical activity guidelines for the general population of at least 150 minutes of at least moderate intensity physical activity per week (Rock et al., 2012; Schmitz et al., 2010; US Department of Health and Human Services, 2008). Studies reporting MVPA duration in minutes were pooled in the meta-analysis, so studies with differences in final values and change scores could be used using mean differences. Studies that did not report moderate and vigorous physical activity separately or MVPA combined in minutes, could not be included in the meta-analysis of physical activity outcomes. For the studies that reported minutes of moderate and vigorous physical activity separately, a new combined MVPA variable was calculated. To combine the means for moderate and for vigorous PA, the following formula was used:

$$\bar{x}_{MVPA} = \bar{x}_{\text{moderate physical activity}} + \bar{x}_{\text{vigorous physical activity}}$$

To combine the standard deviations for moderate and vigorous physical activity, the following formula was used:

$$\sigma_{MVPA} = \sqrt{((\sigma^2_{\text{moderate physical activity}}) + (\sigma^2_{\text{vigorous physical activity}}))}$$

Publication bias was explored using funnel plots prepared in Stata. Due to the small number of included studies for each outcome, tests for funnel plot asymmetry, such as Egger's regression test (Egger, Davey Smith, Schneider, & Minder, 1997) were not deemed appropriate and only visual inspection of funnel plots was conducted.

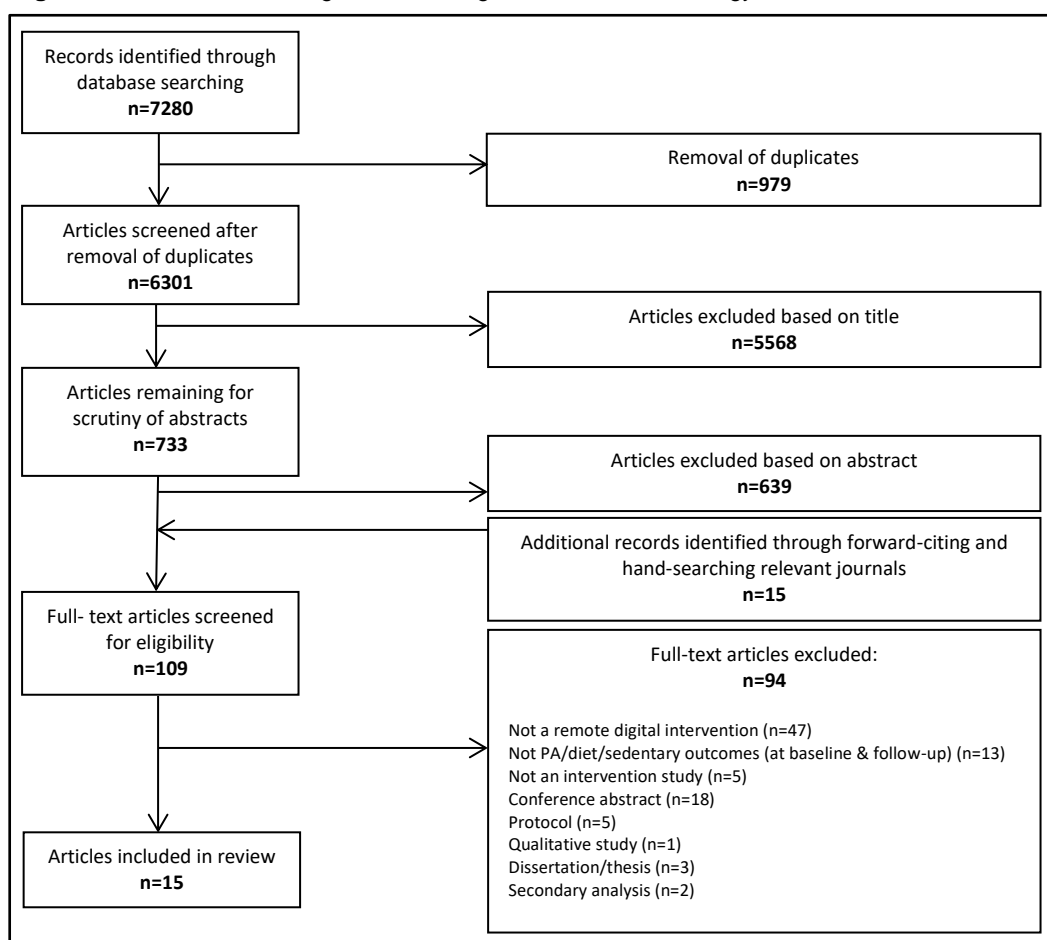
3.4 Results

3.4.1 Study selection

See Figure 3.1 for the PRISMA flow diagram of the study selection process. The search strategy initially identified 7280 records and 15 were included in the final review (Bantum et al., 2014; Berg,

Stratton, Giblin, Esiashvili, & Mertens, 2014; Forbes, Blanchard, Mummery, & Courneya, 2015; Hatchett et al., 2013; Hoffman et al., 2014; Hong et al., 2015; Kanera, Bolman, Willems, Mesters, & Lechner, 2016; Kuijpers et al., 2016; Lee, Yun, et al., 2014; McCarroll et al., 2015; Puzskiewicz, Roberts, Smith, Wardle, & Fisher, 2016; Quintiliani, Mann, Puputti, Quinn, & Bowen, 2016; Rabin et al., 2011; Short et al., 2017; Valle et al., 2013).

Figure 3.1: PRISMA flow diagram illustrating article selection strategy



See Table 3.1 for characteristics of included studies and Table 3.2 for characteristics of intervention types and outcomes. The majority of studies (12/15) were published between 2014 and 2016, with one study published in 2012 (Rabin et al., 2011) and two in 2013 (Hatchett et al., 2013; Valle et al., 2013). Sample sizes ranged between 7 (Hoffman et al., 2014) and 462 participants (Kanera et al., 2016). Eight studies were RCTs (Bantum et al., 2014; Forbes et al., 2015; Hatchett et al., 2013; Kanera et al., 2016; Lee, Yun, et al., 2014; Rabin et al., 2011; Short et al., 2017; Valle et al., 2013) and the remaining 7 were pre-post comparison studies (Berg et al., 2014; Hoffman et al., 2014; Hong et al., 2015; Kuijpers et al., 2016; McCarroll et al., 2015; Puzskiewicz et al., 2016; Quintiliani et al., 2016). The studies used an average of 8 BCTs (range

Table 3.1: Characteristics of included studies

Author, year	Country	Study design	Sample Size	Retention rate at follow-up	Women, %	Age in yrs, mean (SD)	Cancer type(s)
Bantum, 2014	USA	RCT	303	86.1% (303/352)	82	49.3 (11)	Any type of cancer, completed treatment >4 weeks prior to study
Berg, 2014	USA	Pre-post	19	79.2% (19/24)	71	23.4 (3.9)	Adult (18-34 yrs) survivors of childhood cancers (any type)
Forbes, 2015	Canada	RCT	87	91.6% (87/95)	56	65.1 (8.5)	Breast, prostate & colorectal cancer survivors (96% currently disease free; 75% completed treatment)
Hatchett, 2013	USA	RCT	74	87.1% (74/95)	100	No data	Breast cancer survivors, completed treatment
Hoffman, 2014	USA	Pre-post	7	100% (7/7)	71	64.6 (6.5)	NSCLC survivors (immediately before + after surgery/during treatment)
Hong, 2015	USA	Pre-post	26	86.7% (26/30)	69	69 (median)	Any type of cancer survivor, either undergoing or completed treatment
Kanera, 2016	Netherlands	RCT	394 ^a	89.2% (462/518) ^a	80	56.0 (11.4)	Any type of cancer, completed treatment >4 weeks & <56 weeks prior to study, no recurrence
Kuijpers, 2016	Netherlands	Pre-post	73	79.3% (73/92)	100	49.5 (11.4)	Breast cancer survivors, either undergoing or completed treatment 3-12 months prior to study
Lee, 2014	South Korea	RCT	57	96.6% (57/59)	100	43.2 (5.1)	Breast cancer survivors, completed treatment <1 year prior to study
McCarroll, 2015	USA	Pre-post	35	70.0% (35/50)	100	58.4 (10.3)	Overweight/ obese breast and/or endometrial cancer survivors with desire to lose weight, diagnosis <3 years prior to study
Puszkiewicz, 2016	UK	Pre-post	11	100% (11/11)	82	45 (9.4)	Breast, prostate or colorectal cancer survivors, completed treatment
Quintiliani, 2016	USA	Pre-post	10	100% (10/10)	100	58.6 (6.1)	Breast cancer survivors, >2yrs since diagnosis & >6months since end of treatment
Rabin, 2012	USA	RCT	17	94.4% (17/18)	56	32.2 (5.6)	Young adult (18-39) cancer survivors, completed treatment <10yrs prior to study
Short, 2016	Australia	Pre-post ^b	156 ^b	31.7% ^c (156/492)	100	55.0 (9.7)	Breast cancer survivors, completed treatment
Valle, 2013	USA	RCT	66	76.7% (36/86)	91	31.7 (5.1)	Young adult (21-39) cancer survivors, diagnosed >18 years of age, >1 year since diagnosis, completed treatment

^a: Kanera et al. presented physical activity data for 394 participants (sample size used in meta-analysis) however retention for other measures at follow-up was 462 .

^b: Short et al. (2016) is treated as a pre-post study due to the lack of control group across the 3 intervention arms.

^c: Short et al's paper presents results for 3-month follow-up (immediately post-intervention) because retention rate at 6-months was very low (10.8% (53/492). Sample size/retention rate presented here is for 3-month follow-up.

NSCLC: Non-small-cell lung cancer

Table 3.2: Intervention types and outcomes for included studies.

Author, year	Intervention type	Study duration	Description of intervention	Behaviour Change Techniques (BCTs)	Approaches to measurement of engagement/adherence	Control group treatment	Outcomes measured
Bantum, 2014	Online workshop (website)	6 months	6 week online course providing information, skill building, weekly action plans, social networking and peer support, exercise logs, relaxation exercises	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 9.1 Credible source	Mean (SD) online sessions attended was 5.3 (1.28) 67% attended all 6 sessions 86.8% attended >4 sessions	Waitlist control	PA, diet, fatigue, depression, insomnia
Berg, 2014	Emails + associated website	12 weeks	Biweekly emails to deliver module content and website provides graphical depictions of participant-reported health behaviours and health information.	2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour Participants also offered deals for healthy goods/services in local area for completing self-monitoring (regardless of behaviour reported)	Completion of self-monitoring ("check-in assessment") over 12-module period (6 weeks) fell from 91.7% to 66.7%	N/A	PA, SE, alcohol consumption, smoking
Forbes, 2015	Online workshop (website)	10 weeks	9 week workshop to deliver content (e.g. dispelling PA myths, exercising safely, planning/making SMART goals). Website used to log/monitor PA and email feedback.	2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 5.1 Information about health consequences 6.2 Social comparison 9.1 Credible source 10.4 Social reward	Percentage of completed modules fell from 50% (week 1) to 10% (week 9) 94% logged in at least once, 85% recorded PA at least once, 67% viewed modules at least once.	Waitlist control	PA, QoL (cancer-specific), QoL (generic), fatigue
Hatchett, 2013	Email + access to e-counsellor	12 weeks	Emails designed to increase PA by influencing SCT variables. E-counsellor offered tailored PA advice and encouraged participant engagement with intervention.	1.1 Goal setting (behaviour) 1.2 Problem solving 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 9.1 Credible source 13.5 Identity associated with changed behaviour	Not measured/reported	Waitlist control	PA, SE, self-regulation, OE value, exercise role identity
Hoffman, 2014	Nintendo Wii Fit Plus	16 weeks	Virtual walking environment with gradual increase in target walking time. Three Wii Fit Plus balance exercises per day were also recommended.	1.1 Goal setting (behaviour) 1.5 Review behaviour goals 2.3 Self-monitoring of behaviour 8.7 Graded tasks 9.1 Credible source 12.5 Adding objects to the environment	Mean (SD) adherence rate to intervention at end of study was 87.6% (12.2%)	N/A	PA, fatigue, SE

Hong, 2015	Mobile-enabled website	8-12 weeks	Website used for goal setting, activity tracking, personalised feedback and progress reviews, social networking, tips on healthy living and links to reliable health information.	<ul style="list-style-type: none"> 1.1 Goal setting (behaviour) 1.4 Action planning 1.5 Review behaviour goals 1.6 Discrepancy between current behaviour and goal 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 5.1 Information about health consequences 9.1 Credible source 	<p>Website use:</p> <ul style="list-style-type: none"> 12% once/fortnight; 62% once/week; 19% 2-3 times/week 8% 4-5 times/week 	N/A	PA, QoL (generic),
Kanera, 2016	Online workshop (website)	6 months	Automated system to evaluate baseline assessment and select personalised intervention components using 'if-then' algorithms. Users are recommended modules based on assessments but have access to all 8 modules.	<ul style="list-style-type: none"> 1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.5 Review behaviour goals 1.6 Discrepancy between current behaviour and goal 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 5.1 Information about health consequences 6.2 Social comparison 7.1 Prompts/cues 8.2 Behaviour substitution 9.1 Credible source 9.2 Pros and cons 11.2 Reduce negative emotions 13.2 Framing/reframing 	<p>Specific modules were recommended to participants based on current behaviours from 8 modules in total. Participants followed mean (SD) 2.23 (1.58) modules. 25% participants followed PA module, and 62% followed diet module.</p>	Waitlist control	PA, diet, smoking

Kuijpers, 2016	Online portal (website)	4 months	Offers personalised education materials, overview of appointments, access to EMR. Tailored PA support based on clinical characteristics, PA levels and motivation.	1.1 Goal setting (behaviour) 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 6.2 Social comparison 9.1 Credible source	Website logins ranged from 0-62 and duration of use ranged from 2-38 minutes. Participants on-treatment (M=10.9 logins) used website more often than off-treatment (M=5.6 logins) participants but those who were off-treatment had a longer mean duration (15.2 minutes) of log in compared to on-treatment (11.3 minutes)	N/A	PA, QoL (generic), SE
Lee, 2014	Website + text-messaging	12 weeks	Website used for assessment, education, tailored information provision and action planning (goal setting, scheduling, monitoring and automatic feedback). Daily automatic feedback provided on recommended and actual behaviours	1.1 Goal setting (behaviour) 1.4 Action planning 1.6 Discrepancy between current behaviour and goal 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 5.1 Information about health consequences 5.6 Information about emotional consequences 7.1 Prompts/cues 9.1 Credible source	Not measured/reported	50-page booklet on exercise/ diet	PA, diet, QoL (cancer-specific), fatigue, anxiety, depression, SE,
McCarroll, 2015	Mobile app	4 weeks	Participants log nutrition/PA through app which provided real-time personalised feedback. Limited carbohydrate intake to <70g/day and increase fibre intake to 30g/day.	1.1 Goal setting (behaviour) 1.3 Goal setting (outcome) 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 2.4 Self-monitoring of outcomes of behaviour 3.1 Social support (unspecified) 7.1 Prompts/cues 9.1 Credible source 15.1 Verbal persuasion about capability	Not measured/reported	N/A	PA, diet, QoL (cancer-specific), SE, weight, waist circumference, BMI

Puszkiewicz 2016	Mobile app	6 weeks	Tailored PA programme using video demonstrations is recommended based on users' preferred PA goals, duration, type and difficulty of PA.	1.1 Goal setting 1.4 Action planning 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 4.1 Instruction on how to perform a behaviour 6.1 Demonstration of the behaviour 7.1 Prompts/cues 8.7 Graded tasks 10.4 Social reward	Participants used app mean (SD) of 2.07 (0.68) times per week. Mean (SD) session duration was 25.08 (8.22) minutes. Mean (SD) app use duration was 44.00 (20.50) minutes per week (range 24.50-91.00 minutes).	N/A	PA, QoL (cancer-specific & generic), fatigue, BMI, anxiety, depression, sleep quality
Quintiliani, 2016	Text-messaging + Fitbit + telephone counselling	10 weeks	Text messages assess participants' dietary intake and Fitbit assesses weight and step count. Four technology-assisted telephone calls (based on PA, sleep & 2 nutrition-related topics) were guided by motivational interviewing	1.1 Goal setting (behaviour) 1.5 Review behaviour goals 1.6 Discrepancy between current behaviour and goal 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 2.4 Self-monitoring of outcome of behaviour 7.1 Prompts/cues 9.1 Credible source	Of 70 opportunities (7 days/week x 10 weeks) mean (SD) responses to text-messages was 60 (13), recording a step-measurement was 64 (7), recording a weight measurement was 45 (24) and recording a sleep measurement was 43 (19). All participants completed all 4 counselling calls.	N/A	PA, diet, fatigue, perceived stress, SE, weight
Rabin, 2012	Website	12 weeks	PA manual provided matched with participants' "stage of change" and responses to questionnaires on the website. Website also enabled participant to set PA goals and log PA	1.1 Goal setting (behaviour) 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 5.1 Information about health consequences 9.1 Credible source	Mean (SD) website logins was 14.75 (8.46). Mean (SD) number of days participants logged PA was 11.38 (7.93), used goal setting feature was 5.25 (4.17), used stage-based manual was 3.13 (2.17), accessed PA related information was 1.25 (1.28), accessed PA resources was 0.88 (1.13) and accessed PA tips was 0.50 (1.07).	Provided with 3 cancer + survivorship websites	PA, fatigue, POMS,

Short, 2016	Online workshop (website)	12 weeks	3 online modules delivered with a combination of non-tailored information (PA guidelines, increasing motivation and preventing relapse) and tailored support (e.g. based on current PA, outcome expectations, health status, eliciting social support, overcoming barriers, action planning)	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.5 Review behaviour goals 1.6 Discrepancy between current behavioural and goal 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 4.1 Instruction on how to perform a behaviour 5.1 Information about health consequences 5.2 Salience of consequences 7.1 Prompts/cues 8.7 Graded tasks 9.1 Credible source	Mean (SD) website usage duration was 61.1 (80.1) minutes (range 0-550 minutes). Mean (SD) website logins was 5.18 (8.48) (range 1-45). All participants viewed at least one module. 85% in weekly-module group and 73% in monthly-module group viewed all 3 modules. 60% of weekly-module group completed 2 (of 3) modules compared to 46% of monthly-module group. 75% of participants completed at least one action plan. 91.7% in monthly-module group completed 2 action plans compared to 71.7% in weekly module group.	N/A	PA
Valle, 2013	Facebook support group website +	12 weeks	Weekly messages (sent via Facebook) and group administrator posted discussions within the group throughout intervention. Participants also had access to website for goal-setting and PA diary and pedometers to measure steps.	1.1 Goal setting (behaviour) 1.2 Problem solving 1.6 Discrepancy between current behavioural and goal 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 5.1 Information about health consequences 9.1 Credible source 12.5 Adding objects to the environment	Intervention participants posted a total of 153 Facebook comments to group wall compared to 188 comments in control group. 49% of participants in both groups made >2 Facebook posts in study period. Intervention participants set mean of 4.2 goals, and submitted mean of 21.9 PA entries and 13.1 steps entries. 71% tracked PA data at least once. Proportion of participants logging either PA or steps declined from 57.8% in week 1 to 24.4% in week 12.	Basic Facebook group membership	PA, QoL (cancer-specific), BMI

^a: Short et al (2016) is treated as a pre-post study due to the lack of control group across the 3 intervention arms (single module, 3 weekly modules, 3 monthly modules).

PA: physical activity; SE: self-efficacy; SMART: specific, measurable, attainable, realistic, timely; SCT: social cognitive theory; OE: outcome expectancy; QoL: quality-of-life; EMR: electronic medical record

2-16). Self-monitoring of behaviour (n=15), goal setting (behaviour) (n=13), credible source (n=13) and feedback on behaviour (n=12) were the most frequently described BCTs. Short and colleagues' study was the only study which used a 3-arm RCT design where all groups received the same intervention content, but the delivery schedule differed (Short et al., 2017). As there was no true control, for the purposes of this review this study was treated as a pre-post. All fifteen studies assessed the impact of the DHBCIs on physical activity, five on diet (Bantum et al., 2014; Kanera et al., 2016; Lee, Yun, et al., 2014; McCarroll et al., 2015; Quintiliani et al., 2016) and no studies assessed the impact of DHBCIs on sedentary behaviour.

3.4.2 Primary Outcomes

3.4.2.1 Physical Activity and Sedentary Time

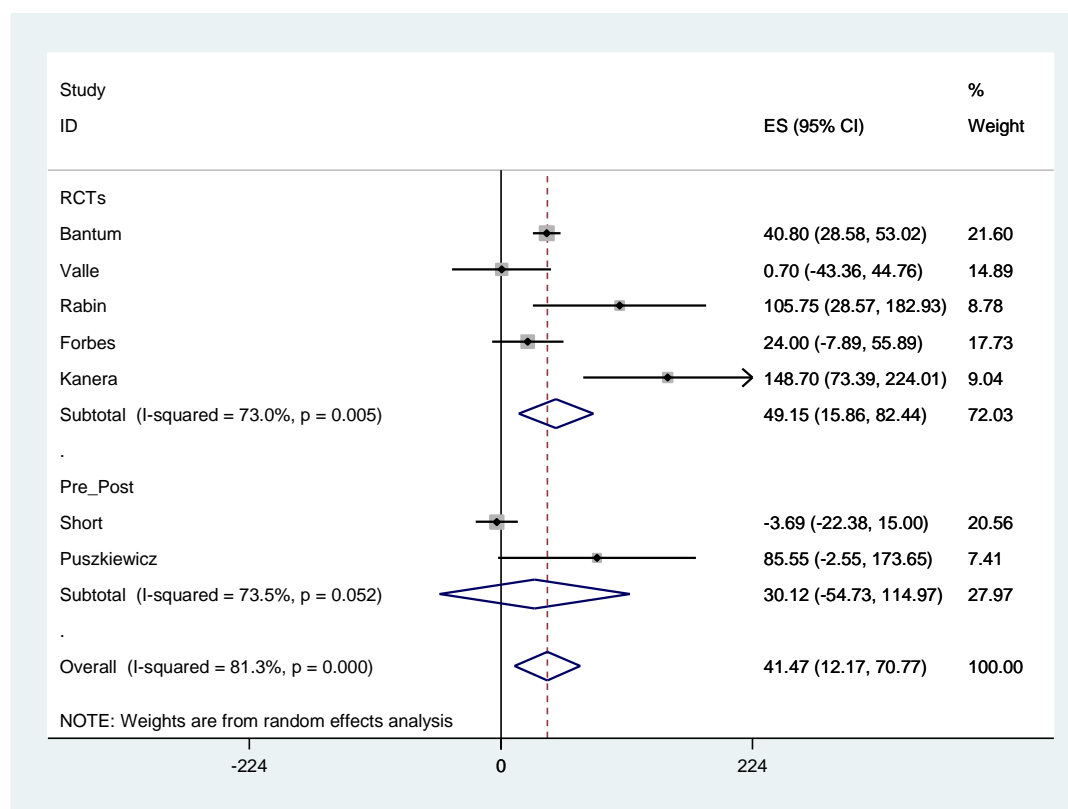
All 15 included studies measured the impact of DHBCIs on physical activity (Bantum et al., 2014; Berg et al., 2014; Forbes et al., 2015; Hatchett et al., 2013; Hoffman et al., 2014; Hong et al., 2015; Kanera et al., 2016; Kuijpers et al., 2016; Lee, Yun, et al., 2014; McCarroll et al., 2015; Puskiewicz et al., 2016; Quintiliani et al., 2016; Rabin et al., 2011; Short et al., 2017; Valle et al., 2013). All used self-reported physical activity as outcomes: 5 used the Godin Leisure-Time Exercise Questionnaire (GLTEQ) (Bantum et al., 2014; Forbes et al., 2015; Puskiewicz et al., 2016; Short et al., 2017; Valle et al., 2013), 2 the International Physical Activity Questionnaire (Kuijpers et al., 2016; Quintiliani et al., 2016), 1 a 7-day PA recall (Rabin et al., 2011), 1 the Short Questionnaire to Assess Health Enhancing Physical Activity (Kanera et al., 2016), 2 identified the number of days in the last 7 that the participant engaged in moderate and/or vigorous physical activity (Berg et al., 2014; Hatchett et al., 2013), 3 studies reported percentage of participants meeting physical activity guidelines (150 minutes of MVPA per week) (Forbes et al., 2015; Lee, Yun, et al., 2014; Rabin et al., 2011), and 2 reported stages of change for physical activity (Hong et al., 2015; Lee, Yun, et al., 2014). Short et al. also reported a resistance training score (Short et al., 2017). Hoffman et al. reported the number of minutes walked, steps walked and number of balance exercises completed (Hoffman et al., 2014). McCarroll et al. reported number of minutes of physical activity completed and the number of calories expended as logged via the participant using the mobile app used for their intervention (McCarroll et al., 2015).

MVPA (minutes) was available for 11 studies (5 as a combined variable (Bantum et al., 2014; Hatchett et al., 2013; Rabin et al., 2011; Short et al., 2017; Valle et al., 2013), 5 as separate

moderate and vigorous variables (combined for the purposes of the meta-analysis) (Berg et al., 2014; Forbes et al., 2015; Kanera et al., 2016; Kuijpers et al., 2016; Quintiliani et al., 2016) and raw data was available for Puzskiewicz et al. (2016) to calculate a combined MVPA variable. Of these 7 (5 RCTs (Bantum et al., 2014; Forbes et al., 2015; Kanera et al., 2016; Rabin et al., 2011; Valle et al., 2013) and 2 pre-post studies (Puzskiewicz et al., 2016; Short et al., 2017)) reported MVPA duration in minutes per week and were pooled in a random effects meta-analysis using data from 1,034 participants (see Figure 3.2). DHBCIs resulted in significant increases in MVPA minutes/week (MD=41; 95% CI: 12-71; $p=0.006$) with very high levels of heterogeneity ($I^2=81\%$). Independently, the RCTs showed a significant increase in MVPA (MD=49, 95% CI: 16-82, $p = 0.004$, $I^2=73\%$). A funnel plot suggested there may be some indication of publication bias among smaller studies (see Appendix C).

Of the other 8 studies which could not be included in the meta-analysis, 4 reported a significant effect of the intervention (Hatchett et al., 2013; Hong et al., 2015; Kuijpers et al., 2016; Lee, Yun, et al., 2014), 2 did not report significant findings (Berg et al., 2014; McCarroll et al., 2015) and 2 did not conduct significance testing due to small sample sizes (Hoffman et al., 2014; Quintiliani et al., 2016). No studies reported effects on sedentary time.

Figure 3.2: Meta-analysis of DHBCIs on MVPA



N.B. p-values shown in Figure 3.2 represent significance for testing of heterogeneity

3.4.2.2 Diet

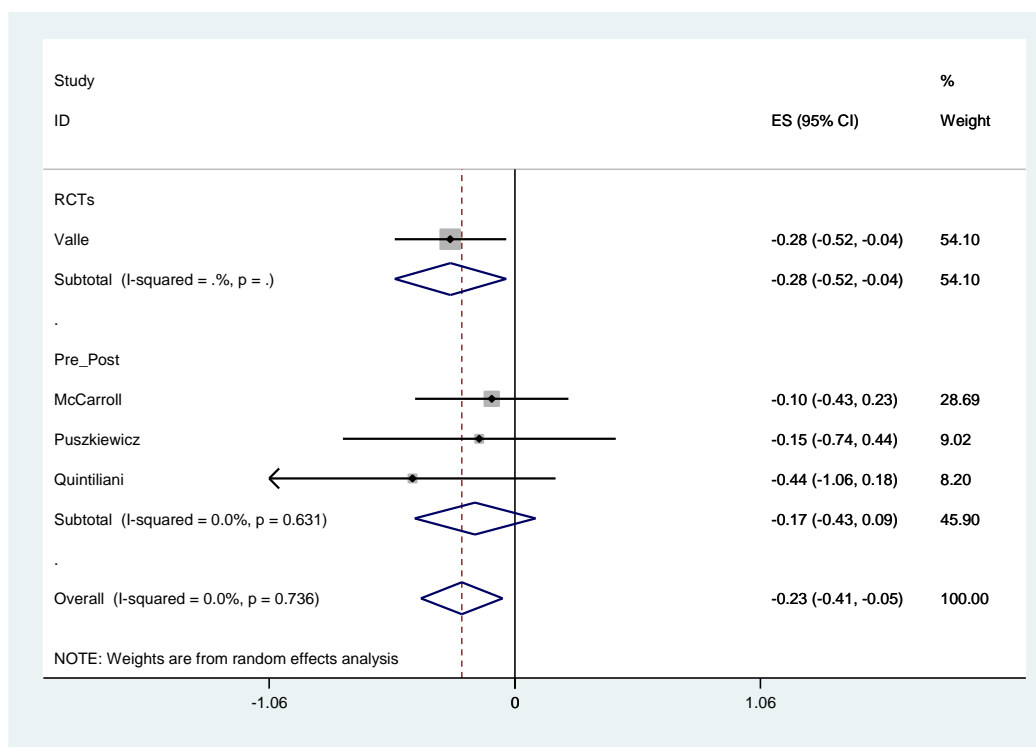
Five studies measured the impact of DHBCIs on dietary intake (Bantum et al., 2014; Kanera et al., 2016; Lee, Yun, et al., 2014; McCarroll et al., 2015; Quintiliani et al., 2016). Due to the substantial heterogeneity in approaches to assessment and measurement of dietary outcomes, a meta-analysis was not considered appropriate. Three studies (Bantum et al., 2014; Kanera et al., 2016; Lee, Yun, et al., 2014) were RCTs and 2 were pre-post studies (McCarroll et al., 2015; Quintiliani et al., 2016). Only two of the studies reported a significant effect on dietary outcomes (Kanera et al., 2016; Lee, Yun, et al., 2014), however this no longer remained significant after correcting for multiple testing in Kanera et al.'s study. Quintiliani et al. did not conduct significance testing, due to the very small sample ($n=10$) (Quintiliani et al., 2016).

3.4.3 Secondary Outcomes

3.4.3.1 BMI/Weight

Four studies assessed BMI and/or weight (1 RCT (Valle et al., 2013) and 3 pre-post studies (McCarroll et al., 2015; Puskiewicz et al., 2016; Quintiliani et al., 2016)). Three assessed BMI (McCarroll et al., 2015; Puskiewicz et al., 2016; Valle et al., 2013) and Quintiliani et al. assessed weight (Quintiliani et al., 2016). Using data from 122 participants (66 participants in RCTs; 56 in pre-post studies), there was a significant pooled reduction in BMI/weight (SMD=-0.23; 95% CI: -0.41, -0.05; $p = 0.011$; $I^2 = 0.0\%$) (see Figure 3.3). The RCT showed a significant reduction in BMI (SMD=-0.28, 95% CI: = -0.52, -0.04, $p = 0.023$). A funnel plot revealed no evidence of publication bias for BMI/weight outcomes.

Figure 3.3: Meta-analysis of DHBCIs on BMI/weight measurements.



N.B. p-values shown in Figure 3.3 represent significance for testing of heterogeneity

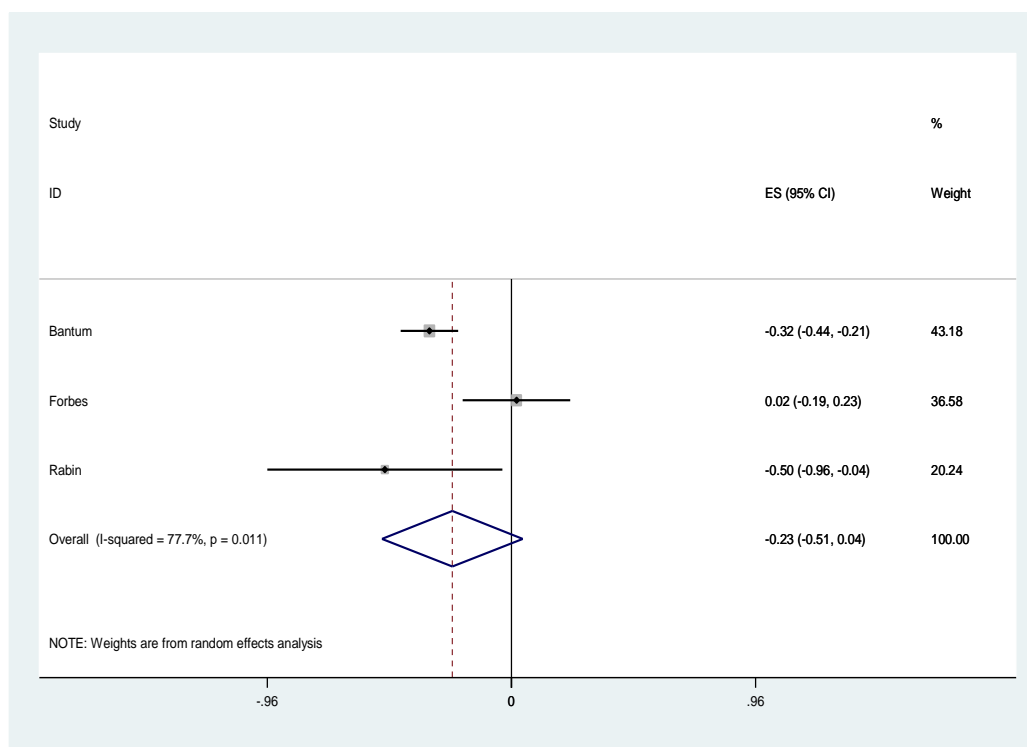
3.4.3.2 Other cancer-relevant outcomes

3.4.3.2.1 Fatigue

Seven studies measured the impact of DHBCIs on fatigue (Bantum et al., 2014; Forbes et al., 2015; Hoffman et al., 2014; Lee, Yun, et al., 2014; Puszkiewicz et al., 2016; Quintiliani et al., 2016; Rabin et al., 2011). Of these, 3 used the Brief Fatigue Inventory (Bantum et al., 2014; Hoffman et al., 2014; Lee, Yun, et al., 2014), 2 used the Functional Assessment of Chronic Illness Therapy-Fatigue (Forbes et al., 2015; Puszkiewicz et al., 2016), one used the Profile of Mood States-Fatigue (Rabin et al., 2011) scale and one used a 0-10 scale (Quintiliani et al., 2016). SMDs were required to pool effects across studies due to the variation in measurement tools. Therefore, meta-analysis was only conducted on the 3 RCTs where appropriate data could be extracted (Bantum et al., 2014; Forbes et al., 2015; Rabin et al., 2011), using data from 406 participants (see Figure 3.4). DHBCIs resulted in a decrease in fatigue but this was not significant (SMD=-0.23; 95% CI: -0.51, 0.05; $p = 0.103$; $I^2 = 78\%$). Once again, very high levels of heterogeneity were displayed for fatigue. A funnel plot revealed no evidence of publication bias for fatigue outcomes. Of the remaining 4 studies, only one reported a significant reduction in

fatigue (Lee, Yun, et al., 2014). Two of these studies did not report significance testing (Hoffman et al., 2014; Quintiliani et al., 2016) due to very small sample sizes (7 and 10, respectively).

Figure 3.4: Meta-analysis of DHBCIs on fatigue

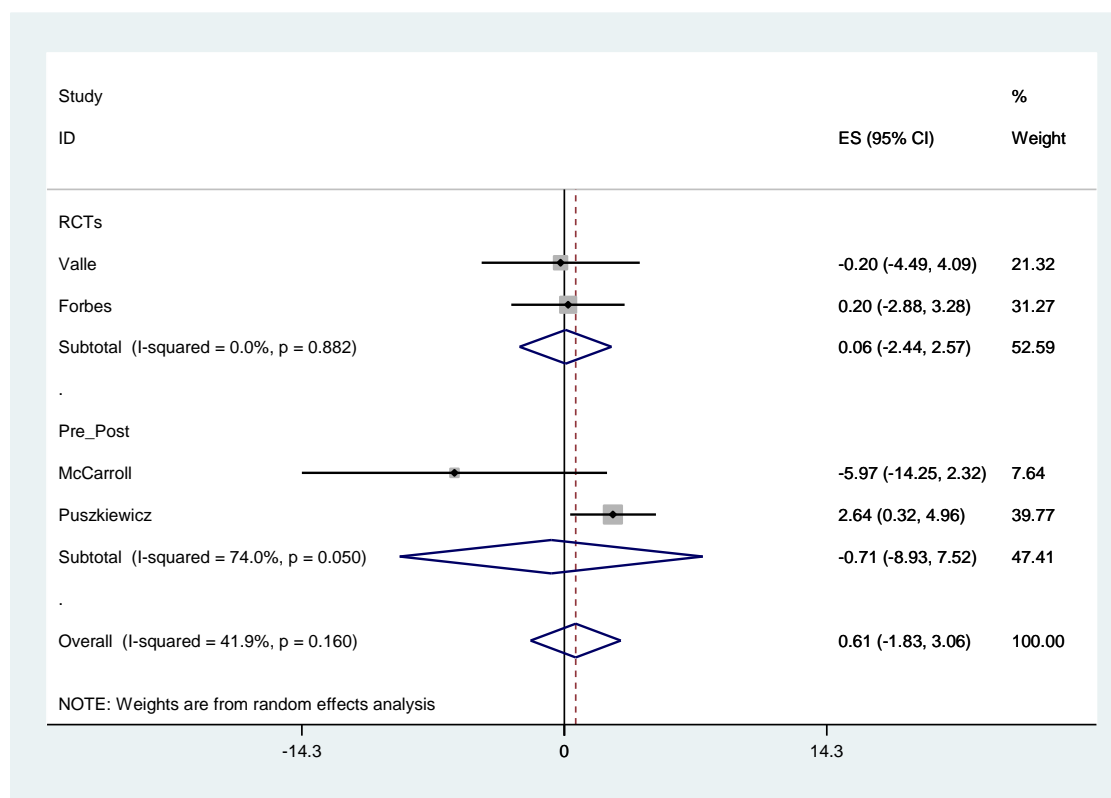


N.B. p-values shown in Figure 3.4 represent significance for testing of heterogeneity

3.4.3.2.2 Cancer-specific quality of life

Five studies assessed cancer-specific measures of quality of life (Forbes et al., 2015; Lee, Yun, et al., 2014; McCarroll et al., 2015; Puzkiewicz et al., 2016; Valle et al., 2013). Four studies used the Functional Assessment of Cancer Therapy-General (FACT-G) (Forbes et al., 2015; McCarroll et al., 2015; Puzkiewicz et al., 2016; Valle et al., 2013) and one used the EORTC QLQ-C30 (Lee, Yun, et al., 2014). The 4 studies using the FACT-G (2 RCTs (Forbes et al., 2015; Valle et al., 2013) and 2 pre-post studies (McCarroll et al., 2015; Puzkiewicz et al., 2016)) were pooled using data from 198 participants (152 participants in RCTs; 46 from pre-post studies) (see Figure 3.5). Overall, there were no significant changes on cancer-specific quality of life (MD=0.61; 95% CI: -1.83, 3.06; $p = 0.62$; $I^2 = 42\%$). Similar results are shown when just pooling results from RCTs (MD=0.06; 95% CI: -2.44, 2.57; $p = 0.960$; $I^2 = 0\%$). A funnel plot revealed no evidence of publication bias for cancer-specific quality of life outcomes. The remaining study also found a non-significant difference between groups (Lee, Yun, et al., 2014).

Figure 3.5: Meta-analysis of DHBCIs on cancer-specific quality of life.



N.B. p-values shown in Figure 3.5 represent significance for testing of heterogeneity

3.4.3.2.3 Generic quality of life

Four studies assessed generic measures of quality of life (Forbes et al., 2015; Hong et al., 2015; Kuijpers et al., 2016; Puszkiewicz et al., 2016). Each study reported various domains of quality of life as opposed to a global score using various measurement tools (i.e. SF-36 (Forbes et al., 2015; Kuijpers et al., 2016), the EuroQol 5 Dimensions (Puszkiewicz et al., 2016) and a 7-item non-validated measure (Hong et al., 2015)). Two studies found no significant changes in any quality of life domains (Forbes et al., 2015; Puszkiewicz et al., 2016). One study found a significant improvement in role functioning-emotional and mental health for those during treatment and a significant improvement in social functioning for those who had finished treatment (Kuijpers et al., 2016). Hong et al. found significant improvements in self-rated health, fatigue, pain, shortness of breath, stress, sleep quality and overall quality of life using a non-validated scale (Hong et al., 2015).

3.4.3.2.4 Mental Health

Three studies measured the impact of DHBCIs on depression (Bantum et al., 2014; Lee, Yun, et al., 2014; Puszkiewicz et al., 2016), none of which reported any significant impact on depression.

Two studies assessed the impact on anxiety (Lee, Yun, et al., 2014; Puzskiewicz et al., 2016), neither of which reported a significant effect. Rabin et al. also measured Profile of Mood States (anger, depression, tension/anxiety, vigor, confusion) and did not find a significant change in scores between groups (Rabin et al., 2011).

3.4.3.2.5 Sleep disturbance

Two studies measured the impact of DHBCIs on sleep disturbance (Bantum et al., 2014; Puzskiewicz et al., 2016). Both studies reported a significant improvement in sleep quality; Bantum et al. showed a significant reduction in insomnia (Bantum et al., 2014) and Puzskiewicz et al. showed a significant improvement in sleep quality (Puzskiewicz et al., 2016).

3.4.4 Theoretical Underpinning

Twelve studies reported some level of theoretical basis to their intervention design (Berg et al., 2014; Hatchett et al., 2013; Hoffman et al., 2014; Hong et al., 2015; Kanera et al., 2016; Kuijpers et al., 2016; Lee, Yun, et al., 2014; McCarroll et al., 2015; Quintiliani et al., 2016; Rabin et al., 2011; Short et al., 2017; Valle et al., 2013). Of those that did mention a theoretical influence, Social Cognitive Theory (SCT) was most frequently reported (Hatchett et al., 2013; Kanera et al., 2016; Kuijpers et al., 2016; McCarroll et al., 2015; Short et al., 2017; Valle et al., 2013), and sometimes used in combination with other theories (i.e. Transtheoretical Model (TTM) (Rabin et al., 2011) or the Theory of Planned Behaviour (Kuijpers et al., 2016)). Other theories included the Theory of Reasoned Action (Berg et al., 2014), Theory of Symptom Self-Management (Hoffman et al., 2014), Theory of Goal Setting (Hong et al., 2015), the TTM alone (Lee, Yun, et al., 2014), and the Social Contextual Model (Quintiliani et al., 2016). The description of the theoretical underpinning of the DHBCIs varied across studies, but was largely of poor quality. Only 7 studies explicitly reported how theory/predictors were used to select/develop intervention techniques (Hatchett et al., 2013; Kanera et al., 2016; Kuijpers et al., 2016; Lee, Yun, et al., 2014; Rabin et al., 2011; Short et al., 2017; Valle et al., 2013) and only 6 studies used theory/predictors to tailor intervention techniques to participants (Hoffman et al., 2014; Kanera et al., 2016; Kuijpers et al., 2016; Lee, Yun, et al., 2014; Rabin et al., 2011; Short et al., 2017). Six studies measured theory-relevant constructs and reported outcomes pre- and post-intervention (Berg et al., 2014; Kuijpers et al., 2016; Lee, Yun, et al., 2014; McCarroll et al., 2015; Quintiliani et al., 2016; Valle et al., 2013). Of these 6 studies, 3 reported no significant change in measures related to self-efficacy

(Berg et al., 2014; Kuijpers et al., 2016; Quintiliani et al., 2016). Lee et al. reported that the 'stage of change' and self-efficacy for physical activity participation and fruit & vegetable consumption was significantly higher in the intervention group (Lee, Yun, et al., 2014) and McCarroll et al. reported a significant increase in self-efficacy between pre- and post-intervention (McCarroll et al., 2015). Valle et al. was the only study which conducted mediational analysis of theoretical constructs/predictors (presented in an associated paper (Valle, Tate, Mayer, Allicock, & Cai, 2015)). However, this study showed that the intervention group reported lower self-efficacy for physical activity and social support from friends on social networking websites compared to the control group. Changes in social support from friends on social networking sites was positively related to changes in MVPA, however it was those in the control group who reported increased social support from friends on social networking sites compared to the intervention group (Valle et al., 2015).

3.4.5 Risk of bias in included studies

See Figure 3.6 for an assessment of the risk of bias in the included studies. Study quality was deemed to be low for the majority of included studies. For the RCTs, there was adequate randomisation sequence generation in the majority of the studies; however allocation concealment was much less clear. The lack of control group in the 7 pre-post studies highly increased the risk of bias, reducing the confidence that can be placed on the observed effects. All of the studies were judged to be high risk for other sources of bias, for instance all 15 studies used self-reported physical activity, as opposed to objective measures (e.g. accelerometry). Some of the RCTs did not report (or it was unclear) whether baseline outcome measures and/or participant characteristics were similar between groups (Bantum et al., 2014; Forbes et al., 2015; Kanera et al., 2016; Rabin et al., 2011; Short et al., 2017; Valle et al., 2013). Furthermore, the representativeness of the sample was fairly narrow in that the majority of the study samples consisted of predominantly female, middle-aged, English-speaking, breast cancer survivors of high SEP, which limits the generalizability of the findings across the wider population of cancer survivors. Most of the studies had small sample sizes (generally ranging between 20-100), and only 3 studies had larger samples (Bantum et al., 2014; Kanera et al., 2016; Short et al., 2017) (303, 462 and 492, respectively). Despite the largest sample size at baseline in Short et al's study, retention was extremely low (32% at 3-months and 11% at 6-months follow-up) (Short et al., 2017).

Figure 3.6: Risk of bias in included studies

	Random sequences generation (selection bias)	Allocation concealment (selection bias)	Incomplete outcome data addressed adequately (attrition)	Blinding of participants to allocation (performance bias)	Blinding of outcome assessment (detection bias)	Selective outcome reporting (reporting bias)	Other bias
Bantum 2014	+	?	+	-	?	+	-
Berg 2014	N/A	N/A	+	-	?	+	-
Forbes 2015	+	?	+	-	?	+	-
Hatchett 2013	?	?	+	-	?	?	-
Hoffman 2014	N/A	N/A	+	-	?	?	-
Hong 2015	N/A	N/A	+	-	?	+	-
Kanera 2016	+	+	+	-	+	+	-
Kuijpers 2016	N/A	N/A	+	-	?	+	-
Lee 2014	+	?	+	+	+	+	-
McCarroll 2015	N/A	N/A	+	-	?	?	-
Puszkiewicz 2016	N/A	N/A	+	-	+	+	-
Quintiliani 2016	N/A	N/A	+	-	?	+	-
Rabin 2012	?	?	+	-	?	+	-
Short 2016	+	+	+	-	+	+	-
Valle 2013	+	?	+	-	?	+	-

3.5 Discussion

This study found that DHBCIs resulted in an increase in MVPA participation of 41 minutes per week. While meta-analysis was not possible for dietary outcomes, there was mixed evidence for a beneficial effect on dietary intake. No studies assessed sedentary behaviour. Meta-analyses also revealed a significant reduction in BMI, a reduction in fatigue which did not reach statistical significance, and no change was seen in cancer-specific measures of quality of life. For other secondary outcomes where meta-analysis was not possible, there was mixed evidence for the effect on domains of generic quality of life measures and theoretical constructs (e.g. self-efficacy). There is no evidence for an improvement in anxiety or depression; and while only two studies assessed sleep disturbance, both reported a significant improvement.

To the best of my knowledge, this was the first meta-analysis to assess the evidence with regards to DHBCIs targeting physical activity and/or diet among cancer survivors. An increase of 41 minutes of MVPA per week is important given that this represents a substantial proportion (27%) of cancer survivors' recommended weekly MVPA participation (Rock et al., 2012; Schmitz et al., 2010; US Department of Health and Human Services, 2008). While there is limited evidence on

the dose-response relationship between MVPA and mortality and recurrence outcomes, a meta-analysis conducted by Schmid et al estimated that each 10 MET-hour per week increase in post-diagnosis physical activity (approximately equivalent to the 150 minutes MVPA/week guideline) was associated with 24% (95% CI: 11-36%) and 28% (95% CI: 20-35%) decreased total mortality risk for breast and colorectal cancer survivors, respectively (Schmid & Leitzmann, 2014). Schmid et al also reported that breast or colorectal cancer survivors who increased their physical activity by any amount between pre- and post-diagnosis, showed a decreased total mortality risk (RR=0.61, 95% CI: 0.46-0.80) compared to cancer survivors who did not change their physical activity level or who were insufficiently active pre-diagnosis (Schmid & Leitzmann, 2014). Therefore, even small increases in MVPA post-diagnosis are likely to be beneficial for cancer survivors.

It is interesting to compare the findings of this study with other meta-analyses using non-digital physical activity interventions among cancer survivors. Whilst this study did not find a significant reduction in fatigue scores (SMD= -0.23), Mishra et al. did find a significant improvement, both for survivors who had completed treatment (SMD= -0.82) (Mishra, Scherer, Geigle, et al., 2012) and who were still undergoing active treatment (SMD= -0.73) (Mishra, Scherer, Snyder, et al., 2012). Furthermore, this study did not find any improvement in cancer-specific measures of quality of life, whilst Mishra et al. reported positive improvements in both of their meta-analyses. Mishra et al. also found significantly improved anxiety and depression, sleep quality and improvements in some domains of generic measures of quality of life (e.g. social, physical and role functioning) (Mishra, Scherer, Geigle, et al., 2012; Mishra, Scherer, Snyder, et al., 2012). The small number of studies assessing these outcomes meant that meta-analyses for these outcomes were not possible in the current study. However, in the studies that did assess these outcomes, there was no evidence for an improvement in anxiety and depression, but both studies assessing sleep reported significant improvements. There was also mixed evidence for individual domains of generic quality of life measures. It is possible that the non-digital interventions included in Mishra et al.'s studies result in larger effect sizes as many of the interventions are supervised by trained staff or involve some level of human interaction, which may foster higher levels of engagement and adherence to the intervention. However, due to the small number of low quality studies included in this review, there is a need for more high quality RCTs, with objective

measures of physical activity, long-term follow-up and larger sample sizes before reliable comparisons between non-digital and DHBCIs can be made.

Sustained engagement with DHBCIs was a significant problem for a number of the studies included in this review. For instance, in the study conducted by Short et al., retention at 3-month follow-up was only 32% (156/492) and 11% (53/492) at 6-month follow-up (Short et al., 2017). Furthermore, while 75% of the sample completed at least one action plan, the average number of action plans completed was only 2.2. Similarly, 50% of participants completed the week 1 module compared to 10% for the week 9 module in Forbes et al.'s study (Forbes et al., 2015). A systematic review has shown that there is a positive relationship between participants' adherence to/engagement with digital interventions and positive physical health outcomes across a range of populations and behaviours, suggesting that efforts to improve effective engagement with DHBCIs could improve behaviour change outcomes (Donkin et al., 2011). It is possible that suboptimal engagement with the DHBCIs in the studies included in this review may explain the reduced effects on outcomes compared to those observed in Mishra et al.'s review of non-digital physical activity interventions (Mishra, Scherer, Geigle, et al., 2012; Mishra, Scherer, Snyder, et al., 2012). Future DHBCIs studies should integrate techniques or components that maintain effective engagement with the intervention for its duration. There is some evidence that technology-based strategies (e.g. reminders, prompts) can encourage user engagement (Alkhalidi et al., 2016). Other aspects which have been identified as important for engagement include ease of use, design aesthetic, feedback, function, ability to change design to suit own preferences, tailored information and unique mobile phone features (Garnett, Crane, West, Brown, & Michie, 2015). Similarly, less time consumption, user-friendly design, real-time feedback, individualised elements, detailed information, and health professional involvement may also improve effectiveness of DHBCIs, in particular mobile apps (Zhao, Freeman, & Li, 2016). Future studies should aim to better understand the link between engagement and effectiveness of DHBCIs targeting physical activity and diet in cancer survivors and define, evaluate and report engagement more consistently so as to better understand techniques that foster effective engagement and mechanisms of action (Yardley et al., 2016).

The majority (10/15) of the studies used an online portal or website to deliver the intervention and, while one of these websites was mobile-enabled (Hong et al., 2015), only two studies used mobile

apps (McCarroll et al., 2015; Puskiewicz et al., 2016). This is interesting given the findings of a review of 23 interventions using mobile apps that found that 17 of the included studies reported a significant effect on behaviour change in the general population (Zhao et al., 2016). It is possible that interventions using mobile apps may be more effective than other types of DHBCIs as smartphones have the benefit of being able to deliver BCTs in real-time, using a device that is usually turned on, usually carried with the person, and often has inbuilt functions to monitor physical activity and deliver immediate feedback. Furthermore, smartphone ownership is higher than laptop/desktop computers (OFCOM, 2018) and therefore smartphone-based interventions could reach a larger population versus other types of DHBCIs (e.g. web-based interventions). Therefore, it would be interesting for future studies to use mobile apps as a mode of intervention delivery and compare the effectiveness of mobile app interventions compared to other DHBCIs as they may foster higher levels of engagement.

Self-monitoring, goal-setting, credible source and feedback on behaviour were the most frequently described BCTs used in the included studies. Due to the heterogeneity in intervention type, mode of delivery, behavioural outcomes and measurement approaches, it is difficult to interpret which BCTs were most effective at changing physical activity/dietary behaviour. Kanera et al.'s study used the most BCTs (n=16) but also used a tailored '*if-then*' algorithm within the intervention to automatically tailor content to participants (Kanera et al., 2016). As a result, it is difficult to ascertain what intervention components or approaches to delivery lead to increased effectiveness. A recent meta-analysis revealed that theory-based interventions are significantly more effective at improving physical activity (Gourlan et al., 2016). SCT was the most commonly reported theoretical basis of the interventions, however several other behaviour change theories were used across the studies. The level of reporting of the extent to which theory was incorporated into the development of the interventions varied across studies, but was generally poor. Only 3 studies did not report any theoretical underpinning. Future studies should aim to explicitly report how theory is used to develop intervention components and tailor the intervention to participants. Measurement and exploration of changes in targeted theoretical constructs (e.g. via mediation analyses) can aid understanding of why interventions may or may not be effective (Michie & Prestwich, 2010) and can be used to refine theoretical models of behaviour change. The lack of clarity about the intervention content, theoretical underpinning and the lack of measurement on theoretical constructs means it is difficult to unpick the mechanism of intervention efficacy. Future

DHBCI studies should clearly report any theoretical underpinning and BCTs used, for instance by using Michie et al.'s Theory Coding Scheme (Michie & Prestwich, 2010) and BCT Taxonomy (v1) (Michie et al., 2013).

3.5.1 Limitations

There are several limitations to this review. Primarily, the data extracted for the meta-analyses reflect unadjusted models. While the forest plot for MVPA minutes/week (Figure 3.2) illustrates that Bantum et al., Rabin et al., and Kanera et al. found a significant effect, the original publications show that this no longer remained significant when adjusting for baseline values and/or other covariates (e.g. demographics, disease characteristics) (Bantum et al., 2014; Rabin et al., 2011) or when adjusted models are controlled for multiple testing (Kanera et al., 2016). Bantum et al. did find a significant increase in vigorous physical activity participation in the adjusted model, but not when combined with moderate physical activity (Bantum et al., 2014). Similar issues arise for the meta-analyses for fatigue and BMI/weight. The studies that show significant findings for fatigue and BMI/weight in the current meta-analyses do not report significant findings when adjusted for baseline and/or covariates in the original publications. Furthermore, a combined MVPA variable was chosen to assess physical activity outcomes to maximise the number of studies that could be included in the meta-analysis and to coincide with current recommendations that cancer survivors should follow the physical activity guidelines for the general population (at least 150 minutes of at least moderate intensity physical activity per week) (Rock et al., 2012; Schmitz et al., 2010; US Department of Health and Human Services, 2008). However, this means the current meta-analysis does not differentiate between different intensities of physical activity: it may be beneficial to evaluate the effect on outcomes at different intensities of physical activity. Visual inspection of funnel plots suggested possible publication bias for smaller studies assessing MVPA outcomes; it is possible that the choice to only include published studies may have increased the potential for publication bias. There was no suggestion of publication bias for BMI/weight, fatigue or cancer-specific quality of life measures.

The risk of bias in included studies was high. The inclusion of one-arm, pre-post studies substantially increases the risk of bias, however the novelty of this area of research warranted the inclusion of these studies and this added valuable insights into the current state of the literature. Few studies assessed outcomes other than physical activity, where only half of the

studies could be included in a meta-analysis. Heterogeneity across studies was very high, likely due to the variability of types of DHBCIs, intervention content, cancer type and populations, outcome measurement tools etc. With the addition of future studies, more specific inclusion criteria could be used to assess effectiveness of more similar studies. All of the physical activity findings used self-report data, which while easy-to-use, inexpensive and validated, often hugely under or overestimate physical activity participation (Prince et al., 2008). Therefore, caution is advised in interpretation of these results until the number of published studies assessing DHBCIs increases and inclusion criteria for future systematic reviews can be more stringent for low-quality trials.

3.5.2 Conclusions

To the best of my knowledge, this is the first meta-analysis of DHBCIs designed to improve physical activity and dietary behaviours among cancer survivors. While the review shows some evidence of an improvement in MVPA, a reduction in BMI, and a trend towards significance for fatigue, large, high-quality RCTs, with objective measures of physical activity and long term follow-up are lacking. Future studies should aim to address these limitations, and the approach of using digital technology in this context appears promising.

Chapter 4 (Study 2): Interest in digital behaviour change interventions among breast, prostate and colorectal cancer survivors in the United Kingdom – a cross sectional survey

4.1 Background

Study 1 found that DHBCIs offer a promising approach to intervention delivery and have the potential to increase cancer survivors' MVPA by 41 minutes per week. Furthermore, data from the most recent Ofcom Communications Market report shows that internet access and smartphone ownership is high in UK adults and that there may be less of a socioeconomic divide in smartphone ownership than with laptop/desktop computers (OFCOM, 2018). However, to understand the potential reach of DHBCIs, it is necessary to explore the level of interest in the target population and to better understand the characteristics of those who are interested in DHBCIs.

In the general population, a nationally representative sample of American adults reported that those who have adopted health apps were younger, female, more highly educated and more likely to meet national physical activity recommendations compared to those who have not used health apps (Carroll et al., 2017). With regards to cancer survivors, two cross-sectional surveys, also conducted in the USA, have explored cancer survivors' interest in DHBCIs. Phillips and colleagues conducted a survey of 270 breast cancer survivors to assess interest in and preferences for technology-supported physical activity interventions (Phillips et al., 2017). Eighty-five percent of the sample were interested in remotely delivered exercise counselling, with 53% interested in using an interactive website, 52% interested in receiving personalised emails and 39% interested in a mobile app. In this study, none of the assessed demographic or disease characteristics were significantly associated with interest in a digital physical activity intervention. However, those who were meeting physical activity recommendations were less likely to indicate interest in participating in a technology-supported physical activity intervention (OR=0.33; 95% CI: 0.13-0.87; $p = 0.02$) (Phillips et al., 2017). This was a relatively small convenience sample of breast cancer survivors and almost all of the sample (99%) owned a computer, 85% owned a smartphone and 65% owned a tablet computer. Furthermore, over half (53%) were already meeting physical activity recommendations of ≥ 150 minutes MVPA per week

(Phillips et al., 2017). Therefore the generalisability of this sample to the wider cancer survivor population is limited.

In a survey of 847 breast (51%; N=429), prostate (39%; N=332) and colorectal (10%; N=86) cancer survivors, 59% indicated interest in computer-based interventions and 22% indicated interested in smartphone-based interventions (Martin et al., 2016). Participants who used other technology-based platforms (e.g. social networking sites and web cameras) showed greater interest in both computer- and smartphone-based interventions, while those who did not own a computer showed greater interest in smartphone-based interventions. There was a significant negative association between age and interest in smartphone-based interventions and those who reported higher levels of physical activity were also more likely to report interest in smartphone-based interventions (Martin et al., 2016). However, although this study was published in 2016, the data was collected in 2010 and the authors acknowledge that smartphone ownership had nearly doubled during that time in the USA, and it had almost tripled during the same time in the UK (OFCOM, 2018). Both Martin et al.'s and Phillips et al.'s studies were conducted in the USA and so it is important to assess interest in DHBCIs among breast, prostate and colorectal cancer survivors in the UK in a sample where data has been collected more recently to reflect increasing internet access and smartphone ownership across the population.

4.2 Aims

The primary aim of this study was to examine the proportion of breast, prostate and colorectal cancer survivors who indicate an interest in DHBCIs. A secondary aim was to explore associations between interest in DHBCIs with socio-demographic and disease characteristics and other factors relevant to the development of a digital physical activity intervention (perceived need to increase physical activity, interest in physical activity interventions more broadly, and participation in MVPA).

4.3 Methods

4.3.1 Design and participants

The 'Health and Lifestyle after Cancer' survey (see Appendix D) was administered to breast, prostate and colorectal cancer survivors who were diagnosed between 2012-2015, through participating NHS sites. The survey gathers extensive data on health, health behaviours,

wellbeing and intervention preferences after a cancer diagnosis. The survey was also used to recruit interested participants to a telephone-based lifestyle intervention as part of a larger study, the Advancing Survivorship after Cancer: Outcomes Trial (ASCOT) (Beeken et al., 2016), which was still ongoing at the time of thesis submission. The surveys were mailed directly to participants between February 2015 and November 2017 by hospital staff (e.g. research nurses, data analysts, administrative staff) and the relevant NHS trusts were compensated for their staff's involvement in this task as the ASCOT study has been adopted onto the National Institute for Health Research Clinical Research Network (CRN) Portfolio. The research team at UCL instructed hospital sites which patients had returned questionnaires (based on identification (ID) number) and sites were instructed to re-send a questionnaire pack to patients who had not returned a questionnaire. Returned questionnaires were accepted until 4th January 2018.

The survey pack included a letter inviting the patient to take part, signed by their consultant (see Appendix E), as well as the paper survey and a link to an online version of the questionnaire, which could be completed via SurveyMonkey³, if preferred. Patients could complete the survey and return it directly to the research team at UCL. Each participant was assigned an ID number (printed onto the front of the paper questionnaire), which was used to record the participants who had been sent and had returned a questionnaire. Each site kept a record of the patients that corresponded to each ID number as researchers at UCL were not permitted to have access to NHS patient identifiable information unless the patient had explicitly provided this on the questionnaire.

4.3.1.1 Inclusion and exclusion criteria

Inclusion criteria were adults (≥ 18 years) who had received a primary diagnosis of breast, prostate or colorectal cancer between 2012-2015 at one of 10 NHS hospital sites across London and Essex. Exclusion criteria were intentionally minimal to ensure that as many cancer patients diagnosed with these 3 cancer types during the time period had the opportunity to take part. Patients were only excluded if: i) the patient was deceased, or ii) if the hospital staff deemed it inappropriate to send the patient a questionnaire (e.g. if the patient had previously requested not to be approached about participation in research studies).

³ <https://www.surveymonkey.com/>

4.3.2 Ethical approval

This study has received ethical approval from the NHS National Research Ethics Committee – South Central Oxford B (reference 14/SC/1369) (Appendix F). Local Research & Development approval was also obtained from each participating NHS Trust and the study has been adopted onto the North Thames CRN portfolio (reference 17783). Patients could complete the survey and return it directly to the research team at UCL. Page 2 of the survey stated that the completion of the questionnaire meant that consent was being provided for research on lifestyle in people diagnosed with cancer. Participants could opt to complete the survey pseudo-anonymously or provide contact details if they were interested in the ASCOT trial.

4.3.3 Measures

A full copy of the questionnaire is in Appendix D. As the questionnaire is part of the larger ASCOT study, only measures of relevance to the current study analyses are described below.

4.3.3.1 Primary outcome

4.3.3.1.1 Interest in digital intervention delivery

Interest in digital intervention delivery was assessed using two items. Participants were asked ‘Would you be interested in any of the following formats of information/advice about making lifestyle changes?’ followed by a list of 10 formats, two of which were digital: ‘internet information’ and ‘an app for mobile/tablet’. Response options were provided on a 5-point scale: 1 = Not at all interested, 2 = A little interested, 3 = Somewhat interested, 4 = Very interested, 5 = Extremely interested. This variable was dichotomised into a ‘not at all interested’ group (1) and an ‘interested’ group (2-5), as anyone who indicates at least some level of interest could potentially be encouraged to participate in this type of intervention.

Steps were taken to address missing data for these items. Interest in internet information or an app were both assessed as part of a larger question assessing 8 other intervention delivery modalities. If a participant had provided an answer for one or more of the 10 intervention delivery modality items (e.g. Figure 4.1), other missing values were changed to “1 = Not at all interested” as it was assumed that the participant only provided answers for the delivery modalities they were interested in. Participants who left the entire question blank were dealt with as missing data, as described in section 4.3.4.1.

Figure 4.1: Example of approach taken to deal with missing data for interest in intervention delivery modalities

6 Would you be interested in any of the following formats of information/advice about making lifestyle changes?					
	Not at all interested	A little interested	Somewhat interested	Very interested	Extremely interested
Short leaflet (up to 5 pages)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Longer leaflet/booklet	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Internet information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
An app for mobile or tablet	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
DVD/Video information	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Telephone call from a health professional	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
One individual session	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Multiple individual sessions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
One group session	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Multiple group sessions	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

4.3.3.2 Independent variables

4.3.3.2.1 Sociodemographic characteristics

In line with previous evidence of associations between sociodemographic characteristics and interest in/use of digital technologies (21st Century Challenges; Choi & Dinitto, 2013; Ginossar & Nelson, 2010; Helsper & Reisdorf, 2013; Kontos, Blake, Chou, & Prestin, 2014; Lopez, Green, Tan-McGrory, King, & Betancourt, 2011; OFCOM, 2018; Yamin et al., 2011), participant age, gender, ethnicity, highest level of education achieved and internet use were assessed. Age was assessed with the question ‘How old are you?’ and answers were provided in years. Gender was assessed with the question ‘What is your sex?’ and response options were ‘male’ or ‘female’. Ethnicity was assessed with the question ‘Which of these best describes your ethnic group?’ with response options: White British / White Irish / Any other White / Black African / Black Caribbean / Any other Black / Indian / Bangladeshi / Pakistani / Chinese / Any other Asian / Mixed White and Black African / Mixed White and Black Caribbean / Mixed White and Asian / Any other mixed / Any other. Participants who ticked any of the ‘Any other...’ ethnic group options could specify their ethnic group in an open response format. Ethnicity was dichotomised into ‘White’ and ‘non-White’ categories, due to the high proportion of the sample who were of a White ethnic group. Highest level of education was assessed with the question ‘Which educational or professional

qualifications do you have?’ with response options: GCSE/School certificate/O-level/CSE, Vocational qualifications (e.g. NVQ1+2), A-level/Higher school certificate or equivalent (e.g. NVQ3), Bachelor Degree or equivalent (e.g. NVQ4), Masters/PhD/PGCE or equivalent, Still studying, No formal qualifications, Other. These response options were used to create a ‘highest level of education achieved’ variable with four categories (None, GCSE/Vocational or equivalent, A-level or equivalent, Bachelor’s Degree or equivalent and above) which was used as a proxy for SEP. Internet use was asked with the question ‘Do you use the internet? (e.g. for health information)’ with response options ‘Yes’ or ‘No’.

4.3.3.2.2 Clinical and disease characteristics

4.3.3.2.2.1 Cancer type

Cancer type was assessed with the question ‘Which of these types of cancer have you been diagnosed with?’ with response options: breast, prostate, bowel (colorectal) and other. Those who indicated they had also been diagnosed with another cancer could specify the other cancer type in an open response format. Participants were asked to provide an approximate date of diagnosis (month/year) for each cancer type they had been diagnosed with. Where participants had been diagnosed with more than one of these three cancer types, their most recent diagnosis was used for this measure.

4.3.3.2.2.2 Cancer spread

Cancer spread was assessed with the question ‘Has this cancer spread to any other parts of your body?’ with response options ‘Yes’, ‘No’, ‘Don’t know’. For the purposes of the analyses in this study, participants who answered ‘Don’t know’ were dealt with as missing data.

4.3.3.2.2.3 Comorbidities

Total number of comorbid conditions was assessed with the question ‘Have you ever had any of the following health problems?’ with response options: osteoporosis, diabetes, asthma, emotional or psychiatric illness, stroke, Parkinson’s disease, Alzheimer’s disease or dementia, lung disease, arthritis, angina, heart attack, heart murmur, irregular heart rhythm, any other heart trouble, another cancer, other. Those who ticked ‘other’ were invited to give details of other comorbid conditions in an open comment space. This information was used to create a variable for the number of ‘other’ comorbid conditions the participant had given. This information was added

together to create a 'total number of comorbidities' variable. This question was developed specifically for this study and participant self-reporting of comorbid conditions has shown a high level of accuracy when compared with medical records in cancer survivors (Vigen et al., 2016; Ye et al., 2017).

4.3.3.2.3 Physical activity measures

4.3.3.2.3.1 Moderate-vigorous physical activity (MVPA) participation

Physical activity was assessed using the GLTEQ (Godin & Shephard, 1985). The GLTEQ has been used extensively in the cancer survivorship literature (Amireault, Godin, Lacombe, & Sabiston, 2015) and has shown favourable correlations with objective measures of physical activity assessed via accelerometry in breast cancer survivors ($r = .53$; $p < .002$) (Grossman, Deuring, Garland, Campbell, & Carlson, 2008) and leukaemia survivors ($r = .57$; $p < .005$) (Tillmann, Darlington, Eiser, Bishop, & Davies, 2002). Participants are asked 'Over the past month, how many times a week on average did you do the following kinds of exercise for more than 15 minutes during your free time?' and indicate the number of times per week and the duration of each session they engage in strenuous, moderate and mild exercise. Strenuous exercise was described as 'heart beats rapidly' and examples included running, jogging, vigorous swimming, cycling; moderate exercise was described as 'not exhausting' and examples included fast walking, easy cycling, easy swimming and mild exercise was described as 'minimal effort' and examples included easy walking, fishing, bowling. The inclusion of the average duration per session for each level of intensity is a slight modification of the original GLTEQ and has been used in other studies assessing physical activity among cancer survivors (Livingston et al., 2015). Average minutes per week spent during each exercise intensity was calculated by multiplying the average number of sessions per week by the average duration of each session (in minutes). MVPA recommendations are at least 150 minutes of moderate or 75 minutes of vigorous physical activity per week (or a combination of the two) (Rock et al., 2012; Schmitz et al., 2010; US Department of Health and Human Services, 2008), therefore the number of minutes spent in strenuous physical activity per week was doubled to determine the equivalent number of minutes of moderate exercise. The doubled number of strenuous intensity minutes per week was added to the number of moderate intensity minutes per week to create a total number of minutes spent in MVPA per week. Those who spend ≥ 150 minutes in MVPA per week were coded as meeting

MVPA recommendations, and those who spend <150 minutes in MVPA per week were coded as not meeting MVPA recommendations.

Steps were taken to reduce the amount of missing data for this variable. For the complete-case analysis, participants who had left the entire GLTEQ blank but had answered “Rarely/Never” to a further question (“During a typical 7-day period (a week), in your leisure time, how often do you engage in any regular activity long enough to work up a sweat (heart beats rapidly)?”) were assumed not to be meeting MVPA recommendations. See section 4.3.4.1 for how missing data were dealt with for this variable in analyses using multiple imputation.

4.3.3.2.3.2 Perceived need to increase physical activity

Perceived need to increase physical activity was assessed using the question “Which of the following best describes you at the present time?” with response options: “I think I should be doing more physical activity”, “I think I should be doing less physical activity”, “I don’t think I need to change my physical activity” and “Don’t know”. Responses were dichotomised into participants who endorsed the belief “I think I should be doing more physical activity” vs. participants who answered with any of the other response options. This question was developed specifically for this study.

4.3.3.2.3.3 General interest in physical activity interventions

General interest in physical activity interventions was assessed using the question ‘How interested would you be in any information/advice to help you increase your physical activity?’ Response options were provided on a 5-point scale: 1 = Not at all interested, 2 = A little interested, 3 = Somewhat interested, 4 = Very interested, 5 = Not applicable. For the purposes of this analysis, those who answered ‘not applicable’ were treated as ‘not at all interested’ and responses were dichotomised into a ‘not at all interested’ group and an ‘interested’ group for participants who responded with a little, somewhat, or very interested. This question was developed specifically for this study. General interest in physical activity interventions was assessed as part of a larger question also assessing general interest in diet, weight, smoking, alcohol and overall healthy lifestyle interventions. To address missing data for this question, if a participant had provided an answer for at least one of the 6 types of interventions, all other missing values were changed to “1 = Not at all interested” as it was assumed that the participant only provided an answer for the interventions they were interested in and therefore a participant only remained

missing if they had left the entire question blank. Participants who left the entire question blank were dealt with as missing data, as described in section 4.3.4.1

4.3.3.2.4 Loneliness

Loneliness was assessed using the 3 item short form of the Revised UCLA loneliness scale (Hughes, Waite, Hawkley, & Cacioppo, 2004), since this has been associated with the use of the internet and digital technologies (Helsper & Reisdorf, 2013) and the use of health and fitness apps (Gao, Li, Zhu, Liu, & Liu, 2016). Items include ‘How often do you feel you lack companionship?’, ‘How often do you feel left out?’ and ‘How often do you feel isolated from others?’ with response options on a 3-point scale: ‘1 = Hardly ever or never’, ‘2 = Some of the time’, and ‘3 = Often’. Scores for each item are added together to create a total loneliness score variable. This scale has displayed satisfactory reliability, internal consistency and both concurrent and discriminant validity (Hughes et al., 2004). Furthermore, the scale is robust across different interview modalities (self-administered and telephone) (Hughes et al., 2004).

4.3.4 Statistical analyses

All analyses were conducted using IBM SPSS Statistics version 21. Planned analyses were pre-registered using the Open Science Framework and can be viewed at: <https://osf.io/74gz8/>. Descriptive statistics were used to examine the prevalence of interest in information/advice about making lifestyle changes via internet information or via an app. Univariable binomial logistic regressions explored associations between the dependent variables (interest in ‘internet information’ or ‘an app for mobile/tablet’) with the following independent variables: age, gender, ethnicity, highest level of education, internet use, total number of comorbidities, cancer spread, loneliness, perceived need to increase physical activity, general interest in physical activity interventions and meeting MVPA recommendations. Then, multivariable binomial logistic regressions were conducted separately for perceived need to increase physical activity, general interest in physical activity interventions and meeting MVPA recommendations with each dependent variable (interest in internet information and an app) adjusted for covariates (age, gender, ethnicity, highest level of education, internet use number of comorbid conditions, loneliness, cancer spread and any of the other exploratory variables that were significant in univariate analyses) to determine adjusted ORs. These covariates were included in adjusted analyses regardless of significance in unadjusted analyses as previous literature suggests, a

priori, that these sociodemographic factors may influence interest in or use of digital technologies/interventions (21st Century Challenges; Choi & Dinitto, 2013; Gao et al., 2016; Ginossar & Nelson, 2010; Helsper & Reisdorf, 2013; Kontos et al., 2014; Lopez et al., 2011; OFCOM, 2018; Yamin et al., 2011). Planned sub-analyses were conducted where all analyses were repeated in each of the three cancer types included in the study, separately. The gender variable was removed for the sub-analyses conducted on the breast and prostate cancer samples.

4.3.4.1 Missing data

Participants with complete data (for every item used in the analysis) (62%; N=3,616) were compared to participants with missing data for one or more items (38%; N=2,224), on each variable used in the analysis, using *t*-tests, Mann-Whitney U tests, χ^2 -tests and logistic regression analyses to explore potential missingness mechanisms. Little's test and the pattern of differences in participants with complete and incomplete data suggested that data were not missing completely at random (MCAR). Multiple imputation was therefore used to address missing data (Kenward & Carpenter, 2007). It is not possible to distinguish between the missing at random (MAR) and missing not at random (MNAR) assumptions using the observed data as it is the unobserved data that can distinguish between MAR and MNAR, which is untestable (Kenward & Carpenter, 2007).

Multiple imputation was used to address missing data such that all the measures described in section 4.3.3 were both imputed and used as predictors in the imputation, and where the other 8 interest in intervention delivery modality items (short leaflet, longer leaflet/booklet, DVD/video information, telephone call from health professional, one individual session, multiple individual sessions, one group session, multiple group sessions) and the other 5 interest in different behavioural interventions items (diet, weight, smoking, alcohol, overall lifestyle interventions) were used as predictors only. The items from the GLTEQ are used to create a variable to indicate whether a participant was meeting vs. not meeting physical activity recommendations. For the GLTEQ items, imputation was carried out for the total minutes per week spent in each of the physical activity intensities (mild, moderate, strenuous). This imputed data was then used to recalculate the total number of minutes spent in MVPA per week and whether the participant was meeting vs. not meeting physical activity recommendations (≥ 150 minutes MVPA per week) in the same way as described in section 4.3.3.2.3.

The multiple imputation was run twice with ten imputations. The analysis was run on each of the imputed datasets separately and the results compared. As the analyses on each pooled imputed dataset revealed a similar pattern of results, the number of imputations did not need to be increased and the results from the first pooled imputed dataset are presented.

4.4 Results

4.4.1 Sample characteristics

Of 10,951 questionnaires sent, a total of 5,840 (53%) usable questionnaires were returned. Survey respondents' characteristics are reported in Table 4.1. A full breakdown of participants' responses to perceived need to increase physical activity, general interest in physical activity interventions and interest in internet information and/or an app for mobile or tablet can be found in Appendix G. Participants had a mean age of 67 years (standard deviation (SD)=12 years; range 26-97) and the majority (90%) were white. Forty-eight percent of the sample had had breast cancer, 32% had had prostate cancer and 21% had had colorectal cancer. Approximately a third (32%) reported no comorbid conditions, 34% reported 1, 19% reported 2 and 15% reported ≥ 3 . The mean total loneliness score of 4.0 (SD = 1.6; range 3-9). Sample characteristics for each of the breast, prostate and colorectal cancer samples can be found in Appendices H-J.

Little's MCAR test revealed that missing data were not MCAR ($p < .001$). Participants with complete data were younger (mean of 65 years vs. 71 years; $p < .001$) and had less comorbid conditions (1.2 vs. 1.4; $p < .001$) than those with incomplete data. Furthermore, female participants (66% complete vs. 57% men), those who use the internet (71% vs. 48% non-internet users), think they should be doing more physical activity (68% vs. 59% other), are interested in physical activity interventions (69% vs. 58% not interested), meet MVPA recommendations (77% vs. 67% not meeting MVPA recommendations), are interested in internet information (75% vs. 61% not interested) and interested in an app for mobile/tablet (76% vs. 63% not interested) had significantly higher proportions of complete data (all $ps < .001$). Those who were degree-educated or above also had significantly greater odds of having complete data compared to those who had no formal qualifications (75% degree-educated vs. 57% no formal qualifications, OR=2.25, $p < .001$). The only variables where data completeness did not differ significantly between groups were loneliness scores, ethnicity and cancer spread.

Table 4.1: Sample characteristics

Characteristics	n (%)
Gender	
Male	2553 (43.7)
Female	3265 (55.9)
Missing data	22 (0.4)
Highest level of education	
No qualifications	1709 (29.3)
GCSE/Vocational	1613 (27.6)
A-level	584 (10.0)
Degree or higher	1380 (23.6)
Missing data	554 (9.5)
Ethnicity	
White	5250 (89.9)
Non-white	554 (9.5)
Missing data	36 (0.6)
Internet use	
Yes	3769 (64.5)
No	1982 (33.9)
Missing data	89 (1.5)
Cancer type	
Breast	2788 (47.7)
Prostate	1842 (31.5)
Colorectal	1210 (20.7)
Cancer spread	
Yes	558 (9.6)
No	4499 (77.0)
Don't know/Missing	783 (13.4)
Number of comorbid conditions	
0	1853 (31.7)
1	1993 (34.1)
2	1119 (19.2)
3+	875 (15.0)
Meeting MVPA guidelines	
Meeting guidelines	1791 (30.7)
Not meeting guidelines	3359 (57.5)
Missing data	690 (11.8)
Perceived need to change PA	
I think I should be doing more PA	2973 (50.9)
Other	2738 (46.9)
Missing data	129 (2.2)
Interest in information/advice to increase PA	
Not at all interested	2102 (36.0)
Interested	3474 (59.5)
Missing data	264 (4.5)
Interest in internet information	
Not at all interested	3230 (55.3)
Interested	2219 (38.0)
Missing data	391 (6.7)
Interest in an app	
Not at all interested	4063 (69.6)
Interested	1386 (23.7)
Missing data	391 (6.7)

PA: physical activity

4.4.2 Interest in digital interventions

The proportion of the sample interested in internet information was 38% (N=2,219). The proportion interested in an app for mobile/tablet was 24% (N=1,386).

4.4.3 Characteristics associated with interest in digital interventions

Table 4.2 shows the results of the logistic regression analyses on the imputed dataset. Complete-case analysis (N=3,616) is available in Appendix K (results were similar). Unadjusted analyses show that participants who were younger, female, non-white, more highly educated, internet users, had less comorbidities, whose cancer had spread, who thought they should do more physical activity and who were interested in physical activity interventions had significantly greater odds of being interested in internet information. The same pattern of results were shown for interest in an app, with participants who reported higher loneliness and those who were meeting MVPA recommendations also showing significantly more interest in an app. In adjusted analyses, significant associations remained between interest in internet information and age (OR=0.96; 95% CI: 0.96-0.97; $p < .001$), education (degree-educated vs. no formal qualifications: OR=1.71; 95% CI: 1.39-2.09; $p < .001$), internet use (internet user vs. non-user: OR=4.56; 95% CI: 3.79-5.50; $p < .001$) and interest in physical activity interventions (interested vs. not interested: OR=2.98; 95% CI: 2.55-3.49; $p < .001$). Furthermore, in adjusted analyses, those who were meeting MVPA recommendations (meeting vs. not meeting recommendations: OR=1.14; 95% CI: 1.00-1.33; $p = .048$) had greater odds of interest in internet information. Women showed significantly lower odds of interest in internet information compared with men (OR=0.75; 95% CI: 0.64-0.88; $p < .001$), which is the opposite direction to the result of unadjusted analyses. Adjusted analyses showed significant associations remained between interest in an app and age (OR=0.94; 95% CI: 0.93-0.95; $p < .001$), ethnicity (non-white vs. white: OR=1.41; 95% CI: 1.14-1.75; $p = .002$), internet use (internet user vs. non-user: OR= 2.64; 95% CI: 2.04-3.42; $p < .001$), interest in physical activity interventions (interested vs. not interested: OR=3.16; 95% CI: 2.59-3.85; $p < .001$) and meeting MVPA recommendations (meeting vs. not meeting recommendations: OR=1.20; 95% CI: 1.05-1.38; $p = .01$). Gender and education were not significantly associated with interest in an app in adjusted analyses. Results of the analyses repeated for each of the three cancer types separately can be found in Appendices L-N.

Additional post-hoc analyses were conducted to further explore the associations between gender and interest in internet information/an app, as unadjusted analyses revealed that female participants had significantly greater odds of interest but adjusted analyses reversed the direction of the association, and demonstrated that male participants had greater odds of interest in internet information (statistically significant) and an app (non-significant). As gender and cancer type are inextricably linked in the breast (99% female) and prostate (100% male) cancer samples, which together accounted for 80% of the overall sample, it was hypothesised that the differences in age and therefore possibly the educational qualifications achieved and internet use, may have differed between the genders/cancer types and that these variables could explain the observed pattern of results. The breast cancer sample had a lower mean age (63 years) compared with both the prostate (72 years) and colorectal (70 years) cancer samples and age was a strong predictor of interest in both internet information and an app. The breast cancer sample had a higher proportion of participants who were degree-educated (27%) compared with the prostate (20%) and colorectal (22%) cancer samples, and education was also a strong predictor of interest in both internet information and an app in unadjusted analyses.

Additional logistic regressions were conducted to examine whether the association between gender and interest in internet information/an app changed after adjusting for only age or only education. After adjusting for only age, female participants had significantly greater odds of interest in internet information (OR=0.76, 95% CI: 0.66-0.86, $p<.001$) and the effect of gender on interest in an app became non-significant (OR=0.87, 95% CI: 0.74-1.03, $p=.111$). After adjusting for only education, the association between gender and interest in internet information was no longer significant (OR=1.08, 95% CI: 0.96-1.22, $p=.209$) and remained significant in the same direction for interest in an app (OR=1.53, 95% CI: 1.34-1.75, $p<.001$).

Table 4.2: Pooled logistic regression analyses for interest in internet information and an app for mobile/tablet (10 imputations)

Demographic characteristics	Internet information							App for mobile/tablet						
	Interested % (N)	OR	Unadjusted CI	p	OR	Adjusted ^a CI	p	Interested % (N)	OR	Unadjusted CI	p	OR	Adjusted ^a CI	p
Age	-	0.94	0.94-0.95	<.001	0.96	0.96-0.97	<.001	-	0.93	0.92-0.93	<.001	0.94	0.93-0.95	<.001
Gender														
Male	38.7 (992)	1.00	-	-	1.00	-	-	20.2 (519)	1.00	-	-	-	-	-
Female	44.7 (1463)	1.28	1.14-1.43	<.001	0.75	0.64-0.88	<.001	30.5 (999)	1.73	1.51-1.97	<.001	0.89	0.74-1.06	.183
Ethnicity														
White	41.5 (2191)	1.00	-	-	1.00	-	-	24.5 (1291)	1.00	-	-	1.00	-	-
Non-White	47.1 (264)	1.26	1.05-1.50	.012	0.81	0.66-1.01	.055	40.5 (227)	2.10	1.75-2.53	<.001	1.41	1.14-1.75	.002
Highest level of education														
No formal qualifications	23.5 (463)	1.00	-	-	1.00	-	-	14.1 (278)	1.00	-	-	1.00	-	-
GCEs/vocational qualifications	45.7 (799)	2.74	2.30-3.27	<.001	1.25	1.02-1.53	.029	28.7 (502)	2.45	2.01-2.99	<.001	0.96	0.77-1.21	.743
A-levels or equivalent	54.8 (345)	3.94	3.17-4.90	<.001	1.64	1.28-2.10	<.001	34.6 (218)	3.22	2.51-4.13	<.001	1.10	0.83-1.47	.492
Degree or higher	57.0 (848)	4.32	3.68-5.07	<.001	1.71	1.39-2.09	<.001	35.0 (521)	3.28	2.70-3.99	<.001	1.08	0.85-1.37	.553
Internet use														
No	14.7 (297)	1.00	-	-	1.00	-	-	9.4 (190)	1.00	-	-	1.00	-	-
Yes	56.6 (2158)	7.58	6.40-8.97	<.001	4.56	3.79-5.50	<.001	34.8 (1328)	5.18	4.06-6.60	<.001	2.64	2.04-3.42	<.001
Number of comorbidities	-	0.88	0.84-0.92	<.001	1.05	0.99-1.10	.100	-	0.84	0.80-0.89	<.001	1.01	0.95-1.08	.696
Cancer spread														
No	41.2 (2144)	1.00	-	-	1.00	-	-	25.2 (1311)	1.00	-	-	1.00	-	-
Yes	48.4 (311)	1.34	1.11-1.61	.002	1.08	0.87-1.34	.507	32.2 (207)	1.41	1.14-1.74	.001	1.12	0.88-1.41	.354
Loneliness	-	1.01	0.97-1.04	.551	1.00	0.96-1.05	.971	-	1.06	1.02-1.11	.002	1.02	0.97-1.07	.491
Belief that should do more PA														
Other	34.3 (939)	1.00	-	-	-	-	-	19.3 (529)	1.00	-	-	1.00	-	-
"I think I should do more PA"	49.4 (1469)	1.87	1.68-2.09	<.001	0.92	0.80-1.06	.246	32.5 (966)	2.01	1.76-2.30	<.001	0.98	0.84-1.15	.817
Interest in information/advice to increase PA														
Not interested	24.2 (534)	1.00	-	-	-	-	-	11.4 (252)	1.00	-	-	1.00	-	-
Interested	52.9 (1921)	3.52	3.10-4.00	<.001	2.98	2.55-3.49	<.001	34.9 (1266)	4.16	3.50-4.95	<.001	3.16	2.59-3.85	<.001
Meeting MVPA recommendations														
Not meeting recommendations	41.1 (1146)	1.00	-	-	-	-	-	24.3 (678)	1.00	-	-	1.00	-	-
Meeting recommendations	42.9 (1309)	1.08	0.97-1.20	.187	1.14	1.00-1.31	.048	27.5 (840)	1.18	1.05-1.33	.008	1.20	1.05-1.38	.010

^a: Adjusted for age, gender, ethnicity, education, internet use, number of comorbidities, cancer spread, loneliness, belief that should do more PA, interest in information/advice to increase PA, meeting MVPA recommendations

4.5 Discussion

Thirty-eight percent of breast, prostate and colorectal cancer survivors report being interested in internet information and 24% are interested in an app for lifestyle intervention delivery after a cancer diagnosis. After adjustment for relevant covariates, participants who were younger, male, more highly educated, internet users, interested in physical activity interventions and meeting MVPA recommendations showed significantly greater odds of interest in internet information. Adjusted analyses also revealed that participants who were younger, non-white, internet users, interested in physical activity interventions and meeting MVPA recommendations had significantly greater odds of interest in an app.

Reported interest in digital interventions was lower than has been reported in a study by Phillips and colleagues who found that 68% of breast cancer survivors were interested in a physical activity intervention using a website or app (Phillips et al., 2017). However, the participants in that study were recruited from a convenience sample. Therefore, the representativeness of that sample is limited and is not likely to reflect the general population of breast, prostate and colorectal cancer survivors in the UK. A larger study of breast, prostate and colorectal cancer survivors, also conducted in the USA, showed that 59% were interested in web-based interventions and that 22% were interested in an app (Martin et al., 2016). While interest in 'internet information' was somewhat lower in the current study compared with Martin et al.'s (2016) results, the results from a smartphone-delivered program/an app were broadly similar. This is despite the fact that the data in Martin et al.'s (2016) study was collected in 2010 and that technology usage patterns have changed considerably during this time across both the American and UK populations. Despite this, the current study provides a more recent estimate of the proportion of breast, prostate and colorectal cancer survivors interested in digital interventions among a sample that is more likely to reflect the UK population.

It was unsurprising that current internet use was strongly associated with interest in internet and app-based interventions in all analyses, given that this provides an indication of access to, use of and confidence and skills to engage with technologies used in DHBCIs. Similar results have been reported in comparable studies assessing the prevalence and characteristics of smokers interested in digital smoking cessation interventions (Brown, Michie, Raupach, & West, 2013). The consistent significant association between younger participants and interest in both internet

information and an app is unsurprising given the higher rates of internet access and smartphone ownership in younger age groups (OFCOM, 2018). The National Cancer Institute's 2015 Health Information National Trends Survey is a nationally representative, cross-sectional survey that explored the sociodemographic characteristics associated with health app use in the general population in the USA. Using this data, Carroll and colleagues also reported that older participants had significantly lower odds of using health apps (Carroll et al., 2017). Furthermore, in an RCT where intervention group participants had the choice of receiving a physical activity intervention delivered via print or web-based materials, older participants were less likely to use web-based intervention materials (Golsteijn et al., 2017). Despite the rapidly increasing ownership of smartphones in older age groups in recent years, age remains a barrier to accessing digital interventions. This is especially important given that the majority of cancer survivors are older adults.

Interestingly, education level was only significantly associated with interest in internet information, whereas education was not associated with interest in an app in adjusted analyses. Data from the UK and USA using several measures indicative of SEP (including occupation, income and education level) show that overall internet access and smartphone ownership is higher among those living in higher SEP households (OFCOM, 2018; Pew Research Center, 2017b). However, there is suggestion that smartphones could offer an easier and more affordable way of accessing the internet, compared to laptop, desktop or tablet computers, in those of lower SEP. In 2016, 20% of Americans living in low-income households were classified as "smartphone-only" internet users (who owned a smartphone but did not have broadband internet access) compared with 4% of those in high-income households, who were more likely to own multiple devices used to access the internet, such as laptop, desktop and tablet computers (Pew Research Center, 2017a). Of those in the highest SEP group in the UK (based on occupation), 86% owned a smartphone and 81% owned a laptop, while in the lowest SEP group, 65% owned a smartphone compared with 43% who owned a laptop (OFCOM, 2017). These figures demonstrate the much larger difference between smartphone and laptop ownership in those of lower SEP versus those of higher SEP. In Martin and colleagues' study of breast, prostate and colorectal cancer survivors, those who did not own a computer showed greater interest in smartphone-based interventions (Martin et al., 2016). These findings could help to explain the similar levels of interest in app-based interventions regardless of education level, which was not evident for internet-based information. It is however,

important to acknowledge that there may be other socioeconomic disparities in access to DHBCIs, such as eHealth literacy skills (Choi & Dinitto, 2013; Neter & Brainin, 2012; O'Connor et al., 2016).

Interestingly, non-White participants showed significantly greater interest in app-based interventions. It has been suggested that a large amount of poor health experienced by minority ethnic groups could be explained by high levels of deprivation (Nazroo, 1997). Therefore, the higher level of interest in app-based interventions among non-white participants could also be explained in a similar way to the results for education, in that smartphones may provide a more accessible and affordable way to use the internet among those of lower SEP, which could therefore result in higher reporting of interest in app-based interventions among non-white participants compared with web-based interventions. Another possible explanation is that people from ethnic minorities are more likely to live in urban versus rural environments, which tend to have better mobile coverage and increased adoption of smartphones. Given the comparatively small sample of non-white versus white participants, it was not possible to further explore patterns among different ethnic groups within the non-white sample analysed in this study.

The association between gender and interest in DHBCIs also revealed interesting findings. In unadjusted analyses, female participants showed greater odds of interest in both internet information and an app. However, after adjustment for relevant covariates, male participants were significantly more interested in internet information and gender was no longer significant for interest in an app. This pattern of results is interesting given that 6 of the studies identified in the systematic review (Study 1 - Chapter 3) were conducted exclusively among female cancer survivors. Among the other included studies involving participants diagnosed with a range of cancer types, all of them were over-represented by female participants. Nationally representative data from the National Cancer Institute's 2015 Health Information National Trends Survey revealed that men had significantly lower odds of having adopted health apps versus women in the general population in the USA (Carroll et al., 2017). However, in the current study, it is important to note that these gender differences may not in fact be differences in gender per se, but differences in cancer types, given that only men can have prostate cancer, and that breast cancer is rare among men. The breast cancer sample in the current study were younger and more highly educated than the prostate (and colorectal) cancer samples and post-hoc analyses that aimed to further explore the pattern of results between gender, age, education and interest in

internet information/an app suggested that women's younger age explained the higher interest in unadjusted analyses. Further research that aims to better understand the link between gender and/or cancer type and interest in, or use of, digital interventions may help to explain these findings, given that much of the behaviour change literature reports an over-representation among female participants.

Interest in physical activity interventions was significantly associated with interest in digital interventions, which may be indicative of the fact that those who are interested in physical activity support in general are likely to report higher interest in various types of physical activity interventions, regardless of modality. Furthermore, those who were already meeting MVPA recommendations had higher odds of interest in digital interventions. This finding was also reported in the study conducted by Martin et al. (2016) and the Health Information National Trends Survey revealed that those who have adopted health apps were significantly more likely to meet national physical activity recommendations compared with non-users (Carroll et al., 2017). Other studies evaluating digital physical activity interventions among cancer survivors have shown reasonably high levels of MVPA at baseline among participants (Forbes et al., 2015; Kuijpers et al., 2016), and recruiting those who are inactive or engaging in low levels of MVPA is particularly challenging among this group. As a result, those working in cancer care play an important role with regards to physical activity promotion, in encouraging those who may not already exhibit interest in physical activity interventions or who are not already meeting physical activity guidelines to participate in physical activity programmes, particularly as these patients potentially stand to gain the most from increasing physical activity.

4.5.1 Strengths and limitations

This study is the largest survey to explore health, wellbeing and intervention preferences among a diverse sample of breast, prostate and colorectal cancer survivors within the UK. Furthermore, this analysis used multiple imputation to address missing data and therefore reducing the potential bias that might result from reporting the complete-case analysis. However, the possibility that the data were MNAR cannot be ruled out, despite the fact that this is impossible to test given that this relies on the missing data itself.

Limitations include the potential validity of the outcome measure of interest in digital interventions given that an expression of interest about an internet/app-based intervention is hypothetical and

provides no information on uptake of such an intervention. An indication of interest does not necessarily mean that a participant would access, download or continue using such a DHBCI over a period of time sufficient to bring about behaviour change. However, the intention of this study was to provide an estimate of the potential reach of a DHBCI and to explore factors that could help to characterise the population who may be most likely to use such an intervention and its potential impact.

Other limitations include the cross-sectional nature of this study. Therefore, these results cannot be used to determine causality. Furthermore, physical activity participation relied on self-reported data, which while easy to use, inexpensive and validated, often hugely overestimates physical activity participation (Prince et al., 2008). Clinical and disease characteristics (e.g. cancer type, spread, comorbidities) were also self-reported and patient records may have been a more accurate approach to obtain this data. Given the large number of participants involved in the current study and the limited resources, it was not possible to make use of objective measures of physical activity (e.g. using pedometers/accelerometers) or link with medical records to obtain patient records for clinical and disease characteristics.

It is impossible to determine how representative the questionnaires that were returned are of the wider sample of breast, prostate and colorectal cancer survivors both within the sites they were recruited from and the larger UK population. However, more females responded to the survey than men, half of the respondents had breast cancer compared with a third who had prostate cancer and a fifth who had colorectal cancer. There was good variation in the educational level of the participants, with just less than a third of the sample having received no formal qualifications and only 24% of the sample were degree-educated. This is broadly in line with the 2011 UK Census data, which reports that, among adults over 50 (92% of this sample), 38% of the population have no formal qualifications and 23% are degree-educated (Office for National Statistics, 2011). Despite the potential limitations, this is the largest study to explore the proportion of breast, prostate and colorectal cancer survivors who are interested in digital interventions and factors associated with interest in the UK.

4.5.2 Conclusion

This study characterises the population of breast, prostate and colorectal cancer survivors who indicate interest in and may be more likely to use digital interventions. Two fifths (38%) were

interested in internet information and approximately a quarter (24%) were interested in an app. However, interest is related to several sociodemographic and participant characteristics. In particular, a “digital divide” still exists for age, and those who are less educated are less likely to indicate interest in internet information. However, there was no difference in interest in app-based interventions with regards to education level and smartphones could provide an easier and more affordable way to engage with digital interventions among those of lower SEP. Those who are interested in physical activity interventions or already meeting physical activity guidelines are more likely to indicate interest in digital interventions. Research is needed to carefully design digital interventions with groups who report lower interest in digital interventions in mind (e.g. co-design, participatory design) and determine how beneficial digital interventions can be best presented to all individuals to overcome this divide via effective targeting and promotion. It is also important to recognise that digital interventions may not be appropriate for, or appealing to, all cancer survivors and it is important that a range of physical activity interventions and services are available to cater to the needs, preferences and circumstances of a heterogeneous population.

Chapter 5 (Study 3): Breast, prostate and colorectal cancer survivors' experiences of using publicly available physical activity mobile apps⁴

5.1 Background

Digital interventions have the potential to increase cancer survivors' MVPA by 41 minutes per week (see systematic review and meta-analysis described in Study 1 - Chapter 3). However, of the 15 studies included in this review, the majority used web-based interventions and only two small feasibility studies evaluated the use of smartphone apps in physical activity promotion (one conducted by our group, and co-first authored by myself) (McCarroll et al., 2015; Puskiewicz et al., 2016). While a smaller proportion of the participants in Study 2 (Chapter 4) reported an interest in app-based interventions versus web interventions, the increasing ownership of smartphones among the older population and their usage among those of lower SEP mean that they could become a more accessible way of accessing digital physical activity interventions. Furthermore, smartphone apps have the benefit of being able to deliver BCTs in real-time using a device that is usually turned on, usually carried with the person, and often has inbuilt functions to monitor physical activity and deliver immediate feedback.

There are over 300,000 health-related mobile applications currently available on commercial app stores (e.g. iOS Apple App Store, Google Play) (Aitken, Clancy, & Nass, 2017). This includes thousands of publicly available physical activity apps which can be used by members of the general population and are readily available to download. It is possible that there are many physical activity apps that are appropriate for cancer survivors that already exist, or which could be adapted in order to increase their suitability for this group. Exploring cancer survivors' experiences of using different types of existing physical activity apps could also offer insight into how feasible and acceptable apps may be as an approach to intervention delivery. This could also help to understand which types of physical activity apps may be most appropriate or successful, before making potentially large investments into app/intervention development.

⁴ A version of this chapter has been published (Appendix O).
Roberts AL, Potts HW, Koutoukidis DA, Smith L, Fisher A. Breast, Prostate, and Colorectal Cancer Survivors' Experiences of Using Publicly Available Physical Activity Mobile Apps: Qualitative Study JMIR Mhealth Uhealth 2019;7(1):e10918. DOI: [10.2196/10918](https://doi.org/10.2196/10918)

Furthermore, using or adapting appropriate existing apps means that additional costs for app development and maintenance may be smaller (or not required) and could offer longer term reliability and sustainability than developing apps within a research setting.

Qualitative research methods provide a rich understanding of people's experiences, thoughts and opinions and seeking the perspectives of intended users is a critical element of digital intervention development (Bradbury, Watts, Arden-Close, Yardley, & Lewith, 2014; Craig et al., 2008; Yardley, Morrison, Bradbury, & Muller, 2015). Robertson and colleagues conducted focus groups with 35 breast, prostate, colorectal and endometrial cancer survivors, during which feedback was sought via open-ended questions and group discussion of potential physical activity app features and messages that were shown to participants during a slide-show presentation. The participants expressed preferences for a casual, concise, and positive tone, tools for personal goal attainment, a prescription for physical activity and an experience that is tailored to the user (Robertson et al., 2017). However, the feedback provided was hypothetical and the participants did not experience using the different app features or receive the different types of messages being explored. Greater ecological validity could be gained by allowing participants to actually experience using different types of apps and BCTs over a period of time, before seeking their feedback. Short and colleagues conducted an experiential mixed-methods study where 10 cancer survivors were referred to one of 15 physical activity apps, which were used for a 1-2 week period (Short, Finlay, Sanders, & Maher, 2018). While this study explored the participants' experience and preliminary efficacy of the app referral service, it did not seek to explore participants' opinions and experiences of using the apps to which they were referred. There is value in gaining a deeper understanding of participants' perceptions of their preferences for, and influences on, engagement with physical activity apps. For the purposes of this study, a broad, integrative definition of engagement is used, comprising "1) the extent (e.g. amount, frequency, duration, depth) of usage and 2) a subjective experience characterised by attention, interest and affect" (p.258) (Perski, Blandford, West, & Michie, 2017).

5.2 Aims

This study aimed to seek breast, prostate and colorectal cancer survivors' opinions of using apps to promote physical activity and to gather their views of existing publicly available physical activity apps, in order to inform future intervention development.

5.3 Methods

5.3.1 Mobile applications

During the initial scoping of the smartphone app stores, no apps that were specifically designed to promote physical activity among cancer survivors were identified. This is in line with the findings of a previous Australian study exploring the use of physical activity apps among cancer survivors (Short et al., 2018). Therefore the physical activity apps considered for this study were identified from apps that were featured in the 'Health and Fitness' section of the British Apple App Store (iOS). This was intended to reflect the types of physical activity apps cancer survivors could choose from if they were to spontaneously look to the App Store for physical activity apps that are available publicly. Other apps that were deemed to be within remit as a result of previous work in digital health, and that may have been suitable for this study were also considered. The following criteria were considered in deciding which apps may be suitable for the study:

- **Content:** the apps needed to vary from each other in terms of the type of physical activity, and their format, features and BCTs to allow for comparison between different types of apps.
- **Typicality:** while the apps needed to vary in terms of their content, it was also important to choose apps that are typical of the various types of popular physical activity apps that are publicly available (e.g. activity trackers, workout programmes). It was also important that the apps chosen were typical of the difficulty level of publicly available physical activity apps in order to seek survivors' views of the appropriateness of the apps from this perspective.
- **Suitability:** the apps needed to be suitable for people who have undergone cancer treatment and therefore needed to have the flexibility to cater for different levels of fitness and familiarity with physical activity. Given the target group, apps that catered for low levels of fitness/familiarity with physical activity, but with an option to increase this if required, were of interest. Each app was reviewed for its suitability for use by breast, prostate and colorectal cancer survivors by a physiotherapist specialising in oncology.
- **Stability:** the apps were required to have been launched at least 2 years prior to the study.
- **Availability:** the apps needed to be available on both iOS and Android devices.

The number of apps to be included in this study was determined based on a number of considerations. This included how many apps would be required to compare multiple participants' opinions across several different physical activity apps, the number of participants required for the study and the feasibility of recruitment and data analysis. Given the consideration of all of the above factors, the four chosen apps were "Human", "The Walk", "The Johnson & Johnson Official 7 Minute Workout" (J&J) and "Gorilla Workout". See Table 5.1 for a description of each of the apps and an assessment of the incorporated BCTs, coded using the BCT Taxonomy (v1) (Michie et al., 2013) by myself and a second researcher (Dr Dimitrios Koutoukidis), with discrepancies resolved via discussion. Figures 5.1-5.4 show screenshots of the four apps.

Table 5.1: App characteristics

App (Developer)	Price	Description	Behaviour Change Techniques (BCTs)
Human (Humanco, Inc.)	Free	Encourages users to meet daily 30/60/90/120 minute goal of walking, running and/or cycling measured using smartphone's activity tracker. Delivers push notifications when users have not met their goal or during periods of inactivity. Compares activity levels to other app users nearby.	1.1 Goal setting (behaviour) 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 6.2 Social comparison 7.1 Prompts/cues 10.3 Non-specific reward
The Walk (Six to Start)	£2.29 (iOS); £2.59 (Android)	An interactive story-based game where walking unlocks audio clips of the next part of the story and other rewards. Time to complete an episode is based on the user's current physical activity level and walking is measured using the smartphone's activity tracker.	2.2 Feedback on behaviour 10.3 Non-specific reward 10.6 Non-specific incentive
The Johnson & Johnson Official 7 Minute Workout (Johnson & Johnson Health and Wellness Solutions, Inc.) (J&J)	Free	7 minute workouts are created to include aerobic and resistance exercises alternating between upper and lower body, core, and total body exercises. The workouts can be tailored to the user's current fitness and motivation levels and are provided with detailed video demonstrations and audio guidance.	1.4 Action planning 2.3 Self-monitoring of behaviour 4.1 Instruction on how to perform behaviour 6.1 Demonstration of the behaviour 7.1 Prompts/cues 8.7 Graded tasks 9.1 Credible source
Gorilla Workout (Heckr LLC)	£0.79 (iOS); £0.83 (Android)	The default programme is tailored to the user's current fitness level and gradually increases in difficulty. Each exercise has written guidance with an associated video with visual and audio demonstrations. Users can also choose to complete their own selection of exercises (from a list of 43) with the same written/video demonstrations. Daily push notifications are delivered to remind users to complete their workout.	4.1 Instruction on how to perform behaviour 6.1 Demonstration of the behaviour 7.1 Prompts/cues 8.7 Graded tasks

Figure 5.1: Screenshots of 'Human'

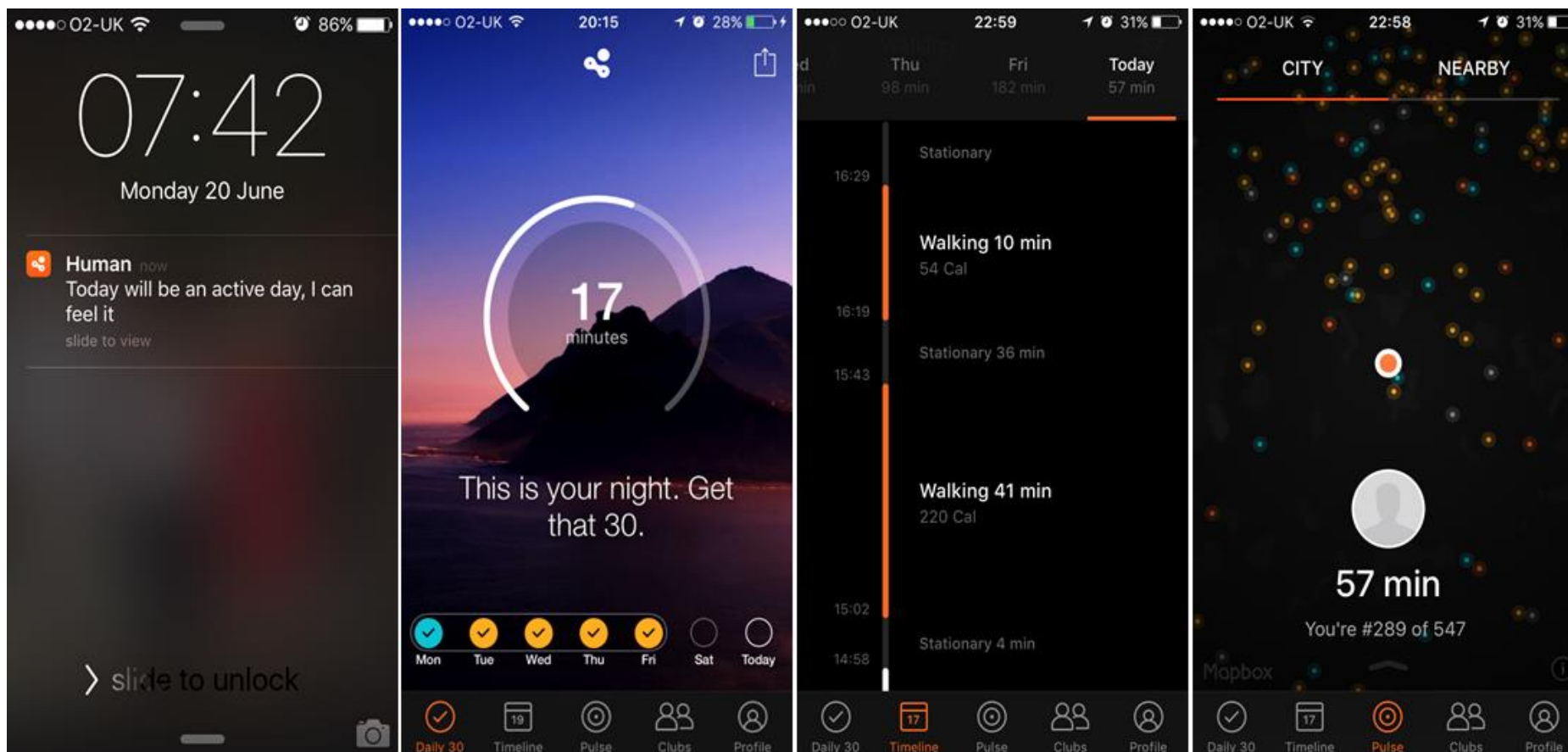


Figure 5.2: Screenshots of 'The Walk'

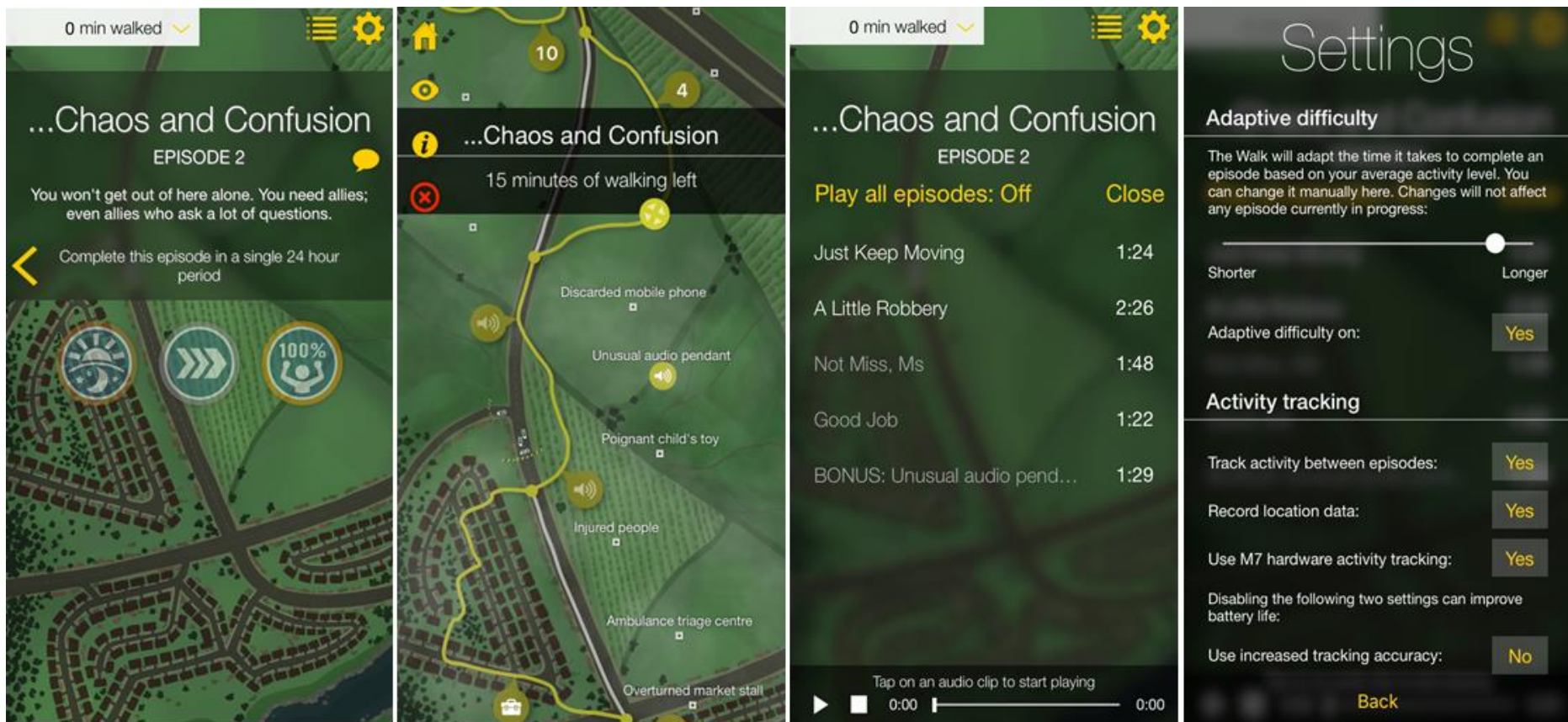


Figure 5.3: Screenshots of 'The Johnson & Johnson Official 7 Minute Workout' (J&J)

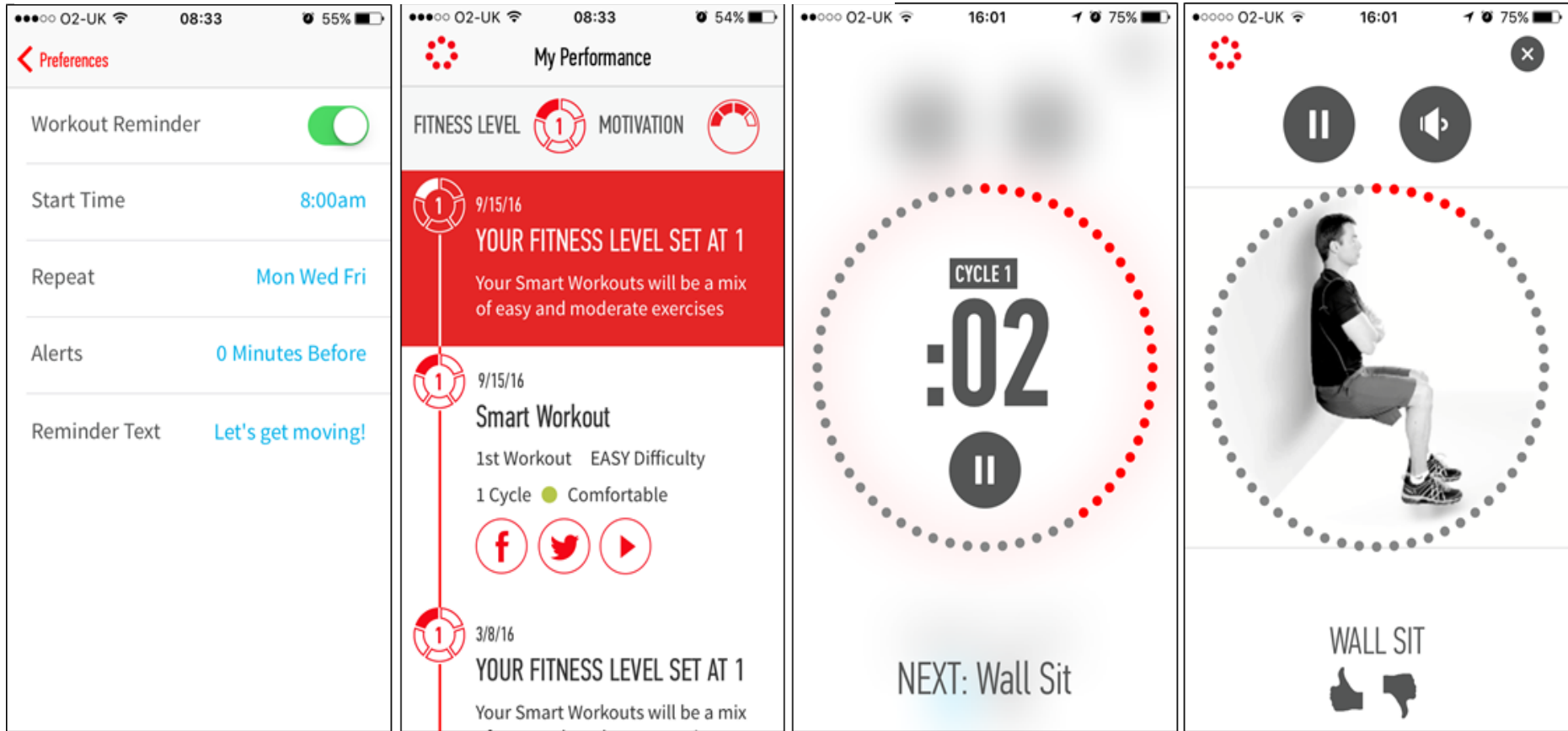
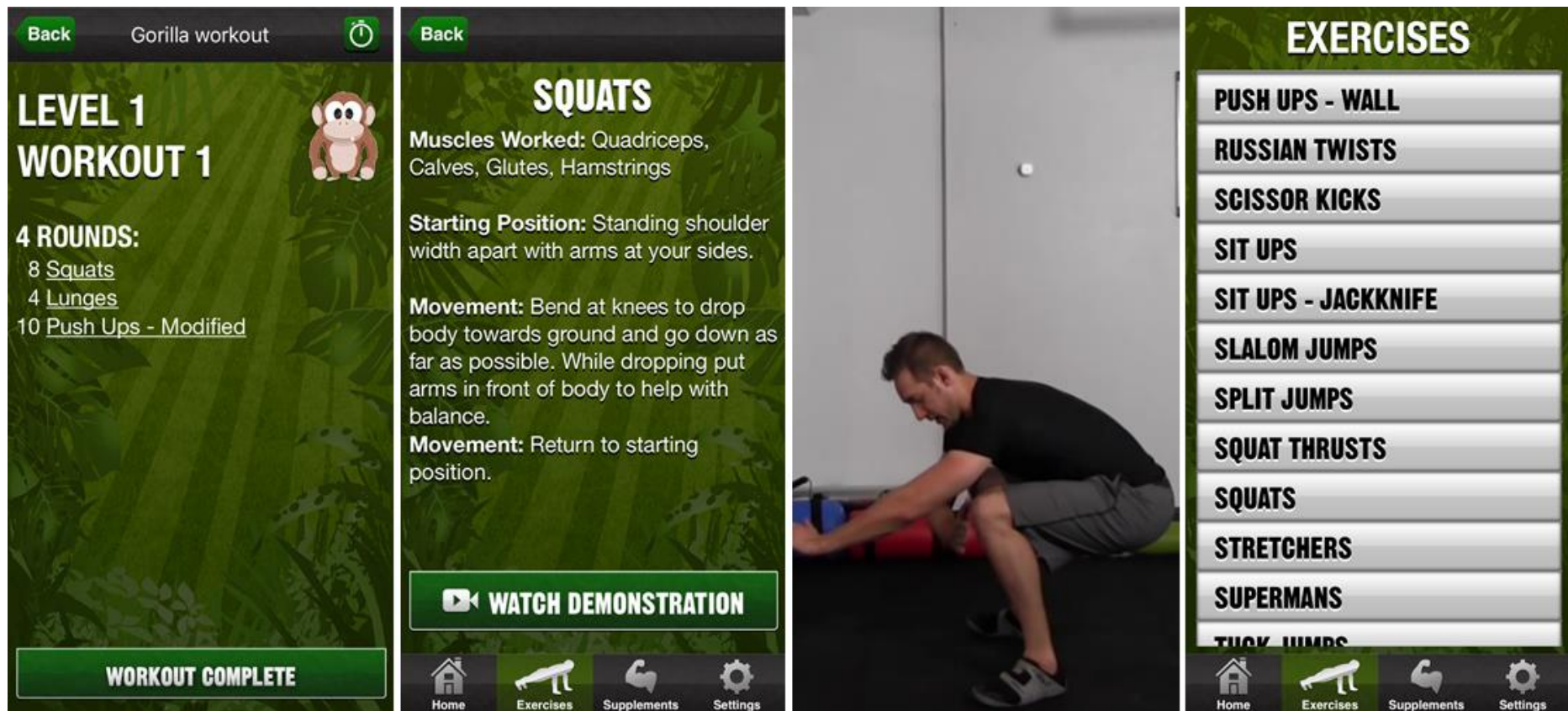


Figure 5.4: Screenshots of 'Gorilla Workout'



5.3.2 Participants

Participants were recruited via advertisements within community-based cancer support groups (either by verbal descriptions from group leaders at meetings or via posters, flyers, email mailing lists), Facebook cancer support groups and charitable organisations (e.g. Macmillan Cancer Support's Cancer Voices, Tackle Prostate Cancer). An initial recruitment target of 32 participants was set to attempt to ensure sufficient representation from participants diagnosed with each of the three cancer types and so that approximately 16 participants would be allocated to use each of the 4 apps throughout the study. If new themes continued to be identified, recruitment would continue until saturation was achieved.

Participants were required to be aged 18 or over, to have been diagnosed with breast, prostate or colorectal cancer, to have finished primary curative treatment (since it is likely that individuals still undergoing primary treatment, or with metastatic disease may require additional support and monitoring to be active), to have no known impairment/comorbidity that meant a clinician had advised them not to exercise, and to own a smartphone. While participants were required to have finished primary curative treatment (surgery, radiotherapy, chemotherapy), participants taking maintenance hormone therapy or under active surveillance were eligible. Participants were offered a £10 voucher as an incentive for completion of this study and reimbursement for the cost incurred if asked to install an app that was not free to download.

5.3.3 Ethical approval

Ethical approval for this study was granted by the UCL Research Ethics Committee (reference: 7663/001; Appendix P). Participants were informed of the study purpose and of their rights via a written information sheet (Appendix Q), and returned a signed consent form (Appendix R) to take part in the study.

5.3.4 Procedure

Participants took part in an initial, brief semi-structured telephone questionnaire that confirmed their eligibility and requested details of their sociodemographic information (age, gender, and ethnicity), cancer diagnosis, and experience of using digital technologies to support physical activity. Participants were asked to describe their perceptions of their current participation in physical activity (e.g. what types of physical activity and how frequently). This was asked as an introductory question to build rapport with the participants at the beginning of the study and to

provide context. An online random number generator⁵ was used to allocate two apps to each participant to allow comparison of app features and content, but to minimise participant burden. Guidance in downloading and installing each app was provided, if required. Participants were asked to spend approximately 2 consecutive weeks using the apps (approximately 1 week using each) and were able to choose the order in which they used the apps. Participants were asked to try to use each app at least 3-4 times throughout the trial week and record any comments or opinions in log-sheets provided. After 2-3 weeks, each participant completed a semi-structured telephone interview, using the interview schedule (Table 5.2) as a guide. Interviews were audio-recorded and transcribed verbatim by an external professional transcription service.

Table 5.2: Semi-structured interview guide

Discussion point	Details
Recap	Confirm which apps participant was asked to download and try.
Download/Install 1 st app:	Ask about the participant's ability to find, download and install each app. Ask participant to: <ul style="list-style-type: none"> • Start by giving overall opinion of app.
2 nd app:	Depending on amount of detail provided in overview, ask participant to: <ul style="list-style-type: none"> • Expand on any points raised in overview. • Comment on likes/dislikes. • Comment on specific app features/behaviour change techniques (dependent on allocated app).
Appropriateness for cancer	Repeat above for 2 nd app. Discuss how appropriate and relevant each of the apps were for their personal circumstances and as a cancer survivor.
Adapting for cancer survivors	Discuss how (if at all) the apps could be adapted for cancer survivors. If so, what adaptations/functions to tailor the app would they make.
Interest in an app	Discuss participant's interest in a physical activity app tailored specifically for people who have had cancer.
Preferred types of physical activity	Discuss types of physical activity that should be promoted to cancer survivors, including intensity, frequency, type of activity and with relevance to current physical activity guidelines (i.e. 150 minutes moderate-vigorous physical activity and 2 sessions of strength and resistance training exercises per week) and how apps could promote these types of physical activity (if at all).
Recommendations	Discuss any physical activity recommendations that were provided to them following cancer diagnosis/treatment and who were they delivered by or where participant looked for them.
Intervention communication	Discuss who should direct cancer survivors to a cancer-specific physical activity app, including when this should be discussed and promoted to patients.

5.3.5 Analysis

A partly deductive and partly inductive approach to thematic analysis was adopted using the stepped approach described by Braun and Clarke (2006). The deductive approach to thematic analysis involved using the BCT Taxonomy (v1) (Michie et al., 2013) as a framework to code any

⁵ <https://www.randomizer.org/>

interview data where participants spoke about app features used to promote behaviour change. The rest of the data was analysed using an inductive approach by reading and re-reading the interview scripts and by iteratively assigning passages of text to relevant codes. An initial coding framework was developed by creating new codes when existing codes were not deemed appropriate and sub-codes were created to further specify aspects of the data. This coding framework was revised during several rounds of data analysis and was used by a second researcher (Dr Dimitrios Koutoukidis; DK) to code 4 (12.5%) of the interviews. In collaboration with DK, a revised, final coding framework was created, with discrepancies agreed via discussion. No new codes were identified, saturation was reached and recruitment was concluded. The final codes (Appendix S) were then applied and incorporated into appropriate themes/sub-themes during discussion. Data analysis was conducted in NVivo 11.

5.4 Results

5.4.1 Sample characteristics

A total of 40 participants were enrolled in the study, and 32 completed telephone interviews. Of the 8 who dropped out, lack of time (n=2), bereavement (n=2), deciding that they didn't want to take part anymore (n=2) and not wanting to update their smartphone's operating system (n=1) or register credit card details with Google Play (n=1) were the listed reasons. Of the 32 participants who completed the study, the mean age was 60 years (range 37-78; SD=11) and the mean time since diagnosis was 46 months (range 10-132; SD=29). Other sample characteristics are displayed in Table 5.3. The mean interview duration was 31 minutes (range 5-44; SD=9).

Table 5.3: Sample characteristics

	N (%)
Gender	
Female	10 (31.3)
Male	22 (68.8)
Ethnicity	
White British	28 (87.5)
White - Other	1 (3.1)
Asian/Asian British	2 (6.3)
Mixed	1 (3.1)
Cancer type	
Breast	8 (25.0)
Prostate	16 (50.0)
Colorectal	8 (25.0)
Experience of using digital technology to support physical activity	
Never used	10 (31.3)
Smartphone installed physical activity app (e.g. Apple Health, SHealth)	5 (15.6)
Currently using a physical activity tracker (e.g. pedometer, Fitbit, Garmen, Strava)	9 (28.1)
Have used a physical activity tracker before but not currently using	5 (15.6)
Using combination of technologies (e.g. smartphone installed physical activity app + physical activity tracker)	3 (9.4)

5.4.2 Thematic analyses

Broadly, three core themes emerged, demonstrating that (1) multiple factors affected engagement with physical activity apps and these factors were often specific to the individual, (2) apps promoting walking were most appealing for cancer survivors and (3) physical activity apps should be integrated into cancer care.

5.4.2.1 Multiple factors affected engagement with physical activity apps and were often specific to the individual

Key determinants of engagement appeared to be the users' perceptions of i) the advantages and disadvantages of using apps to support physical activity, ii) the relevance of the app, iii) the quality of the app, and iv) the BCTs used to promote physical activity.

5.4.2.1.1 Perceived advantages and disadvantages of using apps to support physical activity

The participants identified a number of advantages of physical activity apps, which facilitated engagement. These included the convenience that an app offers in terms of minimal equipment required, low cost and not being required to attend a specific exercise facility:

"Especially if you can, y'know, the workouts, like the Gorilla workouts that I've looked at so far, they're all just using your own body, where you don't need any special equipment, and all the rest of it...and you don't need to spend £30 a month to join a gym to do it"

(68 year old, male, colorectal cancer)

"You can just choose when you decide to do it – so you can think, 'right, I'm gonna do a little workout now', so y'know, pick your moment, put your phone on and just pick whichever one you want"

(52 year old, female, breast cancer)

They also commented that apps could be useful in building confidence/self-efficacy for physical activity and how this can be important in relation to side effects:

"I was left with a lot of tummy problems after my treatment. So in a way you would think that doing a workout at home might suit a lot of people because if their confidence is low, either how they feel about their fitness or that they need to be near the loo or whatever, then being at home should be reassuring, shouldn't it?"

(47 year old, female, breast cancer)

It was also acknowledged that an app-based physical activity programme could be more effective than printed materials due to the ubiquity of smartphones and the more engaging nature of interacting with the programme in real-time:

"Where apps, of course, have a huge advantage, the days of paper things...exercise sheets, and things which end up in the bottom drawer or in the dustbin, err, apps are better than that, because they're on your phone, and they can be updated, as well...you've always got your phone with you. You haven't always got the list with you"

(69 year old, male, prostate cancer)

"it's a bit more interactive and it's there and you can just...I'm gonna press on...whatever this...what's a box jump? For example, and you can press on that and see...see what it is, so it's very, very useful"

(69 year old, male, prostate cancer)

One participant mentioned the possible benefit of apps in terms of the low level of literacy required to interact with the programme:

"Y'know...it's a nice, simple app. You don't need to be that literate"

(60 year old, male, prostate cancer)

However, a number of disadvantages of app-based physical activity interventions were also raised. These included the possible safety implications of unsupervised physical activity:

"if somebody isn't getting advice from a professional first and they're just picking up an app and...wanted to get a bit more active and doing it at home, I think that something like this could be actually be quite risky"

(43 year old, female, breast cancer)

"I think you'd have to be careful that people did it properly and that they did it at the right time and didn't...you know, didn't overdo it...some people think, 'ooh, well I'm doing exercise, it must be doing me good,' but it might not be...cause they're doing it too early, or they're doing it wrong...Because there's no supervision, there's no guarantee, is there?...That would be more for strength-based things, really [compared to walking]"

(59 year old, female, breast cancer)

Participants also experienced a number of technical issues (such as impact on the battery life of the smartphone, mobile data usage and smartphone memory):

"[Human] does drain your battery quite quickly because you have to use, erm, location services all the time...if it was gonna be a regular thing I wouldn't use it every day then just because the fact that it does drain your battery"
(37 year old, female, colorectal cancer)

There were also concerns around data security and access to/usage of personal data:

"of course, with the freebies, as we know, what you're doing is you're signing up to allow them to track your location, other things you might be doing...nothing's really free"
(69 year old, male, prostate cancer)

5.4.2.1.2 Perceived relevance of the app

Participants described a number of factors that influenced their opinions of the perceived relevance of the apps. There was greater reported engagement with apps that were perceived as most relevant to the user. Participants acknowledged that cancer survivors are a heterogeneous group who differ in terms of their physical activity ability and that a successful app must be able to be tailored for this diversity:

"Everybody who's had cancer will have a different level of fitness anyway even after cancer, and they'll have a different level of motivation and a different starting point so that's why that 7 minute app is good...you can choose...depending on where your starting point is."
(52 year old, female, breast cancer)

Participants also highlighted that each individual's experience of cancer, treatment and side effects differs so a physical activity app must somehow acknowledge this diversity:

"depending on what treatment you've had, in terms of, umm, certainly operations, and scars and whether you've got adhesions or...weakened muscles in various places...it's all going to vary, from one cancer to another...there's a lot of variation and, err, that needs to be covered."
(68 year old, male, colorectal cancer)

"[Gorilla Workout] came up with something like....I can't remember what it said, but something like, 'Don't be a slacker, get... you know, get working,' or something, and I was like, 'Err...hang on a minute.' Like, if I'm feeling crap and I'm feeling fatigued, that is not what I want to see."
(38 year old, female, breast cancer)

Furthermore, the participants also described that the types of physical activity that might feel appropriate or relevant to a cancer survivor could vary depending on where the patient is in their cancer trajectory (e.g. diagnosis, treatment, recovery and survivorship):

"I had prostate cancer, and I had an operation. And, if you're looking at an app to try and get patients who've had cancer, y'know, back and fit again, I'm not sure that these exercises [on J&J and Gorilla Workout] were the right ones. I personally felt, that if I were being... had this been about six years ago [around time of treatment], they were too physical. I needed gentler exercises."
(70 year old, male, prostate cancer)

However, there were also several non-cancer specific factors that influenced the perceived relevance of the app to the participants. These factors included the extent to which the app(s) aligned with the participants' physical activity goals:

"I suppose it depends what you're trying to get out of it and, for me, it's looking at trying to regain a level of fitness, because I've probably lost it over the last four months or so. And I see the Seven Minute Workout as the one that will specifically do that whereas, [Human] is just monitoring what I will tend to do anyway."

(65 year old, male, prostate cancer)

The extent to which the difficulty level of the app was suitable for the user also affected perceived relevance. This was particularly apparent for the strength and resistance training apps:

"[Human] was, as I say, very easy. It doesn't cause you any difficulties or problems. So I think anybody can use it. You know, it doesn't really matter how fit you are or how unfit you are, it's not going to be a problem...[with Gorilla Workout] I found, even on the easy level, that some of the exercises were impossible...Level 1 is you can perform 0-10 push-ups, but they still kind of think you're gonna be able to do some. It's, like, I can't do any. And I don't think I'm ever gonna be."

(43 year old, female, breast cancer)

"Um, and then [J&J] had things like press-ups and the plank. I mean, I just thought it was a joke, to be honest...I had a go on a couple of different days. Um, but it was, it was just much too difficult...I felt quite demoralised when they were so difficult. But yeah, something that's, um, you know, much more gentle to build up from, um, I think is quite a nice idea."

(47 year old, female, breast cancer)

The participants also described that the way they interact with their smartphone affects the perceived relevance of certain types of physical activity apps, namely activity trackers that require you to carry the smartphone in order to measure physical activity behaviour:

"[Human] assumes your phone is always on you...mine never is, unless I go out. So, it stays on the hall table...So of course, if it's left on the hall table, you're not moving around at all. So it'll say, 'You're pretty inactive', y'know, 'How about a walk around the block?' and you think, err, I've been doing the housework all morning. I'm exhausted."

(65 year old, male, prostate cancer)

And finally, the participants' self-identity and their perception of whether the app fits with this identity affected their opinion of its perceived relevance:

"And it is a man, isn't it, doing the exercises?...[J&J] was quite masculine, I think...I know it's a silly thing but even if it, if there was a choice of having a woman or a man to watch, you know."

(47 year old, female, breast cancer)

"And of course, umm, on both of them [J&J and Gorilla Workout]...the videos, err, show the sort of slim, fit young, ultra-fit, young men doing it. You think, 'Gosh, I...I haven't looked like that for about 40 years.'"

(69 year old, male, prostate cancer)

5.4.2.1.3 Perceived quality of the app

The participants described several factors that affected their perceived quality of the apps to promote physical activity. The participants expressed greater engagement with the apps that were

perceived to be higher quality, although they did not necessarily agree which those apps were.

The factors affecting perceived quality differed between users.

Primarily, the users described the importance of ensuring that an app is easy to use and intuitive to foster engagement from the first usage:

“the bottom line is that...[The Walk’s] not intuitive...Perhaps I should have looked for a help area, or something, if I wanted to make full use of it, but then I also think, if an app is gonna be good, then it, it needs to lend itself to the user...with Human, again, I didn’t look out for any help areas. It’s just, you start using it, it tells you what, what’s going on, what you’ve done, and you can interpret it quite easily.”

(51 year old, male, prostate cancer)

The participants described the importance of ensuring that an app that tracks physical activity behaviour does so accurately:

“the main issue I had was that [Human] would record activity, but it would get it wrong. So when I was out on a bike ride, umm, it had me doing a mixture of walking, cycling, umm or running...so I just felt that it didn’t really work that well for me”

(68 year old, male, colorectal cancer)

Furthermore, the participants’ description of how well-produced the app was affected their perceived quality of the apps:

“I kept getting a bit confused with the voices. They weren’t different enough in the story. Mainly, as I say, because, um, it was a bit frenetic and people were noisy and speaking quickly and it was a bit jumpy...and just the production of [The Walk], you know...it was a bit jumbled and thrown together almost.”

(65 year old, female, breast cancer)

The J&J app provided an explanation of the scientific evidence-base behind the recommended exercises and workout programme and this was described as increasing the perceived quality and credibility of the app to benefit health:

“I did like the mass of support documentation you could delve down into to find out why the exercises were what they were, and the, umm, sort of, a bit of medical stuff behind it...I felt [J&J] was more medical-oriented...it was looking at your total body, total welfare – and I thought that it felt very professional...I felt the regime was based on good scientific basis.”

(70 year old, male, prostate cancer)

5.4.2.1.4 Opinions of BCTs used to promote physical activity

Opinions of BCTs used to promote physical activity within the apps were sought during the interviews and grouped into the following categories: ‘video demonstrations’, ‘prompts/cues (reminders)’, ‘goal setting, self-monitoring and feedback on behaviour’, ‘incentives, rewards, and gamification’. Participants’ views towards each of these strategies varied considerably and their opinions on these BCTs determined the extent to which the participants engaged with the apps to which they were allocated:

Video demonstrations:

The use of video demonstrations to illustrate how to perform specific exercises correctly was well-received:

“the method of presentation, brilliant. [J&J] was very clear...the bloke was there doing it with you...because you can sort of follow along, without just trying to remember how you should be doing it, and you can look at him to see how he’s got his legs, straight or bent a bit.”

(51 year old, male, colorectal cancer)

Prompts/cues (reminders):

There was mixed feedback on the use of push notifications/reminders to prompt users to engage in physical activity and how effective they were. This depended on the users' opinion of reminders, their tone and how appropriate they were in terms of the time or context in which they were delivered:

“mixed feelings about the sort of constant reminders [Human] gave you...it’s quite good in some respects, because it does make you think, ‘Oh, yeah. Okay. I’ll just go and have a quick walk to the end of the road and back.’ Err...But then when...three or four are coming, you’re thinking, ‘Oh god, would you shut up?’...I didn’t mind ‘Oh, what about a quick walk after lunch?’ that sort of thing...they were quite positive.”

(65 year old female breast cancer)

“there was at least one of those prompts on Human, that actually we followed it. It said something like, ‘Let’s go for a walk,’ and we said, ‘do you know what? Let’s do that’...on other occasions, er, we said, well, actually, it’s dark so we’re not...you tend to start ignoring it ‘cause it might not be appropriate at that time...so it wasn’t a bad thing – but it wasn’t always the right thing at the right time.”

(65 year old, male, prostate cancer)

Goal-setting, self-monitoring and feedback on behaviour:

These BCTs were grouped as they are frequently used alongside each other to promote physical activity and were linked in the app function. For instance, the ‘Human’ app presents the daily 30 minute physical activity goal, facilitates self-monitoring of progress towards the goal by presenting data collected by the smartphone’s activity tracker and then presents feedback on their behaviour to indicate whether that goal was met or not. Therefore, it was difficult to separate out the participants’ opinions of each of these BCTs individually, however the participants generally responded positively to this approach:

“[Human] does show you like summaries and averages. It gives you some interesting information so you can see whether you’re doing better or worse than you were doing yesterday and that kind of thing...it’s nice to have a target and a challenge to work on.”

(43 year old, female, breast cancer)

"I could see that I was actually walking more than I thought. So it all adds up...I think it is interesting to monitor because you can actually see how much you're doing, and...how quickly actually you reach your target. So you could think, like, 'Oh, instead of half hour walking, maybe I could increase it to 45 minutes' or an hour if you want to push yourself. So I think that's definitely a benefit to monitor it...for me, just the data it was interesting and nice to see what I'm actually doing, and be more aware, and in that sense actually that...that already motivated me...to walk a bit extra instead of the bus...so in that sense...I did walk more with the app"
(54 year old, female, breast cancer)

Some participants also discussed their positive experience of these types of BCTs using other digital technologies to support physical activity prior to this study:

"I've just got the [Apple] Health one on my iPhone, which we check the steps every day. So because that's nicely how many steps you've done, how far you've done, and that 10,000 steps...we've both taken that on-board as a very good target...[which is] good because you could have a look and say, 'Oh, crikey. I haven't done enough today' or 'I haven't done enough this week,' or whatever."
(69 year old, male, prostate cancer)

"I find the, you know, the completion of the steps quite satisfying...if I've got to the evening and I'm on, you know, nine thousand and something, I want to make sure I've got that to 10,000 if I walk up and down the stairs a few times, and then actually when you go over, you know, you do feel quite pleased with yourself...[Fitbit] would plot how many days you'd done, how many steps and what your average was for the week and what your average was for the month and that was quite rewarding, because you do feel like you are achieving something"
(47 year old, female, breast cancer)

Incentives/rewards and gamification:

There was mixed feedback on the use of incentives/rewards and gamification to increase engagement with the app and physical activity. This type of BCT was most prevalent in 'The Walk', however participants were generally put off using this app by some of the usability issues mentioned above and the extent to which the app was perceived as relevant to them:

"[The Walk's] trying to show you where, you could possibly take alternate...you could select to do a slightly longer walk, and have the chance of getting more points from other things. Like picking up packages, but I haven't really looked at that."
(60 year old, male, prostate cancer)

Many of the participants said they felt that the gaming aspect to the app was inappropriate for them and they didn't find it interesting:

"I'm not interested in doing that, you know. I mean, even listening to [The Walk], it just got boring...I listened to it as I was walking along and I thought this is not for me really, you know, there was people missing here and people hiding there. I didn't know what it was talking about really. I'm not into that sort of thing."
(71 year old, male, prostate cancer)

5.4.2.2 Apps promoting walking were most appealing for cancer survivors

In acknowledging cancer survivors' varying needs (above), and incorporating their personal experience of cancer with their experience of using the apps in this study, the participants generally agreed that a walking-based app would be most appealing for cancer survivors. Walking was perceived to be safe, accessible, and achievable for the vast majority of people regardless

of their ability, cancer type, treatment type, side effects, or where they are in their cancer journey.

They also said that walking was enjoyable, which increased the likelihood that it would be sustainable and consequently effective:

"First thing to do when you're coming back from the surgery, or any kind of treatment, I think walking is probably the safest way to introduce yourself back into [an] exercise routine."

(51 year old, male, prostate cancer)

"I couldn't use my upper body because of the surgery and then I had the chemo and I just couldn't go to the classes, so...but what I did do was walking, because I thought even if I can't do anything else you can always walk...if you really talk about something people can do right after or maybe even during treatment, I think walking is the easiest, the safest and the best way to start."

(54 year old, female, breast cancer)

However, they did acknowledge the need to ensure that participants are engaging in physical activity that is of high enough intensity to meet the physical activity recommendations:

"People might be having a 10 minute dawdle round the garden centre and think that they've done their exercise...I can see the sort of, the, the challenge with getting the balance, um, between the...it being achievable but also being effective isn't it?"

(47 year old, female, breast cancer)

Some participants recognised the importance of resistance training:

"I think walking is very good, but equally I think it's overall, y'know, a balanced body strength and, and flexibility's important. So, I think it's worth persevering with that approach as well"

(68 year old, male, colorectal)

However, others reported that they did not enjoy or want to do these types of exercises:

"I like the walking better than the exercises...the workouts and that sort of thing...I would hate to get...right into the heavy stuff, er, and tiring myself out, you know, cause we are getting older"

(70 year old, male, prostate cancer)

"I don't like doing exercise, and yet, as I mean in doing strengthening exercise and that sort of thing to build my muscle up, but I don't mind walking"

(70 year old, male, colorectal cancer)

5.4.2.3 Physical activity apps should be integrated into cancer care

The participants agreed that routinely discussing physical activity and being directed towards onward support (including apps) within the cancer care pathway would ensure everyone diagnosed with cancer received support. The participants discussed who would be best placed to direct them towards a physical activity app, and when and how this should be introduced:

5.4.2.3.1 Patients should be directed to physical activity apps

Participants said that discussions around physical activity, including being directed towards resources to support behaviour change (apps or otherwise) should be discussed with patients as a routine part of cancer care:

"I think...there being some sort of formal introduction to the possibility of doing this, then rather it being sort of left for you to find it by yourself... that's what your expert's for."

(69 year old, male, prostate cancer)

"I don't think a lot of people would bother to go out and look, to see what apps they can find to do exercise. So, I think, if you're gonna do one, I think you've got to encourage somehow, you've got to encourage people to say, or to go, 'Oh, that looks good. I'll use that one.'"

(70 year old, male, prostate cancer)

5.4.2.3.2 Healthcare professionals' recommendations are valued

There was a general consensus that the medical team, in particular the Clinical Nurse Specialist (CNS), would be best placed to discuss physical activity and possible interventions with patients. Participants reported feeling that they had built a relationship with their nurse/care team over the course of treatment and that they would trust the advice they provided as safe, accurate and beneficial for their recovery:

"The specialist nurses – so you always have a breast care specialist nurse who looks after you and if they started talking about it and telling you it was a good thing to do – I would have, I would have definitely done it...because you develop such a relationship with the specialist nurse who's in charge of your case."

(52 year old, female, breast, cancer)

"The nurses. I was assigned a support nurse...She was very good at giving me advice, and support...If she had said to me, 'Look, there's a jolly good app. You will need some ex...you need to get back into fitness again, you've had a big op...have a look at this one.' I'd have taken that."

(70 year old, male, prostate cancer)

This was also discussed in the context of the fear/uncertainty that is often raised when trying to increase physical activity post-cancer and the potential for inaccurate and potentially unsafe information, but that they would trust the medical team/CNS:

"I didn't go to any of the support groups although I think they're a good idea, because people do get, you know, a lot from them. I do think it's dodgy if you haven't got a professional person there, because, as I found just sitting in...in the waiting room, um, you know, people have misconceptions...they've got their own ideas about their own treatment and their own health, and um, they start feeding people with, as I say, wrong information and wrong facts...so I was sort of aware that I'd just listen to what [the nurses] told me."

(65 year old, female, breast cancer)

Some participants discussed the impact that receiving physical activity recommendations and feedback from trusted health professionals had on their subsequent participation in physical activity:

"I had one of my check-ups with my consultant, and she said it might be a good time to introduce a tiny little bit of gentle exercise...and so from that point I then got a Fitbit and starting doing 10,000 steps a day, and by the next time I saw her I'd lost a stone and, um, she was very pleased really."

(47 year old, female, breast cancer)

Other participants acknowledged that people seek information from different sources and in different ways so having the information and direction towards an app available via a range of channels may be beneficial:

"I think if you want to promote an app like this, it's, er, it's a good idea maybe to go, er, yeah, do it via various channels, so both a Clinical Nurse Specialist, er, the oncology physios, or charities, like, er, like Prostate Cancer UK or Breast Cancer Care."

(54 year old, female, breast cancer)

5.4.2.3.3 Physical activity should be recommended before and after treatment

Participants suggested that physical activity interventions should be discussed at diagnosis/before treatment as a way to help manage or reduce side effects during and after treatment to promote recovery and self-management:

"I think if it...if it came as part of the pre-treatment package then I think that would be fantastic, 'cause you're already kind of...yes, you're in a state of shock, but if you're being given stuff to help and start playing with it before you actually start your treatment...because once you're in it, it's quite hard...and then another option, definitely after you finish treatment. Like, if you're feeling fatigued around radiotherapy time or after, definitely then."

(38 year old, female, breast cancer)

"What I've been trialling out [Human] that should be in your initial pack. So you...once you're diagnosed with the cancer, then you're given the pack and everything else, what to expect and go through, and I think it should be at that stage, as early as possible...that's the time you need that information."

(54 year old, male, colorectal cancer)

5.5 Discussion

The sample of breast, prostate and colorectal cancer survivors interviewed in this qualitative study were receptive to the idea of apps to increase physical activity, but highlighted that it is important to acknowledge the varying needs and preferences of this heterogeneous group. Participants recognised that the impact of cancer on each individual in terms of cancer type, treatment, prognosis, and experience of side effects can be very different and successful app-based physical activity interventions must account for that diversity, either via appropriate tailoring or several different apps. The results demonstrate the subjective and dynamic nature of engagement with digital interventions and revealed factors that affected engagement for each individual (e.g. their perceptions of the advantages and disadvantages of using apps to promote physical activity, relevance of the app, the quality of the app and of the BCTs used to promote physical activity).

Participants recommended that walking would be the most appealing form of physical activity to recommend using an app and could be recommended at any stage across the cancer trajectory. This was because it was described as feeling safe, achievable, accessible, and enjoyable,

regardless of cancer type, treatments received, or ability, and could be used to increase confidence and fitness before incorporating strength and resistance training as recovery progresses. In terms of the strength and resistance training apps in this study (J&J and Gorilla Workout), there was a perception among participants that even the beginner levels of these apps were too difficult and potentially unsafe, given the age and fitness level of many of the participants, in addition to their experience of side effects and recovery from cancer treatment. However, the participants were receptive to the use of video demonstrations explaining and showing how to perform each exercise. The participants said that they felt that walking-based/activity tracking apps did not need to be specifically tailored towards people who have had cancer as the safety of walking after cancer was not a concern. While most participants recognised the benefit of strength and resistance training, there was a consensus that apps that promote this type of physical activity would need to be tailored more specifically towards specific cancer types (e.g. with regards to location of surgery) and for people with a lower starting level of ability, confidence and familiarity with these types of exercises. Some participants also described strength and resistance training as unenjoyable and that they would be unlikely to adhere to these types of regimes. This illustrates the need to increase awareness about other ways of incorporating the strength and resistance training element of the physical activity recommendations in a way that is more enjoyable or feasible, and that might be more appealing to this group (e.g. yoga, carrying shopping bags) compared to specific workout routines.

The participants suggested that in order to effectively direct cancer survivors towards an app-based physical activity intervention, this should be integrated within the existing cancer care pathway and recommended by their healthcare professionals, particularly CNSs. They described being directed towards an app within the medical setting as providing an opportunity to increase awareness about the cancer-specific benefits of physical activity and appropriate ways to increase activity from a trusted source. The participants recommended that discussing physical activity/directing to ongoing support would be most beneficial before or after treatment, and particularly if it was highlighted as a way to alleviate side effects and promote recovery. They also felt that recommending walking specifically would be appropriate at any point after diagnosis for the majority of cancer survivors. The participants in this study described the value that patients place on the recommendations provided by their clinical team, particularly the CNS and consultants, a finding which is frequently reported elsewhere (Bourke et al., 2018; Hardcastle,

Glasse, et al., 2017; Koutoukidis, Beeken, Lopes, Knobf, & Lanceley, 2016). Furthermore, a recent survey of cancer survivors diagnosed with haematological cancers reported that 82% would use a health app if it was recommended to them by a healthcare professional (Collado-Borrell et al., 2018). Despite this, few cancer survivors receive physical activity recommendations or referrals to exercise programs within routine care (Bourke et al., 2018; Fisher, Williams, Beeken, & Wardle, 2015) and health professionals report little discussion about physical activity with their patients and low awareness of physical activity recommendations for cancer survivors (Daley, Bowden, Rea, Billingham, & Carmicheal, 2008; Koutoukidis et al., 2016; Nadler et al., 2017; Williams, Beeken, Fisher, & Wardle, 2015). Therefore, it is crucial that staff working in cancer care are supported to have discussions about physical activity with patients, direct them towards behavioural support to increase physical activity and refer to specialist programmes, where available. The implementation of recommendations to appropriate physical activity apps in cancer care requires greater exploration.

Most research in physical activity and cancer has been over-represented by female cancer survivors and primarily by women who have had breast cancer. For instance, in a meta-analysis exploring the effects of physical activity after cancer, 25 of the 39 included studies were conducted exclusively in breast cancer patients (Fong et al., 2012). While only 6 of the 15 studies included in the systematic review and meta-analysis described in Study 1 (Chapter 3) were conducted exclusively with breast/endometrial cancer survivors, the other 9 studies were all over-represented by female participants. However, in the current study, 69% (n=22) of the sample were male, driven by the 50% of participants with prostate cancer. During recruitment it became clear that prostate cancer survivors were being recruited much more quickly than breast/colorectal cancer survivors. The decision was taken to stop recruitment for prostate cancer survivors after 16 men diagnosed with prostate cancer had completed their telephone interviews, as this would mean that at least half of the target sample had been diagnosed with prostate cancer and it was important to ensure that both breast and colorectal cancer survivors were also represented in this study. However, a further 15 men with prostate cancer indicated their interest in participating in the study after this point and these men were keen to participate in future studies or remain involved in the project in the future (e.g. through patient & public involvement activities). Interesting differences between the cancer types/genders were observed during the interviews. The prostate cancer survivors in this study seemed less likely to want to engage with face-to-face

services, appeared to be particularly keen on self-monitoring and tracking their physical activity and in comparison to the breast cancer survivors, seemed more willing to attempt some of the muscle strengthening exercises despite being unfamiliar with them, whereas the women tended to be concerned about the lack of supervision or potential risk of harm of engaging in physical activity after cancer treatment. Furthermore, cancer treatment can affect gender identities/body image (e.g. weight gain, loss of muscle tone, sexual dysfunction, incontinence, mastectomy, hair loss). It is possible that the association between masculinity and exercise, physical fitness and strength may be stronger for male, prostate cancer survivors (Hamilton, Chambers, Legg, Oliffe, & Cormie, 2015) than the association between femininity and exercise, fitness and strength in female breast cancer survivors. It is interesting that the results of Study 2 (Chapter 4) suggested that male cancer survivors may show higher levels of interest in digital interventions compared to women, after adjusting for other sociodemographic and patient factors, and the findings from this study may help to explain these results.

This approach, enabling participants to experience searching for, downloading and using selected apps “in the wild” for a period of time, proved to be a time- and resource-efficient method, allowing us to understand how cancer survivors actually experience different types of apps and BCTs. This provides greater ecological validity than previous studies in the area that have, for instance, sought feedback of hypothetical app features and example text-messages from slideshows shown to focus groups of cancer survivors (Robertson et al., 2017). Digital health research has come to appreciate the importance of usability, design and tailoring for engagement (Bradbury et al., 2014; Garnett et al., 2015), however recent reviews have conceptualised engagement with digital health interventions more broadly (O'Connor et al., 2016; Perski, Blandford, West, et al., 2017). O'Connor and colleagues identified factors such as personal agency and motivation, personal life and values, the engagement and recruitment approach, and the quality of the digital health intervention as important for engagement (O'Connor et al., 2016). Perski and colleagues highlighted the delivery method (e.g. aesthetics/design, ease of use, personalisation, message tone), content (e.g. BCTs such as feedback, reminders), the population (e.g. demographic characteristics, personal relevance, self-efficacy) and both the social (e.g. norms, social cues) and physical (e.g. healthcare system, location, time) settings as being important for engagement (Perski, Blandford, West, et al., 2017). A user's perceived relevance of an app was also identified as an important factor for anticipated engagement with apps designed to help users quit or reduce

smoking behaviour or alcohol consumption among smokers and drinkers (Perski, Blandford, Ubhi, West, & Michie, 2017). Together, with the results of this study, ensuring that an app feels relevant to a user appears to be a key factor in ensuring that they engage with it. However, this is particularly challenging, given that an app's perceived relevance will differ between individuals.

The results of this study support findings of a review that synthesised both quantitative and qualitative evidence of engagement with web-based interventions designed to improve quality of life in cancer survivors, which found that interventions that offer content that is specific to their changing needs and that are delivered at an appropriate stage of the cancer trajectory are valued (Corbett et al., 2018). How best to respond to the demand from participants for highly tailored interventions that feel relevant to each individual user is a difficult challenge that is faced across digital health research. It may be more appropriate to identify/develop a number of physical activity apps that are suitable for different groups of cancer survivors and from which individual users could choose an app they think is most suited to them, rather than attempting to develop one app that is flexible enough to meet all needs and preferences of a heterogeneous group of individuals. In light of this challenge, Short and colleagues have developed a physical activity app referral scheme to select the most appropriate publicly available, non-cancer-specific physical activity app for a cancer survivor based on a referral matrix, taking into account the participants' fitness level, physical activity interests, app preferences, and personality characteristics (Short et al., 2018). This novel approach to evaluation of multiple physical activity apps within a referral scheme takes advantage of the large number of appropriate and relevant publicly available physical activity interventions, while offering flexibility, choice, and tailoring to the users' needs and preferences.

This study should be viewed in light of a number of limitations. The sample were self-selecting. This led to a high proportion of participants who were already physically active, and who were interested in technology, and their health and recovery. We did not quantify the participants' current level of physical activity, however none of the participants reported being completely inactive. While this study intended to explore initial opinions of the use of physical activity apps among cancer survivors, we need to understand the views of those who are inactive/engaging in very little physical activity, who may feel less confident in engaging in physical activity or using apps, and who may be unaware of the benefits of physical activity post-cancer diagnosis. The

approach to recruitment means it is not possible to estimate the number of eligible people who saw the adverts versus those who responded. While the participants in this study were able to use the selected apps for between 2-3 weeks, a more realistic experience than discussing hypothetical app features in a single session, this does not completely reflect 'real-life' app usage or engagement. Participants did not choose the apps, and longer term experiences with the apps were not assessed. This may be amplified by the fact the participants knew they were taking part in a research study and so may have been more inclined to persevere with some of the apps they disliked and may have discontinued using otherwise.

5.5.1 Conclusion

In conclusion, this sample of breast, prostate and colorectal cancer survivors were receptive to the use of apps to promote physical activity but felt that in order for apps to be effective among this group, they must feel relevant to the individual. This includes accounting for the needs of those who have been diagnosed with different types of cancer, experienced different types of treatment and side effects, and have different levels of physical activity ability. Walking was highlighted as the most appealing type of physical activity to promote via an app as it is perceived as safe, achievable, accessible, and enjoyable. Walking was also deemed to be the type of physical activity that would be most appropriate regardless of cancer type, treatments or side effects experienced or physical activity ability. We suggest it is useful to also consider the impact of the users' perception of the relevance of an app and how an app relates to their self-identity. This can arise from the app features, but may also be affected by how the app is introduced (e.g. by a trusted health professional). Digital health research has also come to appreciate the importance of usability and its impact on engagement. This methodology has been able to demonstrate the broader and more dynamic influences on engagement with apps and could therefore generalise to evaluations of mHealth products for other health conditions and other health behaviours.

Chapter 6 (Study 4): Breast, prostate and colorectal cancer Clinical Nurse Specialists' perspectives on the use of apps to promote physical activity within cancer care

6.1 Background

The study described in Chapter 5 showed that breast, prostate and colorectal cancer survivors felt that recommendations to appropriate physical activity apps should be integrated into routine cancer care, and that their Clinical Nurse Specialist (CNS) would be the most appropriate healthcare professional to do so. This is consistent with other qualitative research that suggests that cancer survivors are keen to receive physical activity and lifestyle advice in the context of cancer from their clinical team, but reported feeling the amount of guidance they received was unsatisfactory (Koutoukidis et al., 2016; Smith et al., 2017). This is supported by quantitative findings which showed that only 31% of 15,254 colorectal cancer survivors recalled having received any physical activity advice as part of their cancer care (Fisher et al., 2015). This study also showed that those participants who recalled receiving physical activity advice were more likely to meet physical activity guidelines, however this was a cross-sectional study and relied on participant recall of receiving physical activity advice and self-reported measures of physical activity behaviour, both of which are prone to bias. Despite these limitations, Fisher et al.'s study supports the findings reported in Chapter 5 (Study 3), demonstrating the value that patients place on recommendations and advice provided by their clinical team, and the impact that a health professional recommendation can have on subsequent health behaviour (Fisher et al., 2015).

A survey of 460 nurses, surgeons, physicians and allied health professionals caring for cancer patients in the UK revealed that 36% were unaware of any lifestyle guidelines and 51% were unaware of physical activity guidelines for cancer patients (Williams et al., 2015). The same study explored barriers to providing lifestyle advice to their patients. Frequently endorsed barriers included the patient being too frail or unwell (70%), perceived lack of patient interest (48%), lack of time (36%), not being the right person to provide advice (25%) and lack of clear guidelines (25%) (Williams et al., 2015). Twenty-one of the participants from this study agreed to take part in a further qualitative study to explore health professionals' perceptions of providing lifestyle advice in greater depth (Koutoukidis et al., 2018). Health professionals were also concerned about

a potential loss of connection with the patient and fear of the patient feeling blamed or guilty as a result of provision of lifestyle advice, particularly for patients who live in areas of high deprivation or who may face other socioeconomic barriers to improving their health behaviours. The health professionals also raised the challenge of not necessarily feeling like the right person to deliver health behaviour advice due to limited knowledge, a lack of time during their consultations and a lack of appropriate resources to provide to their patients to support health behaviour change (Koutoukidis et al., 2018). A small survey of 48 healthcare professionals involved in cancer care in Ireland revealed that 86% acknowledged the value of physical activity among cancer survivors and that 88% agreed that discussing physical activity was part of their role (Cantwell et al., 2018). However, when asked to provide examples of physical activity recommendations provided, 42% did not provide advice that aligned with current physical activity guidelines for cancer survivors and 12% did not provide any physical activity advice.

Both quantitative and qualitative studies with healthcare professionals from a range of disciplines have given insight into the discussions around physical activity and lifestyle across various professions (Koutoukidis et al., 2018; Williams et al., 2015). However, there is value in exploring the perceptions of each healthcare professional group in more depth given the large differences in their education, training, experience and context within which they work in cancer care. Nurses have been identified as a critical healthcare professional for the delivery of nutrition, diet and lifestyle advice among cancer survivors (Murphy & Girot, 2013). There have been several surveys exploring oncology nurses' physical activity promotion in the Netherlands, the USA, Australia and New Zealand. Almost half (46%) of 327 oncology nurses in the study in the Netherlands felt they had insufficient knowledge to provide advice on physical activity (van Veen et al., 2017). A survey of 274 oncology nurses in the USA found that 75% of nurses reported enquiring about physical activity and approximately two-thirds gave physical activity recommendations (Karvinen, McGourty, Parent, & Walker, 2012). A study of 119 oncology nurses in Australia and New Zealand revealed that they perceived themselves to be the major providers of physical activity advice to their patients and promoted physical activity before, during and after treatment (Keogh et al., 2017). The nurses in both Karvinen et al.'s (2012) and Keogh et al.'s (2017) studies reported several perceived benefits of physical activity among their patients including improvements in quality of life, mental health, coping, ability to carry out activities of daily living and attenuating physical declines from treatment. However, barriers to physical activity promotion included lack

of time, lack of adequate support structures, perceived lack of interest from patients, being unsure what to recommend and potential risks to the patients.

There has been less research on oncology nurses' views in the UK. This is particularly important given the large variation in healthcare systems, nursing training and cancer pathways in different countries. As discussed in Section 1.1.4 in the Introduction (Chapter 1), there has been a shift in the approach to survivorship care in the UK in recent years, with an aim to meet the goal set out in the Cancer Taskforce Strategy that '*every person diagnosed with cancer has access to the elements of the Recovery Package by 2020*' (Independent Cancer Taskforce, 2015). The Recovery Package consists of four interventions:

- Holistic Needs Assessment and Care Planning;
- Treatment Summary;
- Cancer Care Review;
- Health and Wellbeing Events.

These four components aim to provide a support and self-management package focused on the promotion of physical activity as part of a healthy lifestyle, more effective management of the consequences of cancer treatment and greater provision of information, financial and work support (Macmillan Cancer Support). With a greater and more specific focus on the promotion of physical activity as part of the Recovery Package, it is possible that the attitudes and perceptions of health professionals with regards to provision of lifestyle advice, and physical activity advice in particular, may have changed during its implementation across the UK. The majority of the coordination and delivery of the elements of the Recovery Package is usually carried out or overseen by the CNS and Study 3 (Chapter 5) demonstrated the value placed on the recommendations provided by the CNS by the participants. Furthermore, a recent survey of 611 haematology cancer patients reported that 82% would use a health app if their healthcare professional recommended it to them (Collado-Borrell et al., 2018). The recruitment approach and physical settings (e.g. the healthcare system) have also been identified as important in engagement with digital interventions more broadly (O'Connor et al., 2016; Perski, Blandford, West, et al., 2017).

The importance of seeking the views and input of those who are involved in the delivery of an intervention, as well as intended users, in the development of an intervention is well-established (Bradbury et al., 2014; Craig et al., 2008). The CNS is therefore a key stakeholder in the development and implementation of an effective physical activity intervention that could be delivered within routine cancer care.

6.2 Aims

This study aimed to understand breast, prostate and colorectal cancer CNSs' perspectives on physical activity promotion and the role of smartphone app-based physical activity interventions in cancer care.

6.3 Methods

6.3.1 Participant recruitment

Breast, prostate and colorectal cancer CNSs, based in the UK, were recruited via study advertisements distributed through professional organisations including the Contact, Help, Advice and Information Network, the UK Oncology Nursing Society, a Macmillan Cancer Support nursing review panel, the National Colorectal Cancer Nurses Network, and via existing contacts within the NHS. An initial total recruitment target of 21 participants was set, with an aim to recruit approximately 7 nurses from each of the 3 cancer types. If new themes continued to be identified after analysis of these 21 interviews, recruitment would continue until saturation was achieved. Participants were offered a £25 gift voucher as a token of appreciation for completing the study.

6.3.2 Ethical approval

Ethical approval for this study was granted by the UCL Research Ethics Committee (reference: 7663/002; Appendix T). Participants were informed of the study purpose and of their rights via a written information sheet (Appendix U) and returned a signed consent form (Appendix V) to take part in the study.

6.3.3 Procedure

Participants took part in a telephone interview between January and October 2018. A semi-structured interview schedule (Table 6.1) was used as a guide. Interviews were audio-recorded and transcribed verbatim.

Table 6.1: Semi-structured interview guide

Discussion point	Details
Introductions	Brief introductions and confirm participant details including gender, cancer specialty and region of the UK in which they are working. Gain verbal consent to audio-record interview, check time available.
Background and current practice	Ask whether participant currently discusses physical activity with patients If yes, ask to describe: <ul style="list-style-type: none"> • when and how discussions occur • how patients respond • what is discussed/recommended • what resources/support are patients directed to If no: <ul style="list-style-type: none"> • Explore reasons why not and barriers
The CNS role in physical activity promotion	Ask about their thoughts on their role to discuss physical activity with their patients. Prompts: <ul style="list-style-type: none"> • Role of other health professional groups in physical activity promotion • Feedback patient preference for CNS signposting and ask to comment
Physical activity apps in cancer care	Ask participant initial thoughts on using apps to promote physical activity apps among their patients. Prompts: <ul style="list-style-type: none"> • Opportunities and challenges faced with digital/app-based physical activity support • Types of physical activity that could be supported via apps • Types of physical activity apps they would recommend to their patients • Pros and cons of cancer-specific vs. generic physical activity apps • Factors that would encourage or discourage recommending a patient to use a physical activity app (e.g. patient sociodemographic or disease characteristics including cancer type, stage, prognosis, treatment) • Do they currently recommend any apps to their patients (physical activity-based or otherwise)?
Implementation	Ask participant to discuss how the implementation/integration of a physical activity app-based intervention within routine cancer care might be most successful in practice. Prompts: <ul style="list-style-type: none"> • What resources, training or healthcare system changes might be required? • How could other CNSs be informed? • How could it be rolled out across a region/the country?

6.3.4 Analysis

Interview transcripts were analysed using Thematic Analysis. Thematic Analysis was chosen as it is independent of a particular theoretical framework and offers flexibility in the way in which it identifies and describes patterns of meaning across the data (Braun & Clarke, 2006). As such, it can be used to provide a rich understanding of people's experiences, views and perceptions. Other qualitative methods were deemed inappropriate as they focus on how a person gives

meaning to a particular phenomenon (Interpretative Phenomenological Analysis), how language is used and constructed (Discourse Analysis), the development of theory (Grounded Theory) or on the wider social and cultural influences on behaviour (Ethnography).

Data was analysed using an inductive, data-driven approach to the six-stage process of Thematic Analysis described by Braun & Clarke (2006). The initial phase of analysis began by reading and re-reading the first 11 interview transcripts in order to familiarise with the data, then by iteratively assigning passages of text to relevant codes. The initial codes were refined and further specified to develop an initial coding framework, which was developed by generating new codes when existing codes were not deemed appropriate. Sub-codes were created to further specify aspects of the data. This coding framework was revised during several rounds of data analysis and was used by a second researcher (Claire Stevens; CS) to code 4 (21%) of the interviews. In collaboration with CS, a revised, final coding framework was created, with minor discrepancies agreed via discussion. No new codes were identified, saturation was reached and recruitment was concluded. The final codes were then applied and incorporated into appropriate themes or sub-themes during discussion. Data analysis was conducted in NVivo 12.

6.4 Results

6.4.1 Sample characteristics

Thirty CNSs expressed interest in the study, 19 returned consent forms and completed the telephone interview. Data saturation was deemed to have been met after analysis of these 19 interviews and recruitment finished. Of these 19 nurses, 18 (95%) were female, 9 (47%) were colorectal cancer CNSs, 6 (32%) were prostate cancer CNSs and 4 (21%) were breast cancer CNSs.

6.4.2 Thematic analyses

The analysis resulted in 6 key themes: i) policy changes in survivorship care have influenced CNSs' promotion of physical activity; ii) CNSs recognise their role in supporting physical activity but sit within a wider system necessary for effective physical activity promotion; iii) CNSs use several techniques to promote physical activity within their consultations; iv) CNSs tailor their approach to physical activity discussions; v) some aspects of physical activity promotion remain challenging; and vi) CNSs were generally positive about the use of apps to complement existing

physical activity promotion within cancer care. Together these themes describe how CNSs perceive their role and experiences in physical activity promotion in cancer care and their opinions on the use of apps to promote physical activity within routine cancer care.

6.4.2.1 Policy changes in cancer survivorship care have influenced CNSs' promotion of physical activity

Many of the CNSs discussed the impact that the shift in focus in survivorship care and the 'Living With and Beyond Cancer Initiative' has had on cancer care and physical activity promotion in their role:

"it's very much about the survivorship package and...trying to engage with, you know, the Department of Health Cancer Strategy...so our cancer lead-matron, with the rest of the team, has engaged with a program of, you know, Living With and Beyond Cancer and survivorship. And physical activity is very much a part of that. And so, over the last few years, you know, um, our offering to patients of support for those types of things has increased"

(prostate cancer CNS)

"ten years ago, [physical activity's] probably something we didn't talk to our men about. There has been quite a shift...things have changed and we're, you know, really encouraging more self-management and getting people moving"

(prostate cancer CNS)

The implementation of the Recovery Package across the UK was described as an important opportunity to facilitate a conversation about physical activity:

"after they've been seen by us, they attend a Health and Wellbeing Event. So this is where, we then try and encourage patients to come to that and the lady that works for the leisure centre, she actually comes to this event as well. So she gets patients up and moving...So everybody that's finishing treatment gets an invitation to our health and wellbeing events; we have three a year"

(colorectal cancer CNS)

"certainly all of our patients will be having Holistic Needs Assessments and diet and exercise and lifestyle in general it comes up on the Holistic Needs Assessment, so it's a good time to just kind of mention it and that's how I've picked up a couple recently through doing holistic needs and you know, looking up information for them and giving them the DVDs and stuff"

(colorectal cancer CNS)

6.4.2.2 CNSs recognise their role in supporting physical activity but sit within a wider system necessary for effective physical activity promotion

The CNSs stated that discussing and supporting physical activity with their patients was an accepted and key part of their role:

“A nurse would not be fulfilling his or her duty if they didn’t talk about physical activity and nutrition, at my level, to patients...I think it’s absolutely essential that we discuss that and, and it’s done day out, day in, day out within our department”

(prostate cancer CNS)

“we’re encouraged to discuss physical exercise probably at every appointment that we see them...I definitely see that within the role of a CNS nurse...I see my role as helping people live well with their cancer...and exercise is a part of actually, erm, feeling well and good about yourself, isn’t it, so I’d always sort of encourage that...I just think it’s part of our job”

(prostate cancer CNS)

CNSs explained that because patients are often under their care throughout the cancer trajectory, they are able to form relationships, develop a holistic understanding of their circumstances and how their diagnosis and treatment has affected them. Therefore, they described feeling that they are in a good position to inform patients about physical activity, signpost and refer to further physical activity support, and continue to promote and support physical activity throughout treatment and follow-up:

“we’re the point of contact, we see the patient literally from before surgery. I think we’re in a good position to then start to get them back into a normal routine. Um, so we’re in quite a privileged position, really, to know what they were before, to know what their lifestyle was, to know how the operation or the chemotherapy has affected them and then to try and encourage them to get back into, like, have more ownership in terms of becoming back to normal”

(colorectal cancer CNS)

“the CNS is the one that you have the relationship with for patients. So, for instance, in my service they often see a different doctor every time. But the CNS is the one constant in their whole cancer pathway and relationships are forged and built very quickly with our patients...for me it has to be the CNS...and actually, to be honest, it’s the CNS that always gets asked by the patient”

(prostate cancer CNS)

Some CNSs discussed the increased pressure faced by the health service and how this is affecting job roles, including the introduction of a relatively new “support worker” role. CNSs explained that support workers are being/have been introduced in many hospitals to support CNSs with tasks that can be carried out by staff without nursing qualifications (e.g. administrative tasks and signposting patients to information and support). CNSs stated that support workers could be involved in some aspects of physical activity promotion and in some cases this was happening already:

“we are getting more and more support workers which is an excellent role and that would be a, you know, one of the domains of their job would be to be promoting physical activity as well...there’s a national shortage of nurses and particularly, erm Clinical Nurse Specialists...there’s going to be a huge shortfall in prostate cancer nurses in the next few years, I think 50% of CNSs are due to retire and when somebody retires or leaves their post in the NHS what tends to happen is their post is downgraded, partly to save money but also partly because there’s no one with the experience to fill it at a Band 7 role”

(prostate cancer CNS)

However, there were potential concerns about whether support workers delivering physical activity support have the same amount of credibility among patients and whether their role in physical activity promotion may be as influential:

“many of our queries are not complex, you know, they’re, ‘When’s my scan?’, ‘When’s my appointment?’ There’s a lot of things that can be done by someone else but...I guess what I worry about is with, erm, sort of Band 4s I suppose is that they don’t have that kind of in-depth knowledge of how things benefit, you know, or just the breadth of experience to, you know, be convincing. Would they just be like ticking boxes – ‘Oh right, I’ve talked about exercise’ and move on to the next subject sort of thing”

(prostate cancer CNS)

While the CNSs were very aware of their role in physical activity promotion, they also discussed the importance of other healthcare professionals in delivering physical activity recommendations, advice and support for more effective physical activity promotion.

“you’ve got to have the whole team on-board...we’re quite a tight unit and we work really closely in the clinic together, um, and we have ward meetings with all the team...we’re all thinking the same thing, you know. The physio, the consultant radiologist who sees them, the consultant surgeon, the nurse and OT [occupational therapist], they’re all closely involved and we just keep repeating the same message”

(colorectal cancer CNS)

“I think it should be any healthcare professional...I think where we’ve gone wrong as a profession, erm, feeling that nurses should have all the answers, and... [CNSs] are like the be all and end all to the patients. We’re not, you know, there’s lots of healthcare professionals that can help people”

(prostate cancer CNS)

“I do think it probably is part of our role to be doing that but I don’t think it’s solely our role. I think, you know, if they’re seeing physio, for example, when they’ve had surgery, then there’s an opportunity there to be talking to them about further exercises...we don’t always get to clinics to see patients for a follow-up, so consultants have to...take some of that responsibility as well...and...it can be an ongoing thing, so therefore GPs [General Practitioners] probably should take some ownership of it”

(colorectal cancer CNS)

Some nurses described the need to involve other healthcare or exercise professionals to provide the specialist knowledge/input that they felt unable to advise on:

“what I would say to them is if they wanted to go to a gym or something...I mean, you know, there’s no reason why they shouldn’t eventually, but, erm, I think I would say to them, you know, talk to your GP or talk to your consultant or talk to somebody in a gym for advice as to what you should and you shouldn’t be doing”

(colorectal cancer CNS)

However, they acknowledged that they can often only refer particularly complex patients to Physiotherapists and/or Occupational Therapists, but the majority of inactive patients may not meet the need for this type of referral. Therefore, the majority of inactive patients may lack specific support to increase physical activity:

“it’s the tricky bit...the ones who need, who do exercise, you, they carry on, lovely, the ones who can’t, you know, there’s not a lot you can do if someone cannot do any exercise, but then it may be obvious – you know, using physio, or OT to encourage what they can do, and then it’s these ones in the middle. So it’s a way of finding out what their, what they would engage in really and I guess that’s the tricky bit”

(prostate cancer CNS)

Nurses spoke about their perception that when physical activity was endorsed by an oncologist or surgeon, there was a positive impact on physical activity promotion among patients:

“our oncologist...was very vocal about actually trying to combat, um, chemotherapy fatigue...and she was very much exercise is really positive, it really helps. She’s done loads of research into it so actually by keeping active, the reoccurrence of cancer can be reduced. So by saying stuff like that, which she was really pro-exercise in our consultations, it did encourage a lot more [patients]”

(colorectal cancer CNS)

However, they also perceived that other healthcare professionals may be less likely to promote physical activity among their patients:

“other clinicians...see it as probably a nursing issue and not a medical...surgeon’s issue...to be fair they probably haven’t had any training on this. They may have read the evidence but it’s how you then communicate that”

(colorectal cancer CNS)

“I don’t think the message is out there yet...with some of...[the] other disciplines... interestingly surgery because you’d think that people in that field would be wanting to make sure the patients they’re operating on have got the best chance of recovering because it looks good for your personal stats...I don’t think people are aware of the...proper evidence behind actually this person’s gonna spend a day and a half less in hospital if they’re in better shape when they come. So it’s not belittled but I don’t think the value of the intervention is fully understood by all of our colleagues”

(colorectal cancer CNS)

"I think probably you're least likely to get that recommendation from one of the registrars because they just, you know, they haven't been exposed to that...they haven't got the knowledge base as such, from working together quite so much, whereas I think the clinician and the consultants and the CNSs because...we end up sort of working a bit together, it kind of rubs off [laughs]"

(prostate cancer CNS)

Community-based exercise referral schemes for cancer survivors were described positively, among nurses who reported having the ability to refer patients to such services:

"it's cofounded by [the] CCG [clinical commissioning group] and Macmillan...they run physical activity classes at our Macmillan centre...but they'll go out and do a physical activity assessment in someone's home, in their local park, in their local gym, they'll write a programme for somebody and then they can carry that on with their local gym provider or joining health walks or whatever suits them...that's why we're really blessed in this area to have a service where we can say, 'Just go and see these experts'"

(colorectal cancer CNS)

6.4.2.3 CNSs use several techniques to promote physical activity within their consultations

CNSs described several ways in which they try to promote physical activity to their patients, including explaining the cancer-specific benefits of physical activity, adapting their use of language to promote physical activity and promoting physical activity as a way to emphasise patient control.

6.4.2.3.1 Explaining the cancer-specific benefits of physical activity

The CNSs described specifically recommending physical activity to patients as an effective way to cope with and recover from treatment, manage side effects, improve wellbeing, reduce future cancer risk and the risk and burden of other comorbid conditions to encourage patients to increase physical activity:

"part of that is a prehabilitation process, so getting people as fit as we can, ready for whatever treatment they will then go on to have, so that's when we start talking about physical activity...it felt to us that was an ideal opportunity to target people with 'we need you to be active and we need you to be active now' because there will be a waiting list before you start your treatment and we need to get you to optimal...if we can improve things now you'll get home quicker"

(colorectal cancer CNS)

"when people are on hormones it's easy to encourage [physical activity]. Because of all the side effects of hormones, exercise is so good to help with, with all of them and I say to everyone, you know, 'You'll feel tired and the best thing to do is go for a walk. Don't lay down, don't feel tempted.'...And especially with all, you know, weight gain and hot flushes and all the side effects really"

(prostate cancer CNS)

"I try and link the two for them, you know? If you talk about, you know, reduction in recurrence and sort of recovering out of treatment, mental health, you know, muscle strength and healthy heart with reducing risk of diabetes, all those things"

(prostate cancer CNS)

"I do talk to them about the benefits of physical activity, um, particularly in reducing the chances of their cancer coming back but also, um, you know, just for their general health and wellbeing. Some people have other comorbidities as well and some of them actually have, um weight issues, so you know, to help them manage...I think the benefits of not just physically but mentally are really good for people that have got cancer"

(colorectal cancer CNS)

Some nurses specifically mentioned that research evidence demonstrating the benefits of physical activity after cancer can reinforce their recommendations and provide credibility to their advice:

"I was just having a conversation with somebody this morning, er, saying, you know, they feel very weak and we said to her, 'Well, how much exercise are you doing?', 'Well, none. Erm going out maybe once every two weeks.' 'Well, actually the evidence suggests that the more exercise you do, the less weak you will be, the less fatigued you will feel. So actually you need to be going out more, regularly. Even if it's just for a little walk for 10, 15 minutes down the road"

(colorectal cancer CNS)

"we do [discuss physical activity] a lot actually...the oncologists are really good at doing it, one of them in particular, you know, quotes a lot of evidence about a big, err, research study that was done for breast cancer and I think prostate and colorectal about, you know, actually risk of recurrence is lower if they increase their activity...so we do discuss that heavily"

(breast cancer CNS)

6.4.2.3.2 Adapting their use of language to promote physical activity

Several nurses described how they had changed their use of language or used a specific style of communication (e.g. motivational interviewing techniques) during discussions about physical activity:

"I think sometimes there's a difference between whether you signpost somebody or whether you make a referral...I used to be very much about signposting but now I'm very much about referring...You know, I'll say...'I'm not prescribing any medications to you, but I'm actually prescribing physical activity.' So I do tailor it, and use language"

(colorectal cancer CNS)

“most of us have been trained now on motivational interviewing and those are techniques that are...it is a different way of talking isn't it? That feeling that we're in partnership together and we've got some ideas about what's going to be beneficial to you, but we also need to understand where you're coming from and what the barriers and difficulties may be in taking that advice and how we can sort of maybe swing that balance by thinking about what it needs to look like, what the message needs to be for you”

(colorectal cancer CNS)

6.4.2.3.3 Promoting physical activity as a way to emphasise patient control

Emphasising that physical activity is a behaviour that the patient can take control of, involve them in their care and empower patients to promote self-management was also discussed as a way to promote involvement in physical activity:

“I say, ‘Look, we have done our bit, now it's your turn to do your bit,’ you know? And so this is my mantra [laughs] you know, just after the cancer treatment and sometimes people laugh at it but...for me it works, for them it works”

(colorectal cancer CNS)

“I'll say to them obviously, you know, ‘We're keeping a good eye on you. There's things that are outwith your control but there are things that are within your control.’ And then that leads onto the conversation about you know, we know that there's evidence that [physical activity] can – doesn't guarantee – but can reduce the risk”

(colorectal cancer CNS)

“because obviously they lose complete control when they get this diagnosis, they have no control whatsoever over their, erm, disease to some extent...all of a sudden they're relying on medical professionals...the one thing that they can actively change is their diet, their activity levels, to give them the best possible chance of, you know, moving forward”

(prostate cancer CNS)

“I think sometimes when you mention, you know, you've been through all this cancer treatment, you know, you want to do the best for yourself but when you mention that, you know, if you are inactive and overweight you are more likely to be prone to sort of diabetes, stroke, other cancers occurring. It's a little bit of a wake up call for them”

(prostate cancer CNS)

6.4.2.4 CNSs tailor their approach to physical activity discussions

CNSs described a process of adapting their conversations about physical activity to each patient, taking into account various characteristics and factors about the patients in order to tailor their conversations, recommendations and advice. This included tailoring the conversation based on the participants' age, baseline physical activity/fitness levels, and comorbidities:

“I think um, you know, people that are maybe not already physically active...‘cause a lot of people I see – the majority I would say don't have a, a baseline physical activity and then some of them are, are very active or previously were very active, so I think it's trying to gauge where people were at before their diagnosis”

(colorectal cancer CNS)

"it's normally the younger [patients] that are more motivated than, you know, say a little 80-year old lady who's had a small breast cancer who, you know, physically can't increase their activity because they're on a frame. But, you know, even if they are older, we sort of say even, you know, having a walk every day or going up the stairs more is beneficial"

(breast cancer CNS)

"it depends on the age of the patient and any comorbidities that they have, obviously, because for some patients, just actually getting off the sofa and going for a ten-minute walk is the most they've ever done for years. Erm, so we kind of have to gauge it individually on each patient...it's down to pre-existing conditions and things like that"

(prostate cancer CNS)

Conversations about physical activity were also tailored based on each patient's experience of cancer, treatment, side effects and disease stage:

"it varies from patient to patient, obviously, depending on sort of what their, erm, disease state is, erm, where they are in their treatment, erm, you know, so if you've got somebody who is newly diagnosed it might not be appropriate or if you've got somebody who's sort of near the end of life, again it might not be appropriate. So it depends. There's no kind of one answer that fits all"

(colorectal cancer CNS)

"there's a good percentage of patients who have bone metastases that comes with breast patients, erm, especially for the oestrogen-receptive positive ladies...but then it does limit what exercises they can do through risk of, erm, so for example, if it's in the spine then sometimes we get collapses or, erm, impingement on the spinal cord...I think some patients can be quite stable, it's when they're first initially diagnosed we don't like them to do too much while the investigations are taking place but once they're established on treatments then we work with them"

(breast cancer CNS)

"so the groups of patients that I wouldn't discuss [physical activity] is, erm, potentially the patients that come in as an emergency, because, erm, about a third of our patients unfortunately do end up as emergency...and most people at that point would be having emergency surgery and then going on for possible chemotherapy, so the, the activity topic would come up later"

(colorectal cancer CNS)

Tailoring was also based on their perception of the patients' openness or willingness to discuss physical activity:

"we try to be patient-focused, so it might be what their agenda is when we meet, so if it's pain or, you know, or other things we might talk about that, but sometimes there will be an approach of, erm, about the healthy lifestyle and this is where we try to mention it, but not all the time, no...we might have had maybe a bit of resistance because they've got enough on their plate, we won't go any further, either from their body language or somewhere"

(breast cancer CNS)

"it partly depends on what they are like. I mean, some patients are really, 'No, I've got this sorted, I've got a plan in my head, erm, what's going to happen,' and they're, erm, you know they don't want our help as such, because we've got a lot of help available here, erm, to, you know, help people back to exercise. Other patients are quite sort of accepting of like, 'Oh yeah, no, that's quite a good idea...I didn't realise help was available. Oh I'd be quite keen on that,' you know, that sort of attitude"
(prostate cancer CNS)

"I will just take a lead from the patient to be honest, so if somebody says they're fine and they're back to normal, you know, I won't necessarily sort of push the exercise agenda, you know, I'll just say, 'Fine, these are the things that you need to keep an eye out for, keep as active as you can, you know.' So we do try, and sort of discuss it with everyone"
(breast cancer CNS)

Related to this, CNSs said that they adapt their conversations and recommendations about physical activity according to the patients' interests or how engaged they are with physical activity:

"I think it's down to the individual to say, you know, what they want to do. I mean, you know, there will be the person who just wants to read the information, to see, well, maybe they want to just move around a little bit more at home. And there are those that will go out and join a walking group...there are those that will engage with the gym. Um, there are those that are going to get on the bike and do some exercise at home. There's such a wide variety"
(prostate cancer CNS)

"different things are good for different people, aren't they? Some people enjoy a group session of exercise, you know, like some of the ladies might enjoy [an] exercise class or whatever, whereas...for prostate, you know, they may not necessarily enjoy the group, or be quite so keen on the group thing...so probing what they enjoy or what they can sort of do more of to constitute exercise really"
(prostate cancer CNS)

One nurse discussed that physical activity promotion could be postponed in order for patients to focus on changing other health behaviours (i.e. smoking) that are of higher priority for improving health:

"he was about to embark on smoking cessation so we talked about how he could manage smoking cessation and physical activity...and it's a lot, you know, to then try and lose weight as well. So we said we'd focus on the smoking cessation...it's three big, sizeable lifestyle changes that you're asking them to do, and I think to do all three at once possibly would have been um, a bit much"
(colorectal cancer CNS)

6.4.2.5 Some aspects of physical activity promotion remain challenging

The CNSs described several aspects of physical activity promotion that remain challenging. This included a lack of accurate knowledge of the physical activity guidelines and how to communicate them effectively with patients; the potential safety implications of the recommendations they

provide; a lack of patient adherence to physical activity advice or uptake of physical activity services; and a lack of nurse time and resources.

6.4.2.5.1 Lack of accurate knowledge of physical activity guidelines and how to communicate them effectively with patients

Among some nurses interviewed, there was a lack of knowledge of the physical activity guidelines for cancer survivors, and of how best to provide advice to patients. In some instances, this led to reports of recommendations provided that were inaccurate, somewhat vague or at odds with current physical activity guidelines for cancer survivors:

"[we recommend] not to exercise up to the lead up to surgery, but after they've had surgery...we don't say don't exercise at all, we say do gentle exercise and increase it slowly over time...if they go to the gym regularly and work out, then we would say then don't do that type of thing"

(colorectal cancer CNS)

"I probably should know [the guidelines] but I don't...it's just common sense, I think, because we've been doing this for so long, erm, it's sort of second nature...We talk about, you know, doing their, the ten-minute walk a day, you know, simple guidelines from the government...we probably cover it not realising we're covering the guidelines"

(breast cancer CNS)

There was also difficulty with understanding of the guidelines with regards to strength and resistance-training and how to communicate that with patients:

"I think people don't know what to do for [strength and resistance-based training]...we know with hormonal therapy, people lose their muscle tone and some of the men are quite distressed by that, but it's a bit difficult...I think it's very difficult to find, erm, clear guidelines on what that actually means and how they can do it without incurring too much expense...we tend not to say anything because we don't know what we're meant to be recommending"

(prostate cancer CNS)

6.4.2.5.2 Safety implications of the recommendations they provide

CNSs also reported particular concerns about the potential safety of the recommendations they provide and therefore reported feeling that the advice they provide may be overly cautious:

"it's difficult with...because they're so individual...and it's hard for like being a professional...they lean on us and say, 'What can we do?' and it is, it's a bit like the blind leading the blind a bit sometimes because they come to us and ask us can they do specific things but everyone always errs on the side of caution because we don't want to cause more harm than good but then at the back of your mind you're thinking, you know, it's what they're used to, it's what they want to do and it's, you know, psychologically, it's going to be beneficial for them"

(breast cancer CNS)

"obviously strength and resistance-based is good as well and I think maybe sometimes, I don't know if as health professionals we're over cautious about what to suggest to people"

(colorectal cancer CNS)

6.4.2.5.3 Lack of patient adherence to physical activity advice or uptake to physical activity services

Other challenges described include the fact that, despite conversations about physical activity, advice and signposting, the nurses suspect that patients may not adhere to their advice:

"they basically like say, 'Yes, OK' [laughing] but I don't think they actually do it, a lot of them"

(colorectal cancer CNS)

"there's always gonna be the minority of patients, no matter what you tell them, they're not gonna listen and they're gonna carry on drinking their 40 pints a week, or, you know, they're gonna sit on their sofa 24/7. No matter how much you try and guide them in the right direction, it's that thing, isn't it, you can lead a horse to water but you can't make it drink"

(prostate cancer CNS)

Furthermore, the nurses reported that despite the availability of appropriate, local physical activity services, patient barriers to attending these services may result in low uptake:

"we're very fortunate in this area that we have access to free, erm, sessions for men run by the local college and there's like exercises groups for four men at a time and they can do like a four to six-week programme...so the access is there and we do talk to people about it, erm, whether or not they take it up or not is another challenge to get over"

(prostate cancer CNS)

"it's alright bringing up this about exercising, but how they're going to get there, what's the cost of it, err, I live on my own, you know, all these sorts of barriers that are put up. We're sort of raising it and then at the end of the consultation we're saying, 'Well that, in an ideal world, that's what we want you to do'...you've raised their expectation this would be good for them but we can't steer them anywhere, that's a bit disappointing"

(breast cancer CNS)

6.4.2.5.4 Lack of nurse time and resources

Nurse time and resources were also described as other challenges in effective physical activity promotion in cancer care:

"for me, it's probably more of a time issue. I don't have, you know, I'm here on my own so I don't really have enough time to spend with them, to sit down and have those full conversations"

(colorectal cancer CNS)

“it is in terms of resources. We’re already down a breast care nurse and...we’re coming to that age group where a lot of nurse specialists are hitting into their 50s and so quite a lot are taking retirement around 55. So we’ve got two semi-retirements within our service here and they’re not replacing at the minute”

(breast cancer CNS)

6.4.2.6 CNSs were generally positive about the use of apps to complement existing physical activity promotion within cancer care

The nurses considered some of the potential opportunities provided and challenges faced as a result of using apps to promote physical activity within cancer care. The nurses identified that one of the main advantages of app-based physical activity support is that apps can increase accessibility to a physical activity intervention. However, this was also discussed with the caveat that not all of their patients used smartphones or had the digital skills/confidence to engage with an app-based intervention:

“I think it’s a great idea...I think a lot of people look for an app if you were looking to, you know, count your steps or whatever you were doing. So I think it’s a good way to go, but I’m not sure it would be okay for everybody – if you’ve got more perhaps elderly or technophobic people then that might not be appropriate for them. But I think probably for the majority of people you would capture them, yeah”

(colorectal cancer CNS)

“I think that’s a really good idea. I don’t know what percentage of the people have a smartphone but I’d imagine quite a majority probably have a phone where they could use that sort of format...I don’t think there are any age barriers at all to this...but have they got a phone where they can download them and have they got the IT [information technology] skills and wherewithal to navigate apps? So, um, I’m thinking there will be a section in the population who just won’t be able to access them”

(colorectal cancer CNS)

Other advantages offered by apps include the increased convenience and potential to alleviate barriers that may be faced by attending face-to-face services or interventions:

“I think quite a lot of people’s initial impressions of leisure centres are that people go there and they’re really fit and actually, if you’ve been poorly and you’ve got a stoma, you’ve got massive body image [issues] or you’ve lost your hair through chemotherapy and stuff like that. I think actually for those patients, being able to access something in your own home to build your own confidence up gradually, is much better”

(colorectal cancer CNS)

“Well they can access it when, how and when they like, can’t they? I think that would be a bonus. Erm, they’re not tied to gym times or a class time or anything, it’s something they could access 24 hours really. You know, they’d be in control of that, wouldn’t they?”

(prostate cancer CNS)

Apps were also perceived to be a useful tool to help to promote self-management and patients' ownership over their health and wellbeing:

"I think it's quite nice and I think when you say to patients we would like you to use this, you know, we want you to track this, I think they do like taking a bit of ownership for things"

(prostate cancer CNS)

However, CNSs did raise some potential concerns or disadvantages of app-based physical activity interventions, including the lack of supervision from trained exercise professionals:

"there's no one for all solution here, unless you've got an app that takes into account the patient's age, the patient's baseline fitness level and then offers a solution, erm, based on that...that takes that into account...otherwise I think you could potentially, you know, if you're pushing your older patients too hard, you potentially have the opposite effect of what you want can't you?"

(prostate cancer CNS)

"I suppose the only sort of downside would be if people were using it inappropriately, so if they were exercising inappropriately but, you know, how do you kind of monitor that, that's a bit of a tricky one really"

(colorectal cancer CNS)

The potential for a lack of continued engagement with a physical activity app and therefore a lack of a sustained effect on behaviour change was also identified as a possible disadvantage:

"I think they are a useful tool. I don't know how useful they are on a long-term basis...I don't know...whether it's something that people use for like a week or two and then get a bit bored...it probably wouldn't have done enough...you need people to use it for a good, you know, few months to get into the habit of taking regular exercise"

(prostate cancer CNS)

CNSs also spoke about their perceptions of patients' preferences for using a publicly available physical activity app that already can be downloaded from commercial app stores versus an app that has specifically been developed for people affected by cancer:

"Do patients that have cancer want something specific? Probably, they do, I should imagine, because they have gone through a different experience, you know? And their specifics or their requirements might be related to the consequences of treatment...because if you've had cancer you'd probably want something specific to that, you know, from an understanding point of view of people's capabilities and abilities"

(prostate cancer CNS)

"people might not like [a generic app], if they're... 'cause they'll see themselves as having different needs. Although there'll come a point that maybe they want to have...be seen as back to normal again. So maybe that there's differences at different stages of the pathway"

(colorectal cancer CNS)

"I think if there's something already made and it works there's no point, err, making it different. And also I think if you had something that was just for cancer, it's permanently reminding people that they've got cancer or they've had cancer, whereas if you just did it as a general app...that helps to normalise things."

(prostate cancer CNS)

CNSs stated that they felt that apps offer a different approach to delivery of a physical activity intervention, which therefore provides patients with increased choice about how to engage with support to increase activity:

"so it would be, 'There's lots of choices available to you, we've got a physical activities team, you can see somebody face-to-face, you can have a one-off assessment, you can do a range of classes, we can link you in with an app that's been specifically designed for people affected by cancer.' You know, whatever the, the selling points might be. So it, it would just be adding in choice as part of the script...and it's a group of patients for whom life choices have been significantly changed. And to be able to give that choice is very positive"

(colorectal cancer CNS)

CNSs also reported being willing to promote physical activity apps provided there was an evidence-base underpinning their use, or if a particular app had been recommended for their patients by a professional organisation:

"very much like how web-based information now that we use, obviously we kind of signpost our patients to. And so, if there were apps developed that, you know, reflect Department of Health guidelines and things like that then obviously we'd speak to people about that and encourage people to use it"

(prostate cancer CNS)

"I need to be proficient in that myself first, before I advocate it to others. So I would like to learn, I would like to know, I would like to see what exactly is in there because any advice that comes from a specialist, it has to be evidence-based and research based and has to be quite practical. So I would be reluctant to give them advice unless myself has sort of looked into it and tried it out"

(colorectal cancer CNS)

"I would like to use [apps] but I don't know which ones to tell people to use and which would be the most beneficial for them really...which one's the most effective"

(colorectal cancer CNS)

However, they said they would need very clear guidelines about who they could recommend an app to, in order to avoid potential blame if a patient was to injure themselves while using an app:

"I'd have no problem with [recommending an app] actually if there was a guideline to say, you know, a patient whose performance status is like zero, and the, you know their fitness is at this level, then this is their target...because I'm not a fitness expert at all...if you're recommending something it needs to be, it needs to be in black and white and authorised really to be saying those things, because if they go and pull a muscle, they do something detrimental then you don't want to be sued, do you?"

(colorectal cancer CNS)

With regards to how a physical activity intervention could be effectively implemented in routine cancer care, CNSs said that they would need to be provided with accompanying resources to promote the app, including instructions on how to download it and discussed ways to potentially maximise the success of implementation:

"I wouldn't have any problem...saying 'You know, this is an app worth trying,' but I'd ...[need] a little sheet to give them, saying 'This is how you download it, this is what we recommend you do with it.' So it's something that you can give them with their physical activities thing, with their physical activities information you're already giving them"

(colorectal cancer CNS)

6.5 Discussion

The results of this study led to the development of 6 key themes: i) policy changes in survivorship care have influenced CNSs' promotion of physical activity; ii) CNSs recognise their role in supporting physical activity but sit within a wider system necessary for effective physical activity promotion; iii) CNSs use several techniques to promote physical activity within their consultations; iv) CNSs tailor their approach to physical activity discussions; v) some aspects of physical activity promotion remain challenging; and vi) CNSs were generally positive about the use of apps to complement existing physical activity promotion within cancer care.

The CNSs in this study described that physical activity promotion has increased as a result of the greater focus on survivorship care and the Living With and Beyond Cancer Initiative within cancer care. This has led to increased opportunities to discuss physical activity (e.g. via the interventions included as part of the Recovery Package) and as a result, physical activity promotion is regarded as a key and accepted part of the CNS role. The nurses also described their increased knowledge about the benefits of physical activity after a cancer diagnosis (e.g. with regards to improving coping with, and recovering from, treatment, managing side effects, improving wellbeing as well as the potential to reduce future cancer risk and the risk and burden of other common comorbid conditions). The identification of these benefits as facilitators to discussions about physical activity among cancer patients has also been reported in previous surveys of oncology nurses working in the USA, Australia and New Zealand (Karvinen et al., 2012; Keogh et al., 2017). Discussing these benefits with patients and providing education as to how physical activity can improve many of the side effects or challenges patients are facing was interpreted as a specific technique to encourage patients to increase physical activity. Other nurses mentioned how they had made a

conscious change to their language or communication style during consultations regarding physical activity. Examples included nurses specifically saying that they were “prescribing” physical activity or “referring” to services, as opposed to “signposting” and using techniques such as motivational interviewing. Motivational interviewing has been highlighted as having the potential for nurses to help patients improve their lifestyles (Scott, 2010). The nurses also said that they felt that it was important to emphasise physical activity as a part of cancer treatment and care that the patient can take control over, to empower them to play an active role in their health and wellbeing and promote self-management. This was also echoed by the patients in Study 3 (Chapter 5). Emphasising this aspect of control may be an effective way to promote physical activity among cancer patients.

Some CNSs described examples of physical activity recommendations provided to patients that were inaccurate, vague or at odds with established physical activity guidelines for cancer survivors, and the strength-resistance training element of the recommendations was described as being particularly difficult to communicate with patients. Previous research has suggested that 42% of healthcare professionals involved in cancer care (including nurses) did not provide advice that aligned with current physical activity guidelines for cancer survivors (Cantwell et al., 2018). Therefore, improving nurses' knowledge and understanding of the physical activity guidelines and ability to communicate them with patients is required. The CNSs were also concerned about the potential safety and risks to the patient with regards to physical activity promotion and similar concerns have been raised in other studies of oncology nurses (Karvinen et al., 2012; Keogh et al., 2017). The nurses in this study described seeking approval from other healthcare professionals (e.g. consultants, surgeons, allied health professionals) before advising a patient to increase physical activity. However, previous research has also shown limited knowledge and understanding about physical activity guidelines among cancer survivors in other healthcare professional groups too (Cantwell et al., 2018; Koutoukidis et al., 2018; Williams et al., 2015). Effective physical activity promotion requires a consistent message about the importance of physical activity after cancer from a range of healthcare professionals involved in the patients' care. However, the CNSs in this study described a feeling that healthcare professionals from other disciplines might lack the knowledge of the benefits of physical activity for cancer, lack the skills to deliver this advice and don't perceive it to be within their job role. While the CNSs in this study agreed they were the most appropriate professional to refer or coordinate physical activity

support, it is important that CNSs are not regarded as a substitute for exercise professionals as they do not necessarily have the knowledge, skills or confidence for exercise prescription on an individual level.

The nurses in this study also discussed how they try to tailor their consultations around physical activity with regards to several factors about each patient including age, baseline physical activity levels, comorbid conditions, cancer experience (e.g. treatment, side effects, disease stage, distress) as well as the types of physical activity the patient is interested in and how open or willing the patient appears to be to discussing physical activity. However, they described feeling that even though they take those factors into account, it can be very challenging to incorporate them into a specific recommendation for an individual patient and that the advice they give can therefore feel somewhat generic. This has been recognised in an editorial in *The Lancet Oncology*, which states that “it would be naïve to think that there can, or should, be a one-size-fits-all approach to suit all patients” with regards to cancer-specific physical activity guidelines (Lancet Oncology, 2018). As a result, further research is needed to produce more specific physical activity guidelines based on various patient factors (e.g. cancer type, stage, treatment, comorbidities, body composition) to support clinicians to have the confidence to adapt their recommendations to an individual patient accordingly. Related to this, Santa Mina and colleagues state that the existing “guidelines are unable to advise clinicians and qualified exercise professionals about how to identify and manage many potential exercise contraindications, especially given the high degree of heterogeneity in patient risks and comorbidities” (Santa Mina et al., 2018).

Nurses were generally positive with regards to the role that apps can play in physical activity support in cancer care. The nurses recognised that ownership of devices required to download and use apps is increasing and that it is not necessarily dependent on a person's age as to whether a patient is likely to use a smartphones. They felt that apps can increase accessibility to a physical activity intervention as they can remove some of the barriers associated with face-to-face interventions (e.g. travel, time and confidence) and can offer an approach to promote patient self-management. However, many nurses were mindful of the fact that physical activity apps would not necessarily be of interest to, or useful for, specific groups of their patients, including those who do not own smartphones, do not have the skills to use them or for more complex patients who may require more tailored, supervised interventions. As a result, the nurses reported

that they felt that apps are a useful tool to be able to offer in addition to, as opposed to instead of, the current physical activity services they discuss with patients as they can increase patient choice and flexibility with how they want to engage in physical activity support based on their preferences and circumstances. Nurses reported being willing to recommend physical activity apps to their patients provided there was an evidence-base underpinning their use, or if a particular app had been recommended for use among cancer patients from a professional organisation. CNSs also felt that in order to ensure effective implementation of an app-based intervention in cancer care, accompanying resources would be required as well as effective dissemination among colleagues.

6.5.1 Strengths and limitations

This study offers a rich insight into CNSs' perspectives of physical activity promotion within routine cancer care in the UK and factors that may affect the development and implementation of an app-based physical activity intervention. Nurses were recruited from a range of hospitals across England and Scotland providing insight into how physical activity promotion differs across hospitals and regions. Qualitative methodology provides a rich understanding of people's experiences, thoughts and opinions and provides a greater depth of understanding to help explain the pattern of responses observed in quantitative research on the provision of lifestyle advice among cancer healthcare professionals, including nurses (Karvinen et al., 2012; Keogh et al., 2017; Williams et al., 2015). However, there are a number of limitations to discuss. The sample were self-selecting and this may have led to the recruitment of nurses who are particularly interested in and enthusiastic about the promotion of physical activity among their patients. This may affect the conclusions drawn from this study. While the interview schedule was designed to ask questions openly and to minimise the potential for nurses to feel that they should be discussing physical activity with patients, social desirability bias may have led to nurses adapting their responses to ensure that they are regarded positively. Attempts to recruit a similar number of nurses who worked within each of the 3 cancer types were made, to ensure a range of perspectives of physical activity promotion could be collected. It was particularly difficult to recruit breast cancer CNSs, and only 4 of the 19 nurses interviewed in this study worked with breast cancer patients. Some of these 4 breast cancer CNSs appeared more reluctant to discuss physical activity compared with the prostate/colorectal CNSs and seemed to act as gatekeepers in the way that they described discussing physical activity with their patients (e.g. only discussing physical activity if the patient mentioned it). Therefore, breast cancer CNSs' opinions of physical

activity promotion may be under-represented in this study and may differ in comparison to prostate and colorectal CNSs. Further work exploring breast cancer CNSs opinions of physical activity promotion, in comparison with other cancer types, may be beneficial.

6.5.2 Conclusion

The aims of the present study were to explore breast, prostate and colorectal cancer CNSs' perspectives on physical activity promotion and the role of smartphone-based physical activity interventions in cancer care. There were 6 key themes: i) policy changes in survivorship care have influenced CNSs' promotion of physical activity; ii) CNSs recognise their role in supporting physical activity but sit within a wider system necessary for effective physical activity promotion; iii) CNSs use several techniques to promote physical activity within their consultations; iv) CNSs tailor their approach to physical activity discussions; v) some aspects of physical activity promotion remain challenging; and vi) CNSs were generally positive about the use of apps to complement existing physical activity promotion within cancer care. The results of this study provide valuable insight into the CNS role and reveals a number of important considerations for the development and implementation of physical activity interventions within cancer care, with a specific focus on smartphone-based interventions.

Chapter 7: General Discussion

The overall aim of this thesis was to develop an app-based intervention to promote physical activity among people living with and beyond cancer. The studies included in this thesis addressed four key questions related to this overall aim. This chapter summarises the main findings from each study and their contribution to the literature. Implications of the research, limitations and future directions are then discussed.

7.1 Summary of findings and contribution to the literature

Chapter 2 detailed the four main research questions that this thesis attempted to answer.

7.1.1 What is the evidence for digital interventions targeting physical activity in cancer survivors?

'Identifying the evidence-base' is a key component of the Medical Research Council guidance for developing and evaluating complex interventions (Craig et al., 2008). Therefore, the first study identified and synthesised the available evidence of digital interventions targeting physical activity in cancer survivors through a systematic review and meta-analysis. Studies targeting physical activity, diet and/or sedentary behaviour were also included in the review due to the novelty of this area of research and to better understand the use of digital technologies in interventions targeting similar behaviours. The review identified 15 studies, 8 RCTs and 7 one-arm pre-post studies. All 15 measured the impact of DHBCIs on physical activity, 7 of which could be included in the meta-analysis (5 RCTs, 2 one-arm studies; $n=1,034$). Results from the meta-analysis revealed that DHBCIs resulted in a significant increase in MVPA of 41 minutes per week (95% CI: 12-71; $p = .006$). When only RCTs were included in the meta-analysis, the increase in MVPA minutes per week was higher (49 minutes; 95% CI: 16-82; $p = .004$). This is important since evidence from RCTs is of higher quality.

Groen and colleagues recently published a systematic review and meta-analysis of distance-based physical activity interventions in cancer survivors, including digital technologies as well as other remote approaches to intervention delivery (e.g. print materials, telephone interventions). They pooled results from 4,203 participants in 24 RCTs (28 comparisons) and reported an overall small effect of distance-based physical activity interventions versus control on MVPA (SMD=0.21; 95% CI: 0.11-0.32, $p < .001$). Data from 18 RCTs (of 29 included in the review) provided a crude total mean self-reported MVPA change of +49 minutes per week (range: -4 to 168)

(Groen et al., 2018). While this estimate is comparable with the results of the meta-analysis of RCTs described in this thesis, the results cannot be directly compared as Groen and colleagues reported a crude mean change in MVPA minutes, which was not pooled in a meta-analysis where each study was weighted.

Although results supporting distance and digital interventions are promising, results of three systematic reviews suggest that, when compared directly, supervised exercise interventions may be more effective than those delivered remotely (Baumann, Zopf, & Bloch, 2012; Ferrer et al., 2011; Keogh & MacLeod, 2012). However, supervised interventions are time and resource intensive and therefore costly to implement. Furthermore there are issues with low uptake (Bourke et al., 2011; Mutrie et al., 2007) and commonly reported barriers including access, timing of classes, travel, cost, lack of motivation and confidence (Blaney et al., 2013; Courneya et al., 2005; Hardcastle, Glassey, et al., 2017; Hardcastle et al., 2018; Hardcastle, Maxwell-Smith, et al., 2017; Ottenbacher et al., 2011; Rogers et al., 2007). Given that observational data has shown that breast or colorectal cancer survivors who increase their physical activity by any amount between pre- and post-diagnosis show a reduced overall mortality risk (RR=0.61; 95% CI: 0.46-0.80) compared to cancer survivors who did not change their physical activity level or who were insufficiently active pre-diagnosis (Schmid & Leitzmann, 2014), even small increases in MVPA post-diagnosis are likely to be beneficial for cancer survivors. Evidence presented in this thesis suggests that DHBCIs have the potential to increase MVPA by approximately 50 minutes per week, which is approximately a third of the weekly recommended amount of MVPA for cancer survivors (Rock et al., 2012; Schmitz et al., 2010; US Department of Health and Human Services, 2008).

Despite increases in MVPA, the results of Study 1 did not demonstrate a significant improvement in measures of fatigue or quality of life among cancer survivors that has previously been reported in physical activity interventions in cancer survivors (Mishra, Scherer, Geigle, et al., 2012; Mishra, Scherer, Snyder, et al., 2012). With regards to fatigue, only 3 RCTs were included in the meta-analysis, using data from 406 participants. The results demonstrated a reduction in fatigue, however this was not statistically significant (SMD=-0.23; 95% CI: -0.51, 0.05; $p = .10$). Four studies (2 RCTs and 2 one-arm studies) were included in the meta-analysis for cancer-specific quality of life outcomes. There were no significant changes in cancer-specific quality of life (MD=0.61; 95% CI: -1.83, 3.06; $p = .62$), however the small sample sizes and small number of

studies evaluating these outcomes warrant further high quality research. It is also possible that the modest increase in MVPA participation associated with digital interventions in the included studies was not sufficient to demonstrate improvements in other cancer-relevant outcomes (e.g. fatigue and quality of life). For instance, Mishra and colleagues report larger effect sizes for reduction in fatigue (10 studies, SMD=-0.82; 95% CI: -1.50, -0.14) and improvements in cancer-specific quality of life (11 studies, SMD=0.48; 95% CI: 0.16-0.81) in their meta-analyses of primarily supervised exercise trials in cancer survivors (Mishra, Scherer, Geigle, et al., 2012). However, data from 4 studies (1 RCT, 3 one-arm studies) included in this meta-analysis did reveal a significant reduction in BMI/weight (SMD=-0.28; 95% CI: -0.52, -0.04; $p = .011$).

Despite the limitations of the studies included in this review (high risk of bias for the majority of included studies, the lack of objective measures of physical activity and the lack of high quality RCTs with longer-term follow-up and large sample sizes), the systematic review and meta-analysis presented in Chapter 3 was the first to identify and synthesise the available evidence for digital interventions in this context and suggest that digital interventions could be a promising approach to physical activity intervention delivery in cancer survivors.

7.1.2 What proportion of breast, prostate and colorectal cancer survivors are interested in digital health behaviour change interventions and what factors are associated with interest in digital interventions?

Given the potential of digital interventions in physical activity intervention delivery (Study 1) and the high levels of internet access and smartphone ownership in UK adults (OFCOM, 2018), it was important to explore the level of interest in DHBCIs and characteristics associated with interest to understand the potential reach of digital interventions in this context. The results of Study 2 found that 38% of breast, prostate and colorectal cancer survivors are interested in internet-based lifestyle interventions and 24% are interested in app-based lifestyle interventions. After adjustment for relevant covariates, participants who were younger, male, more highly educated, internet users, interested in physical activity interventions and meeting MVPA recommendations showed significantly greater odds of interest in internet information. Adjusted analyses also revealed that participants who were younger, non-White, internet users, interested in physical activity interventions and meeting MVPA recommendations had significantly greater odds of interest in an app.

Interest was lower than has been reported in previous studies. Phillips and colleagues reported that 68% of breast cancer survivors were interested in a physical activity intervention delivered via website/app, however the representativeness of this sample is limited and unlikely to reflect the wider population of cancer survivors (Phillips et al., 2017). A further study of breast, prostate and colorectal cancer survivors reported that 59% were interested in web-based interventions and 22% were interested in an app (Martin et al., 2016). While interest in internet information was somewhat lower in the current study compared with Martin and colleague's results, the results from a smartphone-delivered program/an app were broadly similar. This is despite the fact that the data in Martin et al.'s (2016) study was collected in 2010 and that technology usage patterns have changed considerably during this time across both the American and UK populations. Despite this, the current study provides a more recent estimate of the proportion of breast, prostate and colorectal cancer survivors interested in digital interventions among a sample that is more likely to reflect the UK population.

The consistent significant association between younger participants and interest in both internet information and an app is unsurprising given the higher rates of internet access and smartphone ownership in younger age groups (OFCOM, 2018). Similar findings have been reported in nationally representative cross-sectional surveys in the US and in studies involving cancer survivors (Carroll et al., 2017; Golsteijn et al., 2017). Despite the rapidly increasing ownership of smartphones in older age groups in recent years, age is still negatively associated with interest in digital interventions. This is especially important given that the majority of cancer survivors are older adults. Interestingly, education level was only significantly associated with interest in internet information, whereas education was not associated with interest in an app in adjusted analyses. There is suggestion that smartphones could offer an easier and more affordable way of accessing the internet compared to laptop, desktop or tablet computers among those with low household income (Pew Research Center, 2017a) and cancer survivors who do not own a computer showed greater interest in smartphone-based interventions (Martin et al., 2016). Smartphone/app-based interventions may be more accessible among those of lower SEP and the difference in interest between those of higher and lower educational level is less stark for app-based than internet-based interventions.

The association between gender and interest in DHBCIs revealed interesting findings. In unadjusted analyses female participants showed greater odds of interest in both internet

information and an app. However, after adjustment for relative covariates, male participants were significantly more interested in internet information and gender was no longer significantly associated with interest in an app. Post-hoc analyses that aimed to further explore the pattern of results between gender, age, education and interest in internet information/an app suggested that women's younger age explained the higher interest in unadjusted analyses. The appeal of app-based interventions to male participants was also alluded to in both qualitative studies (Studies 3 and 4). In Study 3, two-thirds of the sample were men, driven by the 50% of the sample who had been diagnosed with prostate cancer. Recruitment had to be closed for prostate cancer survivors in order to ensure that breast and colorectal cancer survivors were sufficiently represented in this study. In Study 4, prostate cancer CNSs also described their perception that app-based interventions were likely to be appealing to their prostate cancer patients due to their lower preference for face-to-face support and high levels of interest in self-monitoring and visual feedback through the use of technology among their patients (e.g. of prostate-specific antigen levels, symptom monitoring and physical activity). Given the often-reported higher interest in, and uptake of, physical activity interventions by female participants across the cancer survivorship and wider behaviour change literature, it is promising that digital interventions may offer an approach to intervention delivery that may appeal more to male participants.

Participants who were already meeting MVPA recommendations had higher odds of interest in both internet- and app-based interventions in this study. This finding was also reported in the study conducted by Martin et al. (2016) among cancer survivors, and nationally-representative general population data from the USA also revealed that those who have adopted health apps were significantly more likely to meet national physical activity recommendations compared with non-users (Carroll et al., 2017). Other studies evaluating digital physical activity interventions among cancer survivors have shown reasonably high levels of MVPA at baseline among participants (Forbes et al., 2015; Kuijpers et al., 2016), and recruiting those who are inactive or engaging in low levels of MVPA is particularly challenging among this group. As a result, those working in cancer care play an important role with regards to physical activity promotion and in encouraging those who may not already exhibit interest in physical activity interventions or who are not already meeting physical activity guidelines to participate in physical activity programmes, particularly as these patients potentially stand to gain the most from increasing physical activity.

7.1.3 What are breast, prostate and colorectal cancer survivors' perspectives of publicly available physical activity smartphone apps?

Exploring cancer survivors' experiences of using different types of publicly available physical activity apps offered insight into how feasible and acceptable apps may be as an approach to intervention delivery and help to understand which types of physical activity apps may be most appropriate or successful for future intervention development. The sample of breast, prostate and colorectal cancer survivors interviewed in qualitative Study 3 were receptive to the use of apps to promote physical activity. The results demonstrated that in order for cancer survivors to engage with physical activity apps, and for physical activity apps to be successful, they must feel relevant to the individual user (e.g. based on each person's physical activity ability, experience of cancer, treatment and side effects, their point in the cancer trajectory, personal physical activity goals and self-identity). Furthermore, users' perceived quality of an app and opinions of the BCTs/app functions affected engagement, but again these factors differed considerably between participants.

As a result, participants felt that apps that promote walking were deemed to be most appropriate as walking is perceived to be safe, accessible, enjoyable and achievable, regardless of the variation that a group of heterogeneous cancer survivors face in terms of their type of cancer, treatments undergone, side effects, baseline level of physical activity and potential risk for harm. Participants were less convinced of the suitability for apps in the promotion of strength and resistance training and many participants reported that even the beginner levels of these apps were too difficult and potentially unsafe, given the age, fitness level of many of the participants, in addition to their experience of side effects and recovery from cancer treatment. However, the participants were receptive to the format of these types of apps, with detailed video demonstrations illustrating how to perform each exercise. Activity tracking/walking-based apps did not provoke the same level of unease and the participants said that they felt that these need not be tailored specifically towards people who have had cancer. While most participants recognised the benefit of strength and resistance training, there was a consensus among participants that apps that promote this type of physical activity would need to be individualised towards different users' specific cancer types (e.g. with regards to location of surgery) and abilities, varying confidence and familiarity with these types of exercises, and perhaps some supervision from a qualified exercise professional may be required. These findings reiterate the

opinion of the CNSs described in Study 4 with regards to the types of activities that could be supported via an app versus those that may need at least some level of supervision. Some participants also described strength/resistance training as unenjoyable and that this meant they would be unlikely to try or to adhere to exercise programmes that included this type of activity. The participants suggested that patients should be signposted to appropriate physical activity apps by members of their clinical team, and CNSs in particular were described as the healthcare professional who were trusted to provide reliable advice to support health and wellbeing. The value that patients place on the lifestyle recommendations provided by their clinical team, particularly the CNS and consultants, is frequently reported elsewhere (Bourke et al., 2018; Hardcastle, Glassey, et al., 2017; Koutoukidis et al., 2016). Furthermore, a recent survey of haematological cancer survivors reported that 82% would use a health app if it was recommended to them by a healthcare professional (Collado-Borrell et al., 2018).

The use of publicly available physical activity apps was a time- and resource-intensive approach to gain valuable and in-depth insight about the types of apps and app features that might be most successful among this population. Previous research in this area has, for example, sought feedback for hypothetical app features and example text-messages from slideshows shown to focus groups of cancer survivors (Robertson et al., 2017). The current study reported in this thesis provided greater ecological validity by enabling participants to experience searching for, downloading and using selected apps for a period of time. This illustrated the dynamic and extremely subjective influences on engagement with digital interventions in the context in which they are used. The results of this study support findings of a review that synthesised both quantitative and qualitative evidence of engagement with web-based interventions designed to improve quality of life in cancer survivors, which found that interventions that offer content that is specific to their changing needs and are delivered at an appropriate stage of the cancer trajectory are valued (Corbett et al., 2018). However, the need to design, develop and support apps that are highly tailored to each individual user is extremely challenging. It may be more appropriate to identify/develop a number of physical activity apps that are suitable for different groups of cancer survivors and from which individual users could choose an app they think is most suited to them, rather than attempting to develop one app that is flexible enough to meet all needs and preferences of a heterogeneous group of individuals.

7.1.4 What are breast, prostate and colorectal cancer survivors' Clinical Nurse Specialists' perspectives on physical activity promotion and the role of smartphone app-based physical activity interventions within cancer care?

As a result of the findings of Study 3, and of the importance of seeking the views and input of those who are involved in the delivery of an intervention, as well as intended users (Bradbury et al., 2014; Craig et al., 2008), CNSs were interviewed to seek their perspectives on physical activity promotion and the potential for app-based physical activity interventions within cancer care. The CNSs discussed the positive impact that the increased awareness on survivorship care (e.g. in the Cancer Strategy and NHS Long Term Plan; Independent Cancer Taskforce, 2015; NHS England, 2019) has had on physical activity promotion within their role and that the implementation of the Recovery Package within cancer care has facilitated opportunities to bring physical activity into routine consultations. With that in mind, CNSs recognise that discussing and supporting physical activity among their patients is an accepted and key part of their role, but highlighted the importance of other healthcare professionals (e.g. consultants, surgeons, GPs) and community-based support in effective physical activity promotion. The benefits of physical activity after cancer (e.g. coping with and recovering from treatment, managing side effects and the potential to reduce future cancer risk and the burden of other comorbid conditions) were described as facilitators to conversations about physical activity with patients, and CNSs described techniques such as adapting their language (“prescribing” physical activity) and motivational interviewing to promote physical activity.

Some CNSs described examples of physical activity recommendations that were inaccurate, vague or at odds with established physical activity guidelines for cancer survivors, and the strength and resistance training element of the recommendations was described as particularly difficult to communicate with patients. Previous research has shown limited knowledge and understanding of the physical activity guidelines among various healthcare professional groups involved in the care of cancer survivors (Cantwell et al., 2018; Koutoukidis et al., 2018; Williams et al., 2015). The CNSs also described how they try to tailor their consultations around physical activity depending on patient factors such as age, baseline physical activity levels, comorbid conditions, cancer experience (e.g. treatment, side effects, disease stage, distress) as well as the types of physical activity the patient is interested in and how open/willing to discuss physical activity the patient is perceived to be. However, they described feeling that even though these

factors are taken into account, it can be very challenging to incorporate them into a specific recommendation to an individual patient and that the advice they give can therefore feel too generic. The need to support healthcare and qualified exercise professionals to provide more specific guidelines based on various patient factors has been highlighted (Newton, Taaffe, et al., 2018; Santa Mina et al., 2018).

The CNSs' perspectives of physical activity promotion more generally was deemed to influence their likelihood to discuss or recommend a physical activity app with a patient. Nurses were generally positive with regards to the role that apps can play in physical activity support in cancer care. The nurses recognised that ownership of devices required to download and use apps is increasing and that digital technologies can increase accessibility to a physical activity intervention by removing some of the barriers associated with face-to-face interventions (e.g. travel, time and confidence). However, many nurses were mindful of the fact that physical activity apps would not necessarily be of interest to or useful for specific groups of their patients, including those who do not own smartphones, do not have the skills to use them or for more complex patients who may require more individualised, supervised interventions. As a result, the nurses reported that they felt that apps were a useful tool to be able to offer in addition to, as opposed to instead of, the current physical activity services they discuss with patients. They described the importance of patient choice and flexibility for how patients wish to engage in physical activity support based on their preferences and circumstances. Nurses reported being willing to recommend physical activity apps to their patients provided there was an evidence-base underpinning their use or if an app had been recommended for use among cancer patients from a professional organisation. CNSs also felt that in order to ensure effective implementation of an app-based intervention in cancer care, accompanying resources would be required as well as effective dissemination among colleagues.

7.2 Limitations

The limitations of each study are discussed in greater detail within each of the relevant chapters. However, this section discusses common limitations that are applicable to several of the studies included in this thesis.

7.2.1 Self-report measures of physical activity

The use of self-report physical activity data is a considerable source of bias in the studies included in this thesis. Self-report measures are at a much higher risk of both recall and social desirability bias and are therefore notorious for their potential for overestimation of physical activity behaviour (Prince et al., 2008). All 15 studies included in the systematic review described in Chapter 3 (Study 1) used self-reported data, and self-report methods were used to assess physical activity participation in the participants who completed the large cross-sectional survey reported in Chapter 4 (Study 2). Objective approaches to data collection, such as accelerometry, would increase the reliability and validity of the findings. Validated self-report measures are often the only feasible way to assess physical activity in large populations (such as Study 2) as they are inexpensive, easy and quick to administer and, are often chosen in studies conducted in smaller sample sizes for the same reasons.

7.2.2 Interviewer effects and social desirability

Social desirability bias is a widespread issue common across psychological, behavioural and social sciences research and refers to the phenomenon whereby research participants tend to respond/ behave in a way that they believe the researcher would like them to and/or presents them in a positive light. This may be particularly prevalent across the studies described in this thesis due to the positive regard held for health behaviours that are important in both disease prevention and self-management within society. This may be especially common within sensitive research areas such as cancer research, where there is potential for risk factor behaviours, such as inactivity, to implicate blame among cancer survivors for their poor health. Therefore, the participants within the studies included in this thesis may have been subject to social desirability bias in their self-reporting of physical activity behaviour as described in section 7.2.1. Furthermore, participants in both of the qualitative studies reported in this thesis may be subject to social desirability bias due to the decision taken to collect interview data via telephone interview. As this approach involved direct contact between the researcher and participant, the potential for social desirability bias may be higher than if for example, a fellow patient/participant researcher had been trained to conduct the interviews and/or assist in data analysis. Therefore, the cancer survivors in Study 3 and CNSs in Study 4 may have adapted their true responses to the questions regarding the acceptability and suitability of physical activity apps for cancer

survivors as they believed this was the response that the researcher wanted to gain from the interviews.

7.2.3 Representativeness of the sample

The representativeness of the sample, and therefore generalisability to the wider population of cancer survivors, was a significant limitation for several of the studies included in this thesis. For instance, the majority of the studies included in the systematic review and meta-analysis (Study 1) were over-represented by female, breast cancer survivors occupying high SEP (e.g. highly educated/high income). The convenience methods used to recruit participants for both Studies 3 and 4 also have the potential to limit the representativeness of these samples. While physical activity behaviour was not explicitly measured in Study 3, none of the cancer survivors who took part reported being inactive and often described an interest in physical activity and technology. Inclusion criteria included owning a smartphone which may not be representative of the wider cancer survivor population. Furthermore, the nurses who took part in Study 4 may have been nurses who were particularly interested in physical activity promotion and the research topic and so may have been more likely to participate. While the proportion of the sample in Study 2 who had no qualifications (29%) or who were degree-educated (38%) was broadly in line with the 2011 UK census data for adults over 50, there was still an over-representation of female breast cancer survivors and only a fifth of the respondents had had colorectal cancer.

7.3 Implications for future research, policy and practice

It was important that the systematic review and meta-analysis (Study 1) was the first study to be completed within this PhD thesis, in order to identify the current evidence-base for digital physical activity interventions in cancer survivors and detect gaps in the literature. The main implication for future research identified from the systematic review was the need for further high quality RCTs, which include objective measures of physical activity, long-term follow-up and larger sample sizes.

Since the search for Study 1 was last completed (8th November 2016), at least a further 16 studies (from 17 publications) that would have met the original eligibility criteria for the systematic review and meta-analysis have been published (see summary tables 7.1 (Appendix W) and 7.2 (Appendix X)) (Frensham, Parfitt, & Dollman, 2018a, 2018b; Galiano-Castillo et al., 2016; Golsteijn et al., 2018; Kanera et al., 2017; Kenfield et al., 2019; Krebs et al., 2017; Mayer et al.,

2018; Orlemann et al., 2018; Ormel, van der Schoot, Westerink, et al., 2018; Paxton et al., 2017; Pope, Zeng, Zhang, Lee, & Gao, 2018; Short et al., 2018; Trinh et al., 2018; Uhm et al., 2017; Valle, Deal, & Tate, 2017; Villaron, Cury, Eisinger, Cappiello, & Marqueste, 2018). This highlights the increasing research interest in this area. Importantly, some of these studies have begun to address the methodological limitations noted in Study 1. While all of the studies in Study 1 used self-report measures of physical activity, five have since used objective measurement approaches (pedometers and/or accelerometers) (Frensham et al., 2018b; Golsteijn et al., 2018; Pope et al., 2018; Trinh et al., 2018; Villaron et al., 2018). Three of these reported significant increases in objectively measured physical activity; two at 3 months (Frensham et al., 2018b; Trinh et al., 2018) and one at 6 months (Golsteijn et al., 2018). Sedentary behaviour was not assessed in any of studies included in Study 1, however four of these more recent studies have done so (Ormel, van der Schoot, Westerink, et al., 2018; Paxton et al., 2017; Pope et al., 2018; Trinh et al., 2018). Of these, two reported positive findings for reducing sedentary behaviour (Paxton et al., 2017; Trinh et al., 2018). A further limitation of Study 1 included the low number of RCTs with larger sample sizes and longer-term follow-up. Several of these more recent studies have been conducted with larger sample sizes, including Golsteijn et al. (2018) with 462 prostate or colorectal cancer survivors at 6-month follow-up, Uhm et al. (2017) with 339 breast cancer survivors at 3-month follow-up and Mayer et al. (2017) with 227 colorectal cancer survivors at 6-month follow-up. A large (n=462) RCT conducted by Kanera et al. included in Study 1 (Kanera et al., 2016) has since had 12-month follow-up outcomes published, which found their tailored web-based intervention demonstrated a significant increase in self-reported MVPA participation among intervention participants versus control at 12-months (Kanera et al., 2017). These studies are important as the larger sample sizes mean that the studies are more likely to be powered to detect changes in behavioural outcomes such as physical activity/sedentary behaviour, however many of the more recent studies also include sample sizes <100 (Frensham et al., 2018a, 2018b; Galiano-Castillo et al., 2016; Kenfield et al., 2019; Krebs et al., 2017; Orlemann et al., 2018; Ormel, van der Schoot, Westerink, et al., 2018; Paxton et al., 2017; Pope et al., 2018; Short et al., 2018; Trinh et al., 2018; Valle et al., 2017; Villaron et al., 2018).

Furthermore, digital interventions are often referred to as a low-cost, broad-reaching solution to delivery of behavioural interventions. However, cost-effectiveness is only the case if they are indeed effective at increasing and maintaining behaviour change in the longer term. Therefore,

reports of positive, long-term follow-up outcomes (e.g. 12 months), such as those reported by Kanera et al. (2017) are valuable. Several more recent studies have also specifically recruited participants who were insufficiently active or had at least one behavioural risk factor (i.e. <150 minutes MVPA per week or <5 portions of fruit & vegetables per day) (Frensham et al., 2018a, 2018b; Krebs et al., 2017; Trinh et al., 2018). Paxton et al. and Valle et al. specifically recruited women who identified as African American, Hispanic or mixed ethnicity (Paxton et al., 2017; Valle et al., 2017). These studies increase the representativeness and generalisability of these studies to the wider cancer survivor population by specifically targeting those who are at increased risk due to socioeconomic deprivation and/or ethnicity and who stand to gain the most from behavioural interventions, within which they are often under-represented.

The quantitative results from Study 2 and the qualitative findings from interviews with both patients and CNSs demonstrate that digital technologies are just one possible solution to the delivery of physical activity interventions and it is important that they are not regarded as a replacement for interventions delivered via other means. As highlighted by the CNSs in Study 4, it is important that there is sufficient choice available for participants to choose the types of physical activity they wish to engage in, with the approach to intervention delivery that they feel is most appropriate for them. Indeed, increasing patient choice may well increase uptake and adherence to any intervention that is chosen by the patient depending on their preferences and circumstances. Instead, the current research literature often compares one type of intervention versus control, failing to consider the diversity of cancer survivors' motivation, preferences and circumstances. As a result, modest uptake/adherence to each type of intervention is often reported, when in practice it may be that certain types of interventions may be more effective among certain groups of cancer survivors. Therefore, cancer survivors could be offered physical activity interventions delivered in one of several modalities and digital interventions (e.g. websites, smartphone apps, wearable activity trackers etc.) could be included in a suite of options for physical activity interventions that can also include face-to-face support, individual or group-based, delivered within the health service or in the community, and other approaches to distance-based support (e.g. telephone or printed materials). Future research is required to better understand which patients may be best suited to which types of intervention delivery approaches (supervised group/individual sessions, print materials, telephone support, digital technologies or several approaches in combination), in which contexts (depending on where a patient is in the cancer

trajectory, and factors related to cancer type, treatment, side effects, comorbidities, the need for supervision and patient preferences) and taking into account patient preference and other factors affecting uptake and adherence.

A recent study has aimed to address this by measuring cancer survivors' readiness for the utilisation of health technology for physical activity rehabilitation (based on their eHealth literacy, self-management and social context) and receptiveness to digital physical activity interventions, and using this information to stratify participants to recommend the approaches that may facilitate physical activity intervention delivery in the most appropriate way, with a higher potential for success (Rossen, Kayser, Vibe-Petersen, Ried-Larsen, & Christensen, 2019). Rossen and colleagues recommend that those with high readiness/high receptiveness receive a "basic introduction to technology-supported exercise rehabilitation" while those with high readiness/low receptiveness can be engaged in "dialogue about reasons for not being open to technology in this context and about the potential benefits of the technology offered. If still not open to try, then [recommend] standard team-based exercise rehabilitation". Those with low readiness/high receptiveness could be provided "extra self-management and emotional support based on their readiness profile [with] thorough introduction and support to technology supported exercise rehabilitation" and those with low readiness/low receptiveness can be offered "standard team-based exercise rehabilitation [with] extra self-management and emotional support based on the readiness profile. Dialogue about the potential benefits of the technology and if they wish to try, then extra support with technological issues" (Rossen et al., 2019). Future work could build on this by incorporating other patient factors (e.g. cancer type, treatment side effects and other late effects, comorbidities, the point in cancer trajectory, motivation, baseline activity level etc.) that can be considered to help determine what type of intervention may be required for each patient, at each point in the cancer trajectory. This type of research will be crucial in maximising the success of physical activity interventions and can help to develop appropriate referral pathways for clinicians to integrate physical activity prescription into routine cancer care. Attention should also be paid to ensuring that evidence-based interventions (digital or otherwise) are implemented and evaluated in practice.

It is also important to consider the types of interventions that might be most appropriate for a patient from a clinical perspective, with regards to the outcomes that are of greatest interest or concern. For instance, Newton and colleagues state that cancer survivors with

cachexia/sarcopenia would require a more personalised assessment and exercise prescription from a qualified exercise professional rather than the generic physical activity recommendations for cancer survivors (Newton, Taaffe, et al., 2018). In these patients, 150 minutes of MVPA per week could exacerbate the muscle, fat, and bone loss as a result of the increasing energy deficit and that carefully prescribed resistance exercise and nutritional support should be recommended in this case (Newton, Taaffe, et al., 2018). Furthermore, Newton and colleagues add that many cancer survivors are older, with several comorbid conditions and supervision and personalisation of an exercise prescription is necessary to reduce the risk of adverse events (e.g. cardiovascular events) (Newton, Taaffe, et al., 2018). The CNSs in Study 4 discussed how they try to tailor their consultations about physical activity with regards to these factors, as well as the patients' experience of treatment and side effects, and perceived willingness to discuss physical activity. The CNSs described the challenge of incorporating this into a specific recommendation where the weekly goal of 150 minutes of MVPA and twice-weekly occasions of resistance training does not seem appropriate. This has been acknowledged in an editorial in *The Lancet Oncology*, which supports the view that one physical activity recommendation for all cancer survivors is inappropriate (Lancet Oncology, 2018). As a result, further research is needed to produce more specific physical activity guidelines based on various patient factors (e.g. cancer type, stage, treatment, comorbidities, body composition) to support clinicians to have the confidence to adapt their recommendations to an individual patient accordingly. Related to this, Santa Mina and colleagues state that the existing "guidelines are unable to advise clinicians and qualified exercise professionals about how to identify and manage many potential exercise contraindications, especially given the high degree of heterogeneity in patient risks and comorbidities" (Santa Mina et al., 2018). Therefore, Santa Mina and colleagues aimed to use the best current available evidence from both cancer and non-cancer clinical populations to identify potential contraindications to exercise (i.e. blood counts, cardiorespiratory signs and symptoms, bone metastases and variations in physical/cognitive function) and provide potential considerations and exercise recommendations based on an informed clinical judgement (Santa Mina et al., 2018).

Walking has been identified as the most preferred type of physical activity in cancer survivors (Wong et al., 2018) and the results of Studies 3 and 4 demonstrated that publicly available physical activity apps that promote walking were acceptable to cancer survivors and CNSs. However, the benefits of higher intensity aerobic physical activity and strength and resistance

training must not be overlooked. Given the benefits of resistance training described in the Introduction (Chapter 1), future work could also aim to determine the feasibility, acceptability and safety of the delivery of resistance training via digital technology.

Walking-based interventions do offer huge potential as walking represents the largest proportion of total activity across age groups in a representative profile of MVPA participation of adults in England (Roberts, Townsend, & Foster, 2016) and contributed towards 73% of the total self-reported MET-hours/week in both pre- and post-diagnosis prostate cancer survivors (Wang et al., 2017). Furthermore, general population adults who achieve an objectively-measured higher step count per day show a reduction in cardiometabolic risk factors (waist circumference, weight, BMI and insulin) (Tudor-Locke et al., 2017). A meta-analysis of 32 RCTs of walking interventions in the general population showed a direct impact of walking on increased aerobic capacity, reduced blood pressure, waist circumference, weight, percentage body fat and BMI (Murtagh et al., 2015). A recent review highlighted that there is strong evidence that walking can prevent and treat depression and anxiety and could improve other mental health outcomes such as happiness and self-esteem (Kelly et al., 2018). In prostate cancer survivors, post-diagnosis walking has shown an inverse association with prostate cancer-specific mortality, although this was not statistically significant ($p = .07$) (Wang et al., 2017). A prospective study of 1,455 men with localised prostate cancer showed that men who walked briskly for at least 3 hours per week had a 57% lower rate of progression compared to men who walked at a gentle pace (HR=0.43; 95% CI: 0.21-0.91) (Richman et al., 2011). Importantly, walking pace was associated with risk of progression, independently of walking duration, indicating the importance of the intensity of physical activity (Richman et al., 2011). There are also large economic benefits of walking promotion. If one in ten 40-60 year old adults in England achieved just 10 minutes of brisk walking per day, it is estimated this would save £310 million per year (Public Health England, 2017).

The huge potential of walking-based interventions and the acceptability of app-based walking interventions among cancer survivors and CNSs led to the identification of Active 10, an app developed by Public Health England, as an app that may be appropriate to recommend to the vast majority of cancer survivors. Active 10 encourages users to walk briskly for at least 10 minutes continuously (known as one Active 10) and users can set a goal to complete between 1 and 3 Active 10s per day, with the overall aim to reach 30 minutes of at least moderate intensity physical activity per day (Brannan et al., 2019). The app distinguishes between total walking and

brisk walking to ensure that users are aware when they are walking briskly enough to ensure moderate intensity (about 3 miles per hour), which confers greater health benefit than slower paced walking (Richman et al., 2011; Stamatakis et al., 2018). Brisk walking is also categorised as moderate intensity physical activity (Ainsworth et al., 2011) and therefore engaging in brisk walking contributes to the weekly recommendation that cancer survivors engage in at least 150 minutes of moderate intensity physical activity per week (Rock et al., 2012; Schmitz et al., 2010; US Department of Health and Human Services, 2008). From a theoretical perspective, the app includes BCTs that have been shown to be associated with improved adherence to/efficacy of physical activity interventions in cancer survivors such as prompts, setting of graded tasks and goal setting (Finne et al., 2018; Turner et al., 2018). Furthermore, app development and associated marketing campaigns were informed by the Capability Opportunity Motivation – Behaviour (COM-B) model (Brannan et al., 2019). Selecting an existing free app that may be appropriate to support increasing physical activity among cancer survivors is highly cost-effective as this avoids investing large sums of money into the development of a new app with similar aims. With this approach, there are no additional costs for app development and maintenance. This is carried out by Public Health England, who are a government agency, which may deliver longer term reliability and sustainability compared to collaborating with commercial partners. There are a number of freely available Active 10 resources for download and Public Health England have given permission to use the Active 10 logo and branding within other intervention promotional materials (e.g. flyers), which could accompany an app recommendation.

As a result of this, Dr Abi Fisher and I (co-Principal Investigators), submitted a successful funding application to Yorkshire Cancer Research (£620,418) to conduct a two-part study to trial the Active 10 app in breast, prostate and colorectal cancer survivors in South Yorkshire over a period of 45 months.

Phase 1 (15 months) of this work will comprise a pilot RCT of the Active 10 app plus associated promotional materials (under development) versus usual care, in a sample of 60 cancer survivors who are undergoing or have recently completed treatment (<6 months). The primary research objective within this first phase of the planned work is to assess the feasibility and acceptability of the trial procedures and methodologies and the success of recruitment. Secondary research objectives are:

- (1) to obtain mean and standard deviation estimates for the primary outcome measure to be used in the large-scale RCT that will inform the sample size calculation;
- (2) to assess willingness of participants to be randomised;
- (3) to assess willingness of patients to consent to linkage with medical records, Hospital Episodes Statistics (HES) and the National Cancer Registration and Analysis Service (NCRAS) registry for longer-term follow-up;
- (4) to perform an early economic evaluation investigating the potential cost-effectiveness of the intervention and an assessment of the value associated with obtaining further information by conducting a full trial;
- (5) to assess reasons for loss to follow-up;
- (6) to assess the overall acceptability of the intervention.

The primary outcome measures in the pilot RCT will be the recruitment rate (number of participants who are referred to research team vs. number of participants who consent to the study), retention rate (proportion of participants who complete 3-month follow-up) and adherence. Public Health England have provided initial support to provide app-collected user engagement data (e.g. usage frequency, duration) to measure adherence. Self-reported app usage will also measure adherence.

The secondary outcome measures will include physical activity (objectively measured using activPAL accelerometers and self-reported physical activity), psychosocial outcomes (including HRQoL, fatigue, sleep quality, anxiety, depression, self-efficacy), BMI and waist circumference and health and social care service use. Other secondary outcomes include the number of participants who consent to take part in the intervention study but do not consent to data linkage with medical records, HES and NCRAS registries; costs relevant to recruitment, implementation and health service use, which will be used to conduct an early assessment of cost-effectiveness in terms of incremental cost per Quality Adjusted Life Year; an estimation of the expected value of perfect information, to inform the value of conducting a full-scale RCT and the acceptability of the intervention.

Acceptability will be determined from a brief feedback survey included with the 3-month follow-up questionnaire and qualitative interviews with a purposive sample of 10 participants (5 from each group) to examine experiences of taking part in the study, being randomised, experiences of using

the app and the intervention materials, adherence to the app, and acceptability of data linkage. Brief qualitative interviews will be conducted with CNSs in participating sites to understand their experiences of being involved in the study and to seek recommendations for implementation of a full RCT. The results of the pilot study (e.g. recruitment rate, retention rate and trial procedures) will determine whether a full RCT (phase 2) is feasible. These results will be taken into account along with reasons for non-participation, interviews with CNSs regarding its implementation and the acceptability of the intervention to participants.

After the pilot study, the outcome measures for the pilot will be analysed and discussed with Yorkshire Cancer Research with regards to the feasibility of a fully-powered RCT during a formal funding review. Conditional on a successful pilot study, Yorkshire Cancer Research intend to fund phase 2 of this work, a full RCT conducted over a further 30 months. The primary research objective of phase 2 is to test the effect of the Active 10 intervention on number of steps/day (primary outcome) over 3 months in patients with breast, prostate or colorectal cancer survivors, who are undergoing or have recently completed treatment (<6 months). The main secondary research objectives are to examine whether any changes in steps per day observed at 3 months are maintained at 6 months, and to test for differences between the intervention and usual care groups in MVPA, light physical activity, physical activity self-efficacy, HRQoL, fatigue, sleep quality, anxiety and depression, BMI, waist circumference and health service use at 3 and 6 months. A health economic analysis of cost-effectiveness will also be conducted and adherence to and satisfaction with the intervention will also be assessed. The pilot analyses will be used to inform the design of this larger, fully-powered RCT and to estimate its required sample size. It may be necessary to recommend amendments to the study design/procedure, however, at this stage, a similar approach to the design, randomisation, intervention content and recruitment method as phase 1 is intended.

7.4 Concluding remarks

Physical activity may prolong survival and reduce cancer recurrence, comorbidities and other late effects, and is effective in improving quality of life and the management of common treatment side effects (e.g. fatigue, pain, sleep disturbance) in cancer survivors. There is a need for evidence-based physical activity interventions that are easier to access, low-cost and have the feasibility to be rolled out to reach a larger number of cancer survivors. The widespread and rising use of the

internet, smartphones and mobile technology mean that digital interventions have the benefit of being able to reach large proportions of the population in a way that could be more cost-effective and scalable. Digital interventions have the potential to increase cancer survivors' MVPA by 41 minutes per week, however there is less evidence for the efficacy of interventions delivered via smartphone apps. Approximately 1 in 4 breast, prostate and colorectal cancer survivors are interested in an app-based lifestyle intervention and cancer survivors report that physical activity apps that account for the varying needs of cancer survivors (e.g. with regards to cancer type, treatment, side effects, baseline fitness), promote walking and are integrated into the cancer care pathway are most likely to be successful. CNSs have a key role in physical activity promotion within cancer care and are a trusted source of support among patients. CNSs are generally positive about the use of app-based physical activity interventions within cancer care. They felt that apps could be a useful tool to offer to patients in addition to, as opposed to instead of, the current physical activity services they discuss with patients, which would increase patient choice and flexibility for how they wish to engage in physical activity support, based on their preferences and circumstances. Future work in this area should aim to strengthen the evidence-base with regards to the efficacy of smartphone-based physical activity interventions in cancer survivors, and better understand the contexts and situations in which they are most effective. Furthermore, it is vital that effective physical activity interventions are implemented better into routine cancer care, that healthcare professionals working within the cancer setting are supported to discuss physical activity with their patients, and signpost patients appropriately, regardless of delivery modality.

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Appendix A. Publication of Study 1

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REVIEW

Digital health behaviour change interventions targeting physical activity and diet in cancer survivors: a systematic review and meta-analysis

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Abstract

Purpose The number of cancer survivors has risen substantially due to improvements in early diagnosis and treatment. Health behaviours such as physical activity (PA) and diet can reduce recurrence and mortality, and alleviate negative consequences of cancer and treatments. Digital behaviour change interventions (DBCI) have the potential to reach large numbers of cancer survivors.

Methods We conducted a systematic review and meta-analyses of relevant studies identified by a search of Medline, EMBASE, PubMed and CINAHL. Studies which assessed a DBCI with measures of PA, diet and/or sedentary behaviour were included.

Results Fifteen studies were identified. Random effects meta-analyses showed significant improvements in moderate-vigorous PA (seven studies; mean difference (MD) = 41 min per week; 95% CI 12, 71) and body mass index (BMI)/weight (standardised mean difference (SMD) = -0.23; 95% CI -0.41, -0.05). There was a trend towards significance for reduced

fatigue and no significant change in cancer-specific measures of quality of life (QoL). Narrative synthesis revealed mixed evidence for effects on diet, generic QoL measures and self-efficacy and no evidence of an effect on mental health. Two studies suggested improved sleep quality.

Conclusions DBCIs may improve PA and BMI among cancer survivors, and there is mixed evidence for diet. The number of included studies is small, and risk of bias and heterogeneity was high. Future research should address these limitations with large, high-quality RCTs, with objective measures of PA and sedentary time.

Implications for cancer survivors Digital technologies offer a promising approach to encourage health behaviour change among cancer survivors.

Keywords Behaviour change · Digital interventions · Physical activity · Cancer survivors · Diet · Sedentary behaviour

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Introduction

Over 14 million people are diagnosed with cancer worldwide each year, and this is expected to rise to 22 million over the next two decades [1]. Improvements in early diagnosis and treatments mean that cancer survival is increasing. In 2012, globally there were 32 million people living beyond 5 years of diagnosis [2] and in the UK, half of people diagnosed with cancer will now survive for more than 10 years [3].

However, long-term negative consequences of cancer and treatment related side-effects are common and often debilitating. Prevalence of fatigue following a cancer diagnosis ranges from 59 to 100% depending on cancer type [4], and pain [5], sleep problems [6], physical side effects (e.g. lymphoedema) [7], weight gain [8], anxiety and depression [9, 10], fear of

cancer recurrence [11] and impaired quality of life (QoL) [12] are all commonly reported. Macmillan Cancer Support, a UK cancer charity, estimates that more than 70% of cancer survivors in the UK (~1.8 million people) are also living with at least one other long-term comorbidity [13]. The most common comorbid conditions are hypertension, obesity, mental health problems and chronic heart disease [13]. The shared risk factors between cancer, obesity and cardiovascular disease (CVD) partially explain comorbidities [14]. However, there is also emerging evidence to suggest that cancer treatment can leave survivors at greater risk for developing these conditions (e.g. due to cardiovascular toxicity of cancer therapy [15]). The greater number and severity of comorbidities is linked to greater risk of death and cancer recurrence among cancer survivors [16]. There is now strong impetus to develop interventions that improve long-term outcomes for cancer survivors.

Health behaviours such as physical activity (PA), sedentary behaviour and diet are important in risk reduction and self-management of cancer, CVD and obesity. For example, a meta-analysis of 22 prospective cohort studies of 123,574 breast cancer survivors found that greater post-diagnosis PA participation reduced all-cause (hazard ratio [HR] = 0.52, 95% CI 0.43, 0.64) and breast cancer-specific mortality (HR = 0.59, 95% CI 0.45, 0.78), and breast cancer recurrence (HR = 0.79, 95% CI 0.63, 0.98) [17]. A meta-analysis of prospective studies of colorectal cancer survivors reported similar conclusions and showed that post-diagnosis PA reduced both all-cause (summary relative risk [RR] = 0.58; 95% CI 0.48, 0.70; $n = 6$ studies) and colorectal cancer-specific mortality (summary RR = 0.61; 95% CI 0.40, 0.92; $n = 5$ studies) [18]. The authors estimated that each 10 metabolic equivalent task (MET)-hour per week increase in post-diagnosis PA was associated with 24% (95% CI 11–36%) and 28% (95% CI 20–35%) decreased total mortality risk for breast and colorectal cancer survivors, respectively [18]. Mishra et al.'s meta-analysis of non-digital interventions focused on the effect of PA on health-related QoL (HRQoL) outcomes in cancer survivors (various types) and found that greater PA participation significantly improved overall HRQoL at up to 12 weeks of follow-up (11 studies, $n = 826$; standardised mean difference [SMD] = 0.48, 95% CI 0.16, 0.81) [19]. Individual meta-analyses of other cancer-relevant outcomes identified in this same Cochrane review also found that PA interventions improved emotional well-being/mental health and social functioning, and reduced anxiety, fatigue, pain and sleep disturbance [19]. Although limited to cross-sectional and prospective studies, there is some evidence that higher levels of sedentary time are associated with lower physical and role functioning domains of QoL, and greater reporting of comorbidities, disability and fatigue [20–22]. As a result of the growing evidence of the benefits of PA following a cancer diagnosis, cancer survivors are encouraged to

avoid inactivity as far as possible and to meet the same PA guidelines as the rest of the adult population of at least 150 min of moderate-vigorous PA (MVPA) and two instances of strength/resistance-based exercises per week [23–25].

Diet may also influence outcomes following a cancer diagnosis. A meta-analysis of three studies ($n = 9966$) suggested that a low-fat diet post diagnosis can reduce breast cancer recurrence by 23% and all-cause mortality by 17% [26]. Another meta-analysis of four prospective cohort studies ($n = 3675$) found that high saturated fat intake increased cancer-specific mortality [27]. A meta-analysis of 56 observational studies in 1,784,404 cancer survivors (various types) showed greater adherence to a Mediterranean-style diet (largely based on vegetables, fruits, nuts, beans, cereal grains, olive oil and fish) was associated with lower all-cause cancer mortality for colorectal, breast, gastric, prostate, liver, head and neck, pancreatic and respiratory cancers [28]. Colorectal cancer survivors consuming a Western diet (high intake of meat, fat, refined grains and desserts) showed greater risk of recurrence and overall mortality compared to those with a prudent diet (high intake of fruits and vegetables, poultry and fish) in a prospective study of 1009 participants [29]. Similar findings have been shown in other prospective cohort studies of breast cancer survivors [30, 31]. Breast cancer survivors with better overall diet quality also reported lower levels of fatigue, independently of PA participation, at 41 months post diagnosis in a prospective cohort study [30].

Longitudinal studies have shown that obesity increases the risk of cancer recurrence among prostate [32], colorectal [33] and breast [34] cancer patients.

Despite the wealth of evidence, cancer survivors' engagement with health behaviours and adherence to lifestyle guidelines for cancer survivors are remarkably poor [35, 36]. The English Longitudinal Study of Ageing demonstrated that the proportion of cancer survivors who engaged in self-reported MVPA at least once per week fell from 13% before their cancer diagnosis to 9% after their cancer diagnosis (compared to a fall of 16 to 15% in the group who did not receive a cancer diagnosis between data collection waves) [37]. Wang et al. found that cancer survivors were less likely to engage in self-reported PA (adjusted odds ratio = 0.79, 95% CI 0.67, 0.93) compared to those without a cancer diagnosis [38]. Furthermore, few cancer survivors meet the minimum recommended guidelines of 150 min of MVPA per week. A study of over 9000 survivors of six types of cancer found that adherence to PA recommendations varied from 30% (uterine cancer) to 47% (skin melanoma); however, this study did use self-reported PA measures [36]. While this study reported that 35% of breast cancer survivors were meeting guidelines, another study which used accelerometers to measure PA objectively found that this can be as low as 16% and those with highest levels of comorbidities were the least active [39]. Consequently, there is a need for evidence-based interventions

that are easy to access, low-cost and which therefore have the feasibility to be rolled out to reach a large number of cancer survivors.

A move towards digital health behaviour change interventions (DBCIs) has been driven by widespread and rising use of the Internet, smartphones and mobile technology [40, 41]. The most recent Ofcom Communications Market report for the UK has shown that the proportion of adults going online using a mobile phone has risen from 20% in 2009 to 66% in 2016 and 71% of adults own a smartphone [41]. DBCIs use technologies such as text messaging, email, mobile applications (apps), video-conferencing (e.g. Skype), social media, websites and online patient portals increasing access to information, connecting patients with health services and as an approach to remote delivery of behaviour change interventions. DBCIs have been used in the promotion of medication adherence [42], management of long-term conditions [43–45], promoting smoking cessation [46] and promoting PA participation and dietary behaviours [47–50]. A recent systematic review of 224 studies reported that Internet and mobile interventions improved diet, PA, obesity, tobacco and alcohol use up to 1 year [51]. Among cancer survivors, a recent systematic review of 27 non-face-to-face intervention studies found telephone interventions as an effective approach to delivering PA and dietary interventions [52]. However, newer digital technologies should now be evaluated in this population as only three of the studies in that systematic review included used web-based methods to deliver the intervention [53–55]. No systematic review or meta-analysis has assessed the efficacy of DBCI interventions targeting PA, diet and/or sedentary behaviour among cancer survivors specifically.

Therefore, the primary objective of this study was to perform a systematic review and meta-analysis of health behaviour interventions using digital technologies in cancer survivors in order to assess their efficacy in promoting PA, reducing sedentary behaviour or improving dietary quality. Secondary aims were to explore any effects of DBCIs on BMI/weight, other cancer-relevant outcomes and the theoretical underpinning of included studies.

Methods

Search strategy

A systematic literature search was conducted from database inception to November 8, 2016, of the following databases: Medline, EMBASE, PsycINFO and CINAHL. Full details of the search strategy/terms used can be found in Online Resource 1. Broadly, the search strategy combined synonyms for PA, diet and/or sedentary behaviour; with types of DBCIs (e.g. website, mobile app, text messaging); and with words for cancer survivor(ship).

Limits included peer-reviewed, English language articles in human subjects. Forward and backward citing of included studies and hand-searching of relevant journals were also conducted to identify relevant articles. The protocol was registered in the PROSPERO database (CRD42016026956). After piloting of the search strategy, no new or relevant articles from other databases specified in the protocol (Cochrane Library, Web of Science, ACM Digital Library, or IEEE Xplore) were identified so these databases were excluded for the final search. As specified in the protocol, the ProQuest database (grey literature) was searched; however, this resulted in >60,000 search results. Results were sorted by relevance, and the first 200 titles were reviewed. No additional, relevant papers which met criteria were identified throughout this process so grey literature was not included.

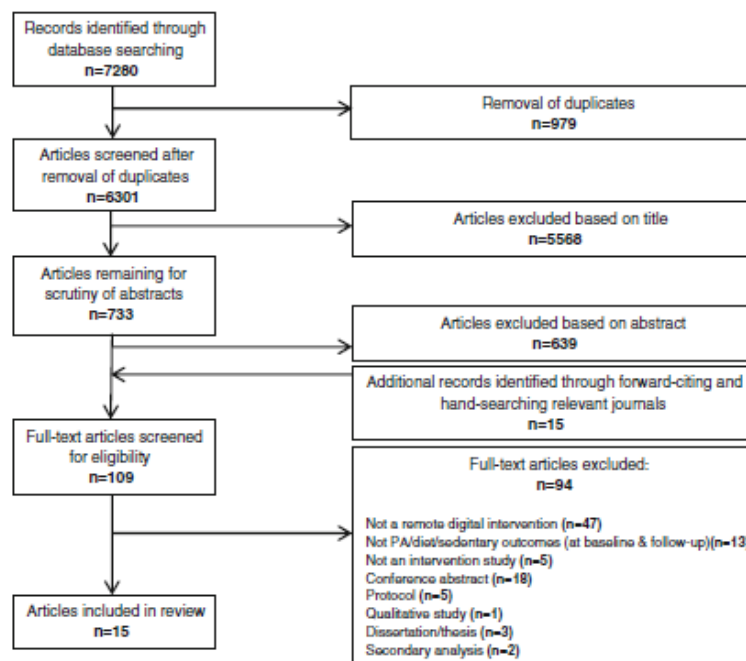
Study selection

Studies were selected in line with the search strategy shown in Fig. 1. Eligible studies included DBCIs delivered remotely and targeting at least one of the following health behaviours: PA, diet and/or sedentary behaviour in adults (≥ 18 years) who had a cancer diagnosis of any type. There were no restrictions on quantitative study designs, so both randomised and non-randomised controlled trials and one-arm pre-post comparison studies could be included. However, qualitative studies and protocols were excluded. Studies must have measured at least one of the target health behaviours (PA, diet and/or sedentary behaviour) at baseline and follow-up, but there were no limits on length of follow-up for inclusion.

Data extraction and quality assessment

Two authors (AR and AF) independently reviewed 109 full-text articles screened for eligibility and extracted the data for included studies including author, country of study, study design, sample size, retention rate, population studied, age of participants, study duration, intervention type (i.e. type of DBCI), description of intervention content (including incorporated behaviour change techniques (BCTs)), approaches to measurement of engagement/adherence to the intervention, control group treatment and outcomes measured. Any discrepancies were resolved through discussion. Michie et al.'s BCT Taxonomy (v1) [56, 57] was used to code BCTs based on information provided in the included studies (and any supplementary material). The Cochrane Collaboration's tool for assessing risk of bias was used to evaluate methodological quality of included studies [58], and Michie and Prestwich's Theory Coding Scheme was used to evaluate the theoretical basis of the included studies [59].

Fig. 1 PRISMA flow diagram illustrating article selection strategy



Statistical methods

Where possible, findings from both RCTs and one-arm pre-post studies were synthesised in random effects meta-analyses using Stata. Effect sizes for the intervention were calculated using the difference in final values between experimental and control groups in RCTs and the change in scores before and after the intervention in pre-post studies. It is not recommended to combine studies using a mixture of final values and change scores when using standardised mean differences (SMDs) across studies using different measurement units/tools to assess an outcome [58]. Therefore, outcomes using the same measurement unit were chosen wherever possible so non-standardised mean differences could be used and RCTs and pre-post studies could be combined in the meta-analyses [58]. Where this was not possible (i.e. fatigue outcomes), SMDs and their associated 95% CIs were calculated, and meta-analyses were conducted for the RCTs only (where the effect size reflects difference in final values between groups). As BMI is largely influenced by weight, the variability in reliability was judged to be similar for weight and BMI. Therefore, SMDs were used to pool the effect of BMI and weight across both the RCTs and pre-post studies reporting these outcomes. For PA outcomes, MVPA was chosen as the outcome measure of interest due to the American College of

Sports Medicine’s recommendation that cancer survivors follow the PA guidelines for the general population of at least 150 min of at least moderate intensity PA per week [24]. Studies reporting MVPA duration in minutes were pooled in the meta-analysis, so studies with differences in final values and change scores could be used using mean differences. Studies that did not report moderate and vigorous PA separately or MVPA combined in minutes were not included in the meta-analysis of PA outcomes. For the studies that reported minutes of moderate and vigorous PA separately, a new combined MVPA variable was calculated. To combine the means for moderate and for vigorous PA, the following formula was used:

$$\bar{x}_{MVPA} = \bar{x}_{moderate\ PA} + \bar{x}_{vigorous\ PA}$$

To combine the standard deviations for moderate and vigorous PA, the following formula was used:

$$\sigma_{MVPA} = \sqrt{(\sigma^2_{moderate\ PA}) + (\sigma^2_{vigorous\ PA})}$$

Publication bias was explored using funnel plots prepared in Stata. Due to the small number of included studies for each outcome, tests for funnel plot asymmetry (e.g. Egger’s

regression test [60]) were not deemed appropriate and only visual inspection of funnel plots was conducted.

Results

Study selection

See Fig. 1 for the PRISMA flow diagram of the study selection process. The search strategy initially identified 7280 records, and 15 were included in the final review [53–55, 61–72].

See Table 1 for characteristics of included studies and Table 2 for characteristics of intervention types and outcomes. The majority of studies (12/15) were published between 2014 and 2016, with one study published in 2012 [54] and two in 2013 [53, 55]. Sample sizes ranged between 7 [64] and 462 [71]. Eight studies were RCTs [53–55, 61, 63, 67, 71, 72], and the remaining seven were pre-post comparison studies [62, 64–66, 68–70]. The studies used an average of eight BCTs (range 2–16). Self-monitoring of behaviour ($n = 15$), goal setting (behaviour) ($n = 13$), credible source ($n = 13$) and feedback on behaviour ($n = 12$) were the most frequently described BCTs. Short et al.'s study [72] was the only study which used a three-arm RCT design where all groups received the same intervention content, but the delivery schedule differed. As there was no true control, for the purposes of this review this study was treated as a pre-post. All 15 studies assessed the impact of the DBCIs on PA, five on diet [61, 67, 68, 70, 71], and no studies assessed the impact of DBCIs on sedentary behaviour.

Primary outcomes

Physical activity and sedentary time

All 15 included studies measured the impact of DBCIs on PA [53–55, 61–72]. All used self-reported PA as outcomes: five used the Godin Leisure-Time Exercise Questionnaire (GLTEQ) [53, 61, 63, 69, 72], two the International Physical Activity Questionnaire (IPAQ) [66, 70], one a 7-day PA recall [54] and one the Short Questionnaire to Assess Health Enhancing Physical Activity (SQUASH) [71]; two identified the number of days in the last seven that the participant engaged in moderate and/or vigorous PA [55, 62]; three studies reported percentage of participants meeting PA guidelines (150 min of MVPA per week) [54, 63, 67] and two reported stages of change for PA [65, 67]. Short et al. [72] also reported a resistance training score. Hoffman et al. [64] reported the number of minutes walked, steps walked and number of balance exercises completed. McCarroll et al. [68] reported number of minutes of PA completed and the number of calories

expended as logged via the participant using the mobile app used for their intervention.

MVPA (minutes) was available for 11 studies (five as a combined variable [53–55, 61, 72], five as separate moderate and vigorous variables (combined for the purposes of the meta-analysis) [62, 63, 66, 70, 71], and raw data was available for Puzskiewicz et al. [69] to calculate a combined MVPA variable). Of these, seven (five RCTs [53, 54, 61, 63, 71] and two pre-post studies [69, 72]) reported MVPA duration in minutes per week and were pooled in a random effects meta-analysis using data from 1034 participants (see Fig. 2). DBCIs resulted in significant increases in MVPA minutes/week (MD = 41; 95% CI 12, 71; $p = 0.006$) with very high levels of heterogeneity ($I^2 = 81%$). Independently, the RCTs showed a significant increase in MVPA (MD = 49, 95% CI 16, 82, $p = 0.004$, $I^2 = 73%$). A funnel plot suggested that there may be some indication of publication bias among smaller studies (see Fig. 1, Online Resource 2).

Of the other eight studies which could not be included in the meta-analysis, four reported a significant effect, [55, 65–67], two did not report significant findings [62, 68] and two did not conduct significance testing due to small sample sizes [64, 70]. No studies reported effects on sedentary time.

Diet

Five studies measured the impact of DBCIs on dietary intake [61, 67, 68, 70, 71]. Due to the variation in approaches to assessment and measurement of dietary outcomes, a meta-analysis was not considered appropriate. Three studies [61, 67, 71] were RCTs and two were pre-post studies [68, 70]. Only two of the studies reported a significant effect on dietary outcomes [67, 71]; however, this no longer remained significant after correcting for multiple testing in Kanera et al.'s study [71]. Quintiliani et al. [70] did not conduct significance testing, due to the very small sample ($n = 10$).

Secondary outcomes

BMI/weight

Four studies assessed BMI and/or weight (one RCT [53] and three pre-post studies [68–70]). Three assessed BMI [53, 68, 69] and Quintiliani et al. assessed weight [70]. Using data from 122 participants (66 participants in RCTs; 56 in pre-post studies), there was a significant pooled reduction in BMI/weight (SMD = -0.23 ; 95% CI -0.41 , -0.05 ; $p = 0.011$; $I^2 = 0.0%$) (see Fig. 2, Online Resource 2). The RCT showed a significant reduction in BMI (SMD = -0.28 , 95% CI -0.52 , -0.04 , $p = 0.023$). A funnel plot revealed no evidence of publication bias for BMI/weight outcomes.

Table 1 Characteristics of included studies

Author, year	Country	Study design	Sample size	Retention rate at follow-up	Women (%)	Age in years, mean (SD)	Cancer type(s)
Bartum, 2014 [61]	USA	RCT	303	86.1% (303/352)	82	49.3 (11)	Any type of cancer, completed treatment >4 weeks prior to study
Berg, 2014 [62]	USA	Pre-post	19	79.2% (19/24)	71	23.4 (3.9)	Adult (18–34 years) survivors of childhood cancers (any type)
Forbes, 2015 [63]	Canada	RCT	87	91.6% (87/95)	56	65.1 (8.5)	Breast, prostate and colorectal cancer survivors (96% currently disease free; 75% completed treatment)
Hatchett, 2013 [55]	USA	RCT	74	87.1% (74/95)	100	No data	Breast cancer survivors, completed treatment
Hoffman, 2014 [64]	USA	Pre-post	7	100% (7/7)	71	64.6 (6.5)	NSCLC survivors (immediately before + after surgery/during treatment)
Hong, 2015 [65]	USA	Pre-post	26	86.7% (26/30)	69	69 (median)	Any type of cancer survivor, either undergoing or completed treatment
Kanera, 2016 [71]	Netherlands	RCT	394 ^a	89.2% (462/518) ^a	80	56.0 (11.4)	Any type of cancer, completed treatment >4 and <56 weeks prior to study, no recurrence
Kuijpers, 2016 [66]	Netherlands	Pre-post	73	79.3% (73/92)	100	49.5 (11.4)	Breast cancer survivors, either undergoing or completed treatment 3–12 months prior to study
Lee, 2014 [67]	South Korea	RCT	57	96.6% (57/59)	100	43.2 (5.1)	Breast cancer survivors, completed treatment <1 year prior to study
McCarroll, 2015 [68]	USA	Pre-post	35	70.0% (35/50)	100	58.4 (10.3)	Overweight/obese breast and/or endometrial cancer survivors with desire to lose weight, diagnosis <3 years prior to study
Paszkiwicz, 2016 [69]	UK	Pre-post	11	100% (11/11)	82	45 (9.4)	Breast, prostate or colorectal cancer survivors, completed treatment
Quintiliani, 2016 [70]	USA	Pre-post	10	100% (10/10)	100	58.6 (6.1)	Breast cancer survivors, >2 years since diagnosis and >6 months since end of treatment
Rabin, 2012 [54]	USA	RCT	17	94.4% (17/18)	56	32.2 (5.6)	Young adult (18–39) cancer survivors, completed treatment <10 years prior to study
Short, 2016 [72]	Australia	Pre-post ^b	156 ^b	31.7% ^c (156/492)	100	55.0 (9.7)	Breast cancer survivors, completed treatment
Valko, 2013 [53]	USA	RCT	66	76.7% (56/86)	91	31.7 (5.1)	Young adult (21–39) cancer survivors, diagnosed >18 years of age, >1 year since diagnosis, completed treatment

^aKanera et al. presented physical activity data for 394 participants (sample size used in meta-analysis); however, retention for other measures at follow-up was 46.2

^bShort et al. (2016) is treated as a pre-post study due to the lack of control group across the three intervention arms

^cShort et al.'s paper presents results for 3-month follow-up (immediately post-intervention) because retention rate at 6 months was very low (10.8% (53/492)). Sample size/retention rate presented here is for the 3-month follow-up

Table 2 Intervention types and outcomes for included studies

Author, year	Intervention type	Study duration	Description of intervention	Behaviour change techniques (BCTs)	Approaches to measurement of engagement/adherence	Control group treatment	Outcomes measured
Bauman, 2014 [61]	Online workshop (website)	6 months	6-week online course providing information, skill building, weekly action plans, social networking and peer support, exercise logs, relaxation exercises	1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified)	Mean (SD) online sessions attended was 5.3 (1.28) 67% attended all 6 sessions 86.8% attended >4 sessions	Waitlist control	PA, diet, fatigue, depression, insomnia
Berg, 2014 [62]	Emails + associated website	12 weeks	Biweekly emails to deliver module content and website provides graphical depictions of participant-reported health behaviours and health information.	9.1 Credible source 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour Participants also offered deals for healthy goods/services in local area for completing self-monitoring (regardless of behaviour reported)	Completion of self-monitoring ('check-in assessment') over the 12-module period (6 weeks) fell from 91.7 to 66.7%	N/A	PA, SE, alcohol consumption, smoking
Forbes, 2015 [63]	Online workshop (website)	10 weeks	9-week workshop to deliver content (e.g. dispelling PA myths, exercising safely, SMART planning/making SMART goals). Website used to monitor PA and email feedback.	2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 5.1 Information about health consequences 6.2 Social comparison 9.1 Credible source 10.4 Social reward	Percentage of completed modules fell from 50% (week 1) to 10% (week 9) 94% logged in at least once, 85% recorded PA, at least once, 67% viewed modules at least once	Waitlist control	PA, QoL (cancer-specific), QoL (generic), fatigue
Hatchett, 2013 [55]	Email + access to e-counsellor	12 weeks	Emails designed to increase PA by influencing SCT variables. E-counsellor offered tailored PA advice and encouraged participant engagement with intervention.	1.1 Goal setting (behaviour) 1.2 Problem solving 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 9.1 Credible source 13.5 Identity associated with changed behaviour	Not measured/reported	Waitlist control	PA, SE, self-regulation, OE value, exercise role identity
Hoffman, 2014 [64]	Nintendo Wii Fit Plus	16 weeks	Virtual walking environment with gradual increase in target walking time. Three Wii Fit Plus balance exercises per day were also recommended.	1.1 Goal setting (behaviour) 1.5 Review behaviour goals 2.3 Self-monitoring of behaviour 8.7 Graded tasks 9.1 Credible source 12.5 Adding objects to the environment	Mean (SD) adherence rate to intervention at end of study was 87.6% (12.2%)	N/A	PA, fatigue, SE
Hong, 2015 [65]	Mobile-enabled website	8–12 weeks	Website used for goal setting, activity tracking, personalised feedback and progress reviews, social networking, tips on healthy living and links to reliable health information	1.1 Goal setting (behaviour) 1.4 Action planning 1.5 Review behaviour goals 1.6 Discrepancy between current behaviour and goal 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 5.1 Information about health consequences	Website use 12% once/fortnight; 62% once/week; 19% 2–3 times/week 8% 4–5 times/week	N/A	PA, QoL (generic)
Kanera, 2016 [71]	Online workshop (website)	6 months	Automated system to evaluate baseline assessment and select personalised intervention components using '15-min' algorithms. Users are recommended modules based on	9.1 Credible source 1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.5 Review behaviour goals 1.6 Discrepancy between current behaviour and goal 2.2 Feedback on behaviour	Specific modules were recommended to participants based on current behaviours from 8 modules in total. Participants followed mean (SD) 2.23 (1.58) modules. 25% participants followed PA	Waitlist control	PA, diet, smoking

Table 2 (continued)

Author, year	Intervention type	Study duration	Description of intervention	Behaviour change techniques (BCTs)	Approaches to measurement of engagement/adherence	Control group treatment	Outcomes measured
Kuijper, 2016 [66]	Online portal (website)	4 months	assessments but have access to all 8 modules. Offers personalised education materials, overview of appointments, access to EMB. Tailored PA support based on clinical characteristics, PA levels and motivation.	<ul style="list-style-type: none"> 2.2 Self-monitoring of behaviour 3.1 Social support (unspecified) consequences 6.2 Social comparison 7.1 Prompts/cues 8.2 Behaviour substitution 9.1 Credible source 9.2 Prais and cons 11.2 Reduce negative emotions 13.2 Framing/reframing 1.1 Goal setting (behaviour) 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 6.2 Social comparison 9.1 Credible source 	module, and 62% followed diet module.	N/A	PA, QoL (generic), SE
Lee, 2014 [67]	Website + text messaging	12 weeks	Website used for assessment, education, tailored information provision and action planning (goal setting, scheduling, monitoring and automatic feedback). Daily automatic feedback provided on recommended and actual behaviours	<ul style="list-style-type: none"> 1.1 Goal setting (behaviour) 1.4 Action planning 1.6 Discrepancy between current behaviour and goal 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 5.1 Information about health consequences 5.6 Information about emotional consequences 7.1 Prompts/cues 	Website logins ranged from 0 to 62, and duration of use ranged from 2 to 38 min. Participants on treatment (M = 10.9 logins) used the website more often than off-treatment (M = 5.6 logins) participants but those who were off treatment had a longer mean duration (15.2 min) of log in compared to those on treatment (11.3 min)	50-page booklet on exercise/diet	PA, diet, QoL (cancer-specific), fatigue, anxiety, depression, SE
McCarroll, 2015 [68]	Mobile app	4 weeks	Participants log nutrition/PA through app which provided real-time personalised feedback. Limited carbohydrate intake to <70 g/day and increase fibre intake to 30 g/day.	<ul style="list-style-type: none"> 9.1 Credible source 1.1 Goal setting (behaviour) 1.3 Goal setting (outcome) 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 2.4 Self-monitoring of outcomes of behaviour 3.1 Social support (unspecified) 7.1 Prompts/cues 9.1 Credible source 	Not measured reported	N/A	PA, diet, QoL (cancer-specific), SE, weight, waist circumference, BMI
Pazkiewicz, 2016 [69]	Mobile app	6 weeks	Tailored PA programme using video demonstrations is recommended based on users' preferred PA goals, duration, type and difficulty of PA.	<ul style="list-style-type: none"> 15.1 Verbal persuasion about capability 1.1 Goal setting 1.4 Action planning 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 	Participants used app mean (SD) of 2.07 (0.68) times per week. Mean (SD) session duration was 25:08 (8:22) minutes. Mean (SD) app use duration	N/A	PA, QoL (cancer-specific and generic), fatigue, BMI, anxiety, depression, sleep quality

Table 2 (continued)

Author, year	Intervention type	Study duration	Description of intervention	Behaviour change techniques (BCTs)	Approaches to measurement of engagement/adherence	Control group treatment	Outcomes measured
Quintillani, 2016 [70]	Text messaging + Fitbit + telephone counselling	10 weeks	Text messages assess participants' dietary intake, and Fitbit assesses weight and step count. Four technology-assisted telephone calls (based on PA, sleep and 2 nutrition-related topics) were guided by motivational interviewing	<ul style="list-style-type: none"> 4.1 Instruction on how to perform a behaviour 6.1 Demonstration of the behaviour 7.1 Prompts/cues 8.7 Graded tasks 10.4 Social reward 1.1 Goal setting (behaviour) 1.5 Review behaviour goals 1.6 Discrepancy between current behaviour and goal 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 2.4 Self-monitoring of outcome of behaviour 7.1 Prompts/cues 9.1 Credible source 	<p>was 44.00 min (20.50) per week (range 24.50–91.00 min)</p> <p>Of 70 opportunities (7 days/week × 10 weeks), mean (SD) responses to text messages was 60 (13), according a step measurement was 64 (7), recording a weight measurement was 45 (24) and recording a sleep measurement was 43 (19). All participants completed all 4 counselling calls.</p> <p>Mean (SD) website login was 14.75 (8.46). Mean (SD) number of days participants logged PA was 11.38 (7.93), used goal setting feature was 5.25 (4.17), used stage-based manual was 3.13 (2.17), accessed PA-related information was 1.25 (1.28), accessed PA resources was 0.88 (1.13) and accessed PA tips was 0.50 (1.07).</p>	N/A	PA, diet, fatigue, perceived stress, SE, weight
Rabin, 2012 [54]	Website	12 weeks	PA manual provided matched with participants' stage of change and responses to questionnaires on the website. Website also enabled participant to set PA goals and log PA.	<ul style="list-style-type: none"> 1.1 Goal setting (behaviour) 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 5.1 Information about health consequences 9.1 Credible source 	<p>Mean (SD) website login was 14.75 (8.46). Mean (SD) number of days participants logged PA was 11.38 (7.93), used goal setting feature was 5.25 (4.17), used stage-based manual was 3.13 (2.17), accessed PA-related information was 1.25 (1.28), accessed PA resources was 0.88 (1.13) and accessed PA tips was 0.50 (1.07).</p>	Provided with 3 cancer + survivorship websites	PA, fatigue, POMS,
Short, 2016 [72]	Online workshop (website)	12 weeks	3 online modules delivered with a combination of non-tailored information (PA guidelines, increasing motivation and preventing relapse) and tailored support (e.g. based on current PA, outcome expectations, health status, eliciting social support, overcoming barriers, action planning)	<ul style="list-style-type: none"> 1.1 Goal setting (behaviour) 1.2 Problem solving 1.4 Action planning 1.5 Review behaviour goals 1.6 Discrepancy between current behavioural and goal 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 4.1 Instruction on how to perform a behaviour 5.1 Information about health consequences 5.2 Salience of consequences 7.1 Prompts/cues 8.7 Graded tasks 9.1 Credible source 	<p>Mean (SD) website usage duration was 61.1 min (80.1) (range 0–550 min). Mean (SD) website login was 5.18 (8.48) (range 1–45). All participants viewed at least one module. 85% in the weekly module group and 75% in the monthly module group viewed all 3 modules. 60% of the weekly module group completed 2 (of 3) modules compared to 46% of the monthly module group. 75% of participants completed at least one action plan. 91.7% in the monthly module group completed 2 action plans compared to 71.7% in weekly module group.</p>	N/A	PA
Vallé, 2013 [53]		12 weeks		<ul style="list-style-type: none"> 1.1 Goal setting (behaviour) 			

Table 2 (continued)

Author, year	Intervention type	Study duration	Description of intervention	Behaviour change techniques (BCTs)	Approaches to measurement of engagement/adherence	Control group treatment	Outcomes measured
	Facebook support group + website		Weekly messages (sent via Facebook) and group administrator posted discussions within the group throughout intervention. Participants also had access to website for goal setting and PA diary and pedometers to measure steps.	1.2 Problem solving 1.6 Discrepancy between current behaviour and goal 2.2 Feedback on behaviour 2.3 Self-monitoring of behaviour 3.1 Social support (unspecified) 5.1 Information about health consequences 9.1 Caching source 12.5 Adding objects to the environment	Intervention participants posted a total of 153 Facebook comments to group wall compared to 188 comments in control group. 49% of participants in both groups made >2 Facebook posts in the study period. Intervention participants set a mean of 4.2 goals, and submitted a mean of 21.9 PA entries and 13.1 steps entries. 71% tracked PA data at least once. Proportion of participants logging either PA or steps declined from 57.8% in week 1 to 24.4% in week 12.	Basic Facebook group membership	PA, QoL (cancer-specific), BMI

* Short et al. (2016) is treated as a pre-post study due to the lack of a control group across the three intervention arms (single module, three weekly modules, three monthly modules) PA physical activity, SE self-efficacy, SMART specific, measurable, attainable, realistic, timely, SCT social cognitive theory, OE outcome expectancy, QoL quality of life, EMR electronic medical record

Other cancer-relevant outcomes

Fatigue

Seven studies measured the impact of DBCIs on fatigue [54, 61, 63, 64, 67, 69, 70]. Of these, three used the Brief Fatigue Inventory (BFI) [61, 64, 67], two used the Functional Assessment of Chronic Illness Therapy-Fatigue (FACIT-F) [63, 69], one used the Profile of Mood States-Fatigue (POMS-Fatigue) [54] scale and one used a 0–10 scale [70]. SMDs were required to pool effects across studies due to the variation in measurement tools. Therefore, meta-analysis was only conducted on the three RCTs where appropriate data could be extracted [54, 61, 63], using data from 406 participants (see Fig. 3, Online Resource 2). DBCIs resulted in a decrease in fatigue, but this was not significant (SMD = -0.23; 95% CI -0.51, 0.05; $p = 0.103$; $I^2 = 78\%$). Once again, very high levels of heterogeneity were displayed for fatigue. A funnel plot revealed no evidence of publication bias for fatigue outcomes. Of the remaining four studies, only one reported a significant reduction in fatigue [67]. Two of these studies did not report significance testing [64, 70] due to very small sample sizes (7 and 10, respectively).

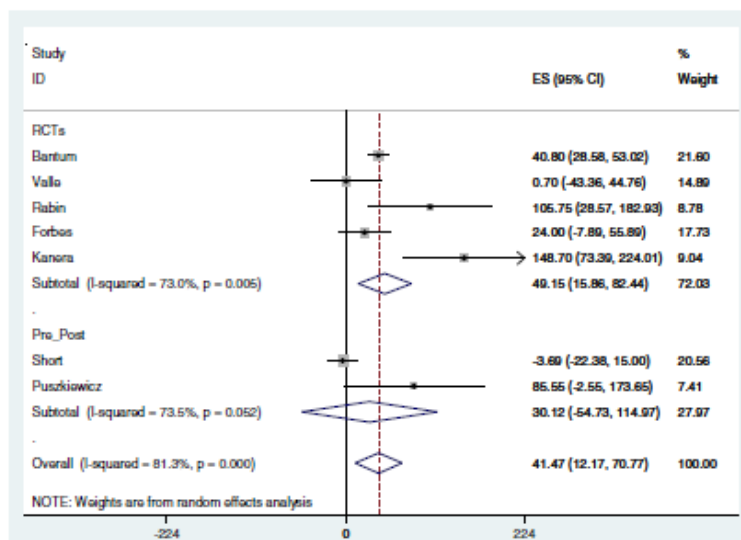
Cancer-specific QoL

Five studies assessed cancer-specific measures of QoL [53, 63, 67–69]. Four studies used the FACT-G [53, 63, 68, 69] and one used the Quality of Life Questionnaire-Core 30 (QLQ-C30) [67]. The four studies using the FACT-G (two RCTs [53, 63] and two pre-post studies [68, 69]) were pooled using data from 198 participants (152 participants in RCTs; 46 from pre-post studies) (see Fig. 4, Online Resource 2). Overall, there were no significant changes on cancer-specific QoL (MD = 0.61; 95% CI -1.83, 3.06; $p = 0.62$; $I^2 = 42\%$). Similar results are shown when just pooling results from RCTs (MD = 0.06; 95% CI -2.44, 2.57; $p = 0.960$; $I^2 = 0\%$). A funnel plot revealed no evidence of publication bias for cancer-specific QoL outcomes. The remaining study also found a non-significant difference between groups [67].

Generic QoL

Four studies assessed generic measures of QoL [63, 65, 66, 69]. Each study reported various domains of QoL as opposed to a global score using various measurement tools (i.e. Short Form (36) Health Survey (SF-36) [63, 66], the EuroQol 5 Dimensions (EQ5D) [69] and a seven-item non-validated measure [65]). Two studies found no significant changes in any QoL domains [63, 69]. One study found a significant improvement in role functioning-emotional and mental health for those during treatment and a significant improvement in social functioning for those who had finished treatment [66].

Fig. 2 Metaanalysis of DBCIs on MVPA



N.B. p-values shown in Figure 2 represent significance for testing of heterogeneity

Hong et al. found significant improvements in self-rated health, fatigue, pain, shortness of breath, stress, sleep quality and overall QoL using a non-validated scale [65].

Mental health

Three studies measured the impact of DBCIs on depression [61, 67, 69], none of which reported any significant impact. Two studies assessed the impact on anxiety [67, 69], neither of which reported a significant effect. Rabin et al. [54] also measured Profile of Mood States (anger, depression, tension/anxiety, vigour, confusion) and did not find a significant change in scores between groups.

Sleep disturbance

Two studies measured the impact of DBCIs on sleep disturbance [61, 69]. Both studies reported a significant improvement in sleep quality; Bantum et al. [61] showed a significant reduction in insomnia, and Puszkiewicz et al. [69] showed a significant improvement in sleep quality.

Theoretical underpinning

Twelve studies reported some level of theoretical basis to their intervention design [53–55, 62, 64–68, 70–72]. Of those that did mention a theoretical influence, Social Cognitive Theory (SCT) was most frequently reported [53, 55, 66, 68, 71, 72], and sometimes used in combination with other theories (i.e.

Transtheoretical Model (TTM) [54] or the Theory of Planned Behaviour (TPB) [66]. Other theories included the Theory of Reasoned Action [62], Theory of Symptom Self-Management [64], Theory of Goal Setting [65], the TTM alone [67] and the Social Contextual Model [70]. The description of the theoretical underpinning of the DBCIs varied across studies, but was relatively poor. Only seven studies explicitly reported how theory/predictors were used to select/develop intervention techniques [53–55, 66, 67, 71, 72], and only six studies used theory/predictors to tailor intervention techniques to participants [54, 64, 66, 67, 71, 72]. Six studies measured theory-relevant constructs and reported outcomes pre and post intervention [53, 62, 66–68, 70]. Of these six studies, three reported no significant change in measures related to self-efficacy [62, 66, 70]. Lee et al. [67] reported that the 'stage of change' and self-efficacy for PA and fruit and vegetable consumption was significantly higher in the intervention group, and McCarroll et al. [68] reported a significant increase in self-efficacy between pre and post intervention. Valle et al. was the only study which conducted mediational analysis of theoretical constructs/predictors (presented in an associated paper [73]). However, this study showed that the intervention group reported lower self-efficacy for PA and social support from friends on social networking websites compared to the control group. Changes in social support from friends on social networking sites were positively related to changes in MVPA; however, it was those in the control group who reported increased social support from friends on social networking sites compared to the intervention group [73].

Risk of bias in included studies

See Fig. 3 for an assessment of the risk of bias in the included studies. Study quality was deemed to be low for the majority of included studies. For the RCTs, there was adequate randomisation sequence generation in the majority of the studies; however, allocation concealment was much less clear. The lack of a control group in the seven pre-post studies highly increased the risk of bias, reducing the confidence which can be placed on the observed effects. All of the studies were judged to be high risk for other sources of bias, for instance all 15 studies used self-reported PA, as opposed to objective measures (e.g. accelerometry). Some of the RCTs did not report (or it was unclear) whether baseline outcome measures and/or participant characteristics were similar between groups [53, 54, 61, 63, 71, 72]. Furthermore, the representativeness of the sample was fairly narrow in that the majority of the study samples which consisted of predominantly female, middle-aged, English-speaking, breast cancer survivors of high educational/income level, which likely limits the generalizability of the findings across the wider population of cancer survivors. Most of the studies had small sample sizes (generally ranging between 20 and 100), and only three studies had larger samples [61, 71, 72] (303, 462 and 492, respectively). Despite the largest sample size at baseline in Short et al.'s study [72], retention was extremely low (32% at 3 months and 11% at 6 months of follow-up).

Discussion

The current meta-analysis found that DBCIs resulted in an increase in MVPA participation of approximately 40 min per week. While meta-analysis was not possible for dietary outcomes, there was mixed evidence for an effect on dietary intake. No studies assessed sedentary behaviour. Meta-analyses also revealed a significant reduction in BMI, a reduction in fatigue which did not reach statistical significance, and no change was seen in cancer-specific measures of QoL. For other secondary outcomes where meta-analysis was not possible, there was mixed evidence for the effect on domains of generic QoL measures and theoretical constructs (e.g. self-efficacy). There is no evidence for an improvement in anxiety or depression, and while only two studies assessed sleep disturbance, both reported a significant improvement.

To our knowledge, this is the first meta-analysis to assess the current evidence with regards to DBCIs targeting PA and/or diet among cancer survivors. An increase in approximately 40 min of MVPA per week is important given that this represents a substantial proportion (27%) of cancer survivors' recommended weekly MVPA participation [23–25]. While there is limited evidence on the dose-response relationship between MVPA and mortality and recurrence outcomes, Schmid et al. estimated that each 10 MET-hour per week increase in post-diagnosis PA (approximately equivalent to the 150-min MVPA/week guideline) was associated with 24% (95% CI 11–36%) and 28% (95% CI 20–35%) decreased total mortality risk for breast and colorectal cancer survivors, respectively [18]. Schmid et al. also reported that breast or colorectal cancer survivors who increased their PA by any amount between pre and post diagnosis showed a decreased total mortality risk (RR = 0.61, 95% CI 0.46–0.80) compared to cancer survivors who did not change their PA level or who were insufficiently active pre diagnosis [18]. Therefore, even small increases in MVPA post diagnosis are likely to be beneficial for cancer survivors.

It is noteworthy that a third of the included studies were published in 2016, illustrating the rise in research interest of the effectiveness of DBCIs. It is interesting to compare the findings of this study with other meta-analyses using non-digital PA interventions among cancer survivors. While we did not find a significant reduction in fatigue (SMD = -0.23), Mishra et al. did find a significant improvement, both for survivors who had completed treatment (SMD = -0.82) [19] and who were still undergoing active treatment (SMD = -0.73) [74]. We also did not find any improvement in cancer-specific measures of QoL, while Mishra et al. reported positive improvements in both of their meta-analyses. Mishra et al. also found significantly improved anxiety and depression, sleep quality and improvements in some domains of generic measures of QoL (e.g. social, physical and role functioning) [19, 74]. The small number of studies assessing these outcomes

	Random sequences generation (selection bias)	Allocation concealment (selection bias)	Incomplete outcome data addressed adequately (attrition bias)	Blinding of participants to allocation (performance bias)	Blinding of outcome assessment (detection bias)	Selective outcome reporting (reporting bias)	Other bias
Bantum 2014	+	?	+	-	?	+	-
Berg 2014	N/A	N/A	+	-	?	+	-
Forbes 2015	+	?	+	-	?	+	-
Hatchett 2013	?	?	+	-	?	?	-
Hoffman 2014	N/A	N/A	+	-	?	?	-
Hong 2015	N/A	N/A	+	-	?	+	-
Kanera 2016	+	+	+	-	+	+	-
Kuijpers 2016	N/A	N/A	+	-	?	+	-
Lee 2014	+	?	+	+	+	+	-
McCarroll 2015	N/A	N/A	+	-	?	?	-
Puszkiewicz 2016	N/A	N/A	+	-	+	+	-
Quintiliani 2016	N/A	N/A	+	-	?	+	-
Rabin 2012	?	?	+	-	?	+	-
Short 2016	+	+	+	-	+	+	-
Valle 2013	+	?	+	-	?	+	-

Fig. 3 Risk of bias in included studies

meant that meta-analyses for these outcomes were not possible in the current study. However, in the studies that did assess these outcomes, we did not find any evidence for an improvement in anxiety and depression, but both studies assessing sleep reported significant improvements. We also found mixed evidence for individual domains of generic QoL measures. It is possible that the non-digital interventions included in Mishra et al.'s studies result in larger effect sizes as many of the interventions are supervised by trained staff or involve some level of human interaction, which may foster higher levels of engagement and adherence to the intervention. However, due to the small number of low-quality studies included in this review, there is a need for more high-quality RCTs, with objective measures of PA, long-term follow-up and larger sample sizes before reliable comparisons between non-digital and DBCIs can be made.

Sustained engagement with DBCIs was a significant problem for a number of the studies included in this review. For instance, in the study conducted by Short et al., retention at the 3-month follow-up was only 32% (156/492) and 11% (53/492) at the 6-month follow-up [72]. Furthermore, while 75% of the sample completed at least one action plan, the average number of action plans completed was only 2.2. Similarly, 50% of participants completed the week 1 module compared to 10% for the week 9 module in Forbes et al.'s study [63]. A systematic review has shown that there is a positive relationship between participants' adherence/engagement with digital interventions and positive physical health outcomes across a range of populations and behaviours, suggesting that efforts to improve effective engagement with DBCIs could improve behaviour change outcomes [75]. It is possible that suboptimal engagement with the DBCIs in the studies included in this review may explain the reduced effects on outcomes compared to those observed in Mishra et al.'s review of non-digital PA interventions [19, 74]. Future DBCI studies should integrate techniques or components that maintain effective engagement with the intervention for its duration. There is some evidence that technology-based strategies (e.g. reminders, prompts) can encourage user engagement [76]. Other aspects which have been identified as important for engagement include ease of use, design aesthetic, feedback, function, ability to change design to suit own preferences, tailored information and unique mobile phone features [77]. Similarly, less time consumption, user-friendly design, real-time feedback, individualised elements, detailed information and health professional involvement may also improve effectiveness of DBCIs, in particular mobile apps [78]. Furthermore, future studies should aim to better understand the link between engagement and effectiveness of DBCIs targeting PA and diet in cancer survivors and define, evaluate and report engagement more consistently so

as to better understand techniques that foster effective engagement and mechanisms of action [79].

The majority (10/15) of the studies used an online portal or website to deliver the intervention, and, while one of these websites was mobile-enabled [65], only two studies used mobile apps [68, 69]. This is interesting given the findings of a recent review of 23 interventions using mobile apps that found that 17 of the included studies reported a significant effect on behaviour change in the general population [78]. It is possible that interventions using mobile apps may be more effective than other types of DBCIs due to the widespread usage of and constant access to smartphones and the Internet. The most recent Ofcom Communications Market report conducted in the UK reports that 71% of UK adults own a smartphone and 66% use their smartphone to access the Internet most frequently [41]. Therefore, it would be interesting for future studies to use mobile apps as a mode of intervention delivery and compare the effectiveness of mobile app interventions compared to other DBCIs as they may foster higher levels of engagement.

Self-monitoring, goal-setting, credible source and feedback on behaviour were the most frequently described BCTs used in the included studies. Due to the heterogeneity in intervention type, mode of delivery, behavioural outcomes and measurement approaches, it is difficult to interpret which BCTs were most effective at changing PA/dietary behaviour. Kanera et al.'s study used the most BCTs ($n = 16$) but also used a tailored if-then algorithm within the intervention to automatically tailor content to participants; therefore, it is difficult to ascertain what intervention components or approaches to delivery lead to increased effectiveness. A recent meta-analysis revealed that theory-based interventions are significantly more effective at improving PA [80]. SCT was the most commonly reported theoretical basis of the interventions; however, several other behaviour change theories were used across the studies. The level of reporting of the extent to which theory was incorporated into the development of the interventions varied across studies, but was generally poor. Only three studies did not report any theoretical underpinning. Future studies should aim to explicitly report how theory is used to develop intervention techniques and tailor the intervention to participants. Measurement and exploration of changes in targeted theoretical constructs (e.g. via mediation analyses) can aid understanding of why interventions may or may not be effective [59] and can be used to refine theoretical models of behaviour change. The lack of clarity about the intervention content and theoretical underpinning and the lack of measurement on theoretical constructs mean it is difficult to unpick how or why the interventions which improved behaviour in this review were effective. Future DBCI studies should clearly report any theoretical underpinning and behaviour

change techniques used, for instance by using Michie et al.'s Theory Coding Scheme [59] and Behaviour Change Technique Taxonomy [56].

There are several limitations to this review. Primarily, the data extracted for the meta-analyses reflect unadjusted models. While the forest plot for MVPA minutes/week (Fig. 2) illustrates that Bantum et al. [61], Rabin et al. [54] and Kanera et al. [71] found a significant effect, the original publications show that this no longer remained significant when adjusting for baseline values and/or other covariates (e.g. demographics, disease characteristics) [54, 61], or when adjusted models are controlled for multiple testing [71]. Bantum et al. [61] did find a significant increase in vigorous PA participation in the adjusted model, but not when combined with moderate PA. Similar issues arise for the meta-analyses for fatigue and BMI/weight. The studies that show significant findings for fatigue and BMI/weight in the current meta-analyses do not report significant findings when adjusted for baseline and/or covariates in the original publications. Therefore, pooling the adjusted results would reduce the overall effect size substantially, and it is likely that this would no longer remain significant. Furthermore, a combined MVPA variable was chosen to assess PA outcomes to maximise the number of studies that could be included in the meta-analysis and to coincide with the American College of Sports Medicine's recommendation that cancer survivors should follow the PA guidelines for the general population (at least 150 min of at least moderate intensity PA per week) [25]. However, this means the current meta-analysis does not differentiate between different intensities of PA: it may be beneficial to evaluate the effect on outcomes at different intensities of PA. Visual inspection of funnel plots suggested possible publication bias for smaller studies assessing MVPA outcomes; it is possible that our choice to only include published studies may have increased publication bias. There was no suggestion of publication bias for BMI/weight, fatigue or cancer-specific QoL measures.

The risk of bias in included studies was high. The inclusion of one-arm, pre-post studies substantially increases the risk of bias; however, we felt that the novelty of this area of research warranted the inclusion of these studies and that this added valuable insight into the current state of the literature. Few studies assessed outcomes other than PA, where only half of the studies could be included in a meta-analysis. Heterogeneity across studies was very high, likely due to the variability of types of DBCIs, intervention content, cancer type and populations, outcome measurement tools, etc. With the addition of future studies, more specific inclusion criteria could be used to assess effectiveness of more similar studies. All of the PA findings used self-report data, which while easy to use, inexpensive and validated, often hugely underestimate or overestimate PA participation [81]. Therefore, we advise that these results are interpreted with caution until the number of published studies assessing

DBCIs increases and inclusion criteria for future systematic reviews can be more stringent for low-quality trials.

To the best of our knowledge, this is the first meta-analysis of DBCIs designed to improve PA and diet among cancer survivors. While the review shows some evidence of an improvement in MVPA, a reduction in BMI and a trend towards significance for fatigue, large, high-quality RCTs, with objective measures of PA and long-term follow-up, are lacking. Future studies should aim to address these limitations, but the approach of using digital technology in this context appears promising.

Compliance with ethical standards

Conflict of interest HP has previously received consultancy from myownteam. AR, AF, LS and MH declare that they have no conflict of interest.

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Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors. The current study was a review/meta-analysis of existing studies that did not involve collection of new data.

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Appendix B. Search strategy/search terms for Study 1

Medline (Ovid)

1. physical activity.mp. or exp Motor Activity/
2. limit 1 to (english language and humans)
3. physical fitness.mp. or exp Physical Fitness/
4. limit 3 to (english language and humans)
5. fitness.mp.
6. limit 5 to (english language and humans)
7. exp Exercise/ or exp Exercise Therapy/ or exercise*.mp.
8. limit 7 to (english language and humans)
9. exercise therap*.mp.
10. limit 9 to (english language and humans)
11. diet*.mp. or exp Diet/ or exp Diet Therapy/
12. limit 11 to (english language and humans)
13. exp Food Habits/ or exp Energy Intake/ or dietary quality.mp.
14. limit 13 to (english language and humans)
15. sedentary lifestyle*.mp. or exp Life Style/
16. limit 15 to (english language and humans)
17. exp Sedentary Lifestyle/ or exp Health Behavior/ or sedentary behavior?r*.mp.
18. limit 17 to (english language and humans)
19. sedentary time.mp.
20. limit 19 to (english language and humans)
21. lifestyle.mp.
22. limit 21 to (english language and humans)
23. health behavior?r*.mp.
24. limit 23 to (english language and humans)
25. exp Health Promotion/ or behavior?r change*.mp.
26. limit 25 to (english language and humans)
27. 2 or 4 or 6 or 8 or 10 or 12 or 14 or 16 or 18 or 20 or 22 or 24 or 26
28. self management.mp. or exp Self Care/
29. limit 28 to (english language and humans)
30. intervention.mp.
31. limit 30 to (english language and humans)
32. sitting.mp.
33. limit 32 to (english language and humans)
34. exp Body Weight/ or exp Diet, Reducing/ or exp Weight Loss/ or weight control.mp.
35. limit 34 to (english language and humans)
36. body weight.mp.
37. limit 36 to (english language and humans)
38. weight reduction.mp.
39. limit 38 to (english language and humans)
40. weight loss.mp.
41. limit 40 to (english language and humans)
42. exp Health Education/
43. limit 42 to (english language and humans)
44. 29 or 31 or 33 or 35 or 37 or 39 or 41 or 43
45. exp Health Knowledge, Attitudes, Practice/
46. limit 45 to (english language and humans)
47. 44 or 46
48. 45 or 46 or 47
49. exp Eating/
50. limit 49 to (english language and humans)
51. 2 or 4 or 6 or 8 or 10 or 12 or 14 or 16 or 18 or 20 or 22 or 24 or 26 or 29 or 31 or 33 or 35 or 37 or 39 or 41 or 43 or 46 or 50
52. internet.mp. or exp Internet/
53. limit 52 to (english language and humans)
54. telemedicine.mp. or exp Telemedicine/
55. limit 54 to (english language and humans)
56. mhealth.mp.

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57. limit 56 to (english language and humans)
 58. ehealth.mp.
 59. limit 58 to (english language and humans)
 60. exp Software/ or web based.mp.
 61. limit 60 to (english language and humans)
 62. website*.mp.
 63. limit 62 to (english language and humans)
 64. exp Cell Phones/ or cell phone*.mp.
 65. limit 64 to (english language and humans)
 66. mobile phone*.mp.
 67. limit 66 to (english language and humans)
 68. smartphone*.mp. or exp Smartphone/ or exp Computers, Handheld/
 69. limit 68 to (english language and humans)
 70. exp Mobile Applications/ or mobile app*.mp.
 71. limit 70 to (english language and humans)
 72. computer*.mp.
 73. limit 72 to (english language and humans)
 74. exp User-Computer Interface/
 75. limit 74 to (english language and humans)
 76. mobile health.mp.
 77. limit 76 to (english language and humans)
 78. SMS.mp.
 79. limit 78 to (english language and humans)
 80. exp Electronic Mail/ or exp Text Messaging/ or text messag*.mp.
 81. limit 80 to (english language and humans)
 82. email.mp.
 83. limit 82 to (english language and humans)
 84. web portal.mp.
 85. limit 84 to (english language and humans)
 86. exp "Delivery of Health Care"/
 87. limit 86 to (english language and humans)
 88. exp Technology/
 89. limit 88 to (english language and humans)
 90. exp Medical Informatics/
 91. limit 90 to (english language and humans)
 92. exp Web Browser/
 93. limit 92 to (english language and humans)
 94. web app*.mp.
 95. limit 94 to (english language and humans)
 96. 53 or 55 or 57 or 59 or 61 or 63 or 65 or 67 or 69 or 71 or 73 or 75 or 77 or 79 or 81 or 83 or 85 or 87 or 89 or 91 or 93
 97. cancer surviv*.mp.
 98. limit 97 to (english language and humans)
 99. cancer patient*.mp.
 100. limit 99 to (english language and humans)
 101. 98 or 100
 102. 51 and 96 and 101

EMBASE (Ovid)

103. physical activity.mp. or exp exercise/ or exp physical activity/
104. limit 1 to (human and english language)
105. physical fitness.mp. or exp fitness/
106. limit 3 to (human and english language)
107. fitness.mp.
108. limit 5 to (human and english language)
109. exercise*.mp.
110. limit 7 to (human and english language)
111. exercise therap*.mp. or exp kinesiotherapy/
112. limit 9 to (human and english language)
113. exp diet/ or exp low calory diet/ or exp low carbohydrate diet/ or diet*.mp. or exp low fat diet/
114. limit 11 to (human and english language)
115. exp dietary intake/ or dietary quality.mp. or exp caloric intake/
116. limit 13 to (human and english language)
117. exp feeding behavior/
118. limit 15 to (human and english language)
119. exp sedentary lifestyle/ or sedentary lifestyle*.mp.
120. limit 17 to (human and english language)
121. exp health behavior/ or sedentary behavio?r*.mp.
122. limit 19 to (human and english language)
123. exp sitting/ or sedentary time.mp.
124. limit 21 to (human and english language)
125. lifestyle.mp. or exp lifestyle modification/
126. limit 23 to (human and english language)
127. health behavio?r*.mp.
128. limit 25 to (human and english language)
129. exp behavior change/ or exp health promotion/ or behavio?r change*.mp.
130. limit 27 to (human and english language)
131. intervention.mp. or exp intervention study/
132. limit 29 to (human and english language)
133. weight reduction.mp. or exp weight reduction/
134. limit 31 to (human and english language)
135. weight change.mp. or exp weight change/
136. limit 33 to (human and english language)
137. exp weight control/ or weight control.mp.
138. limit 35 to (human and english language)
139. sitting.mp.
140. limit 37 to (human and english language)
141. body weight.mp.
142. limit 39 to (human and english language)
143. weight loss.mp.
144. limit 41 to (human and english language)
145. 2 or 4 or 6 or 8 or 10 or 12 or 14 or 16 or 18 or 20 or 22 or 24 or 26 or 28 or 30 or 32 or 34
or 36 or 38 or 40 or 42
146. internet.mp. or exp Internet/
147. limit 44 to (human and english language)
148. telemedicine.mp.
149. limit 46 to (human and english language)
150. exp medical informatics/ or exp mobile phone/ or exp computer program/ or mhealth.mp.
151. limit 48 to (human and english language)
152. ehealth.mp. or exp telehealth/
153. limit 50 to (human and english language)
154. telehealth.mp.
155. limit 52 to (human and english language)
156. web based.mp.
157. limit 54 to (human and english language)
158. exp online system/ or website*.mp.
159. limit 56 to (human and english language)
160. cell phone*.mp. or exp text messaging/
161. limit 58 to (human and english language)
162. mobile phone*.mp.

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163. limit 60 to (human and english language)
 164. exp personal digital assistant/ or smartphone*.mp.
 165. limit 62 to (human and english language)
 166. exp mobile application/ or mobile app*.mp.
 167. limit 64 to (human and english language)
 168. exp teleconsultation/
 169. limit 66 to (human and english language)
 170. exp telemonitoring/
 171. limit 68 to (human and english language)
 172. exp teletherapy/
 173. limit 70 to (human and english language)
 174. email.mp. or exp e-mail/
 175. limit 72 to (human and english language)
 176. mobile health.mp.
 177. limit 74 to (human and english language)
 178. SMS.mp.
 179. limit 76 to (human and english language)
 180. text messag*.mp.
 181. limit 78 to (human and english language)
 182. mobile device*.mp.
 183. limit 80 to (human and english language)
 184. 45 or 47 or 49 or 51 or 53 or 55 or 57 or 59 or 61 or 63 or 65 or 67 or 69 or 71 or 73 or 75 or 77 or 79 or 81
 185. exp cancer survivor/ or cancer survivor*.mp.
 186. limit 83 to (human and english language)
 187. exp cancer patient/ or cancer patient*.mp.
 188. limit 85 to (human and english language)
 189. 84 or 86
 190. 43 and 82 and 87

PsycINFO (Ovid)

1. physical activity.mp. or exp Physical Activity/
2. limit 1 to (human and english language)
3. physical fitness.mp. or exp Physical Fitness/
4. limit 3 to (human and english language)
5. exp Exercise/ or exp Physical Education/ or exp Health Promotion/ or exp Health/ or fitness.mp.
6. limit 5 to (human and english language)
7. exercise*.mp.
8. limit 7 to (human and english language)
9. exercise therap*.mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
10. limit 9 to (human and english language)
11. exp Eating Behavior/ or exp Food Intake/ or exp Diets/ or exp Food/ or diet*.mp.
12. limit 11 to (human and english language)
13. exp Body Weight/ or dietary quality.mp. or exp Health Behavior/ or exp Weight Control/
14. limit 13 to (human and english language)
15. exp Lifestyle/ or exp Activity Level/ or sedentary lifestyle*.mp.
16. limit 15 to (human and english language)
17. sedentary behavior?r*.mp.
18. limit 17 to (human and english language)
19. sedentary time.mp.
20. limit 19 to (human and english language)
21. exp Lifestyle Changes/ or lifestyle.mp.
22. limit 21 to (human and english language)
23. health behavior?r*.mp.
24. limit 23 to (human and english language)
25. exp Behavior Change/ or exp Intervention/ or behavior?r change*.mp.
26. limit 25 to (human and english language)
27. self management.mp. or exp Self Management/
28. limit 27 to (human and english language)
29. intervention.mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
30. limit 29 to (human and english language)
31. sitting.mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
32. limit 31 to (human and english language)
33. weight control.mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
34. limit 33 to (human and english language)
35. body weight.mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
36. limit 35 to (human and english language)
37. weight reduction.mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
38. limit 37 to (human and english language)
39. weight loss.mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
40. limit 39 to (human and english language)
41. 2 or 4 or 6 or 8 or 10 or 12 or 14 or 16 or 18 or 20 or 22 or 24 or 26 or 28 or 30 or 32 or 34 or 36 or 38 or 40
42. internet.mp. or exp Internet/
43. limit 42 to (human and english language)
44. telemedicine.mp. or exp Telemedicine/
45. limit 44 to (human and english language)
46. exp Mobile Devices/ or exp Cellular Phones/ or exp Technology/ or mhealth.mp. or exp Health Care Delivery/
47. limit 46 to (human and english language)
48. exp Electronic Communication/ or ehealth.mp.
49. limit 48 to (human and english language)

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50. exp Computer Mediated Communication/ or exp Websites/ or web based.mp. or exp Online Therapy/
 51. limit 50 to (human and english language)
 52. exp Computer Applications/ or website*.mp.
 53. limit 52 to (human and english language)
 54. cell-phone*.mp
 55. limit 54 to (human and english language)
 56. mobile phone*.mp.
 57. limit 56 to (human and english language)
 58. smartphone*.mp.
 59. limit 58 to (human and english language)
 60. mobile app*.mp.
 61. limit 60 to (human and english language)
 62. computer*.mp.
 63. limit 62 to (human and english language)
 64. mobile health.mp.
 65. limit 64 to (human and english language)
 66. exp Messages/ or SMS.mp.
 67. limit 66 to (human and english language)
 68. email.mp.
 69. limit 68 to (human and english language)
 70. exp Information Technology/ or web portal.mp.
 71. limit 70 to (human and english language)
 72. exp Computers/
 73. limit 72 to (human and english language)
 74. exp Information Systems/
 75. limit 74 to (human and english language)
 76. text messag*.mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
 77. limit 76 to (human and english language)
 78. 43 or 45 or 47 or 49 or 51 or 53 or 55 or 57 or 59 or 61 or 63 or 65 or 67 or 69 or 71 or 73 or 75 or 77
 79. cancer surviv*.mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
 80. limit 79 to (human and english language)
 81. cancer patient*.mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures]
 82. limit 81 to (human and english language)
 83. exp Survivors/
 84. limit 83 to (human and english language)
 85. 80 or 82 or 84
 86. 41 and 78 and 85

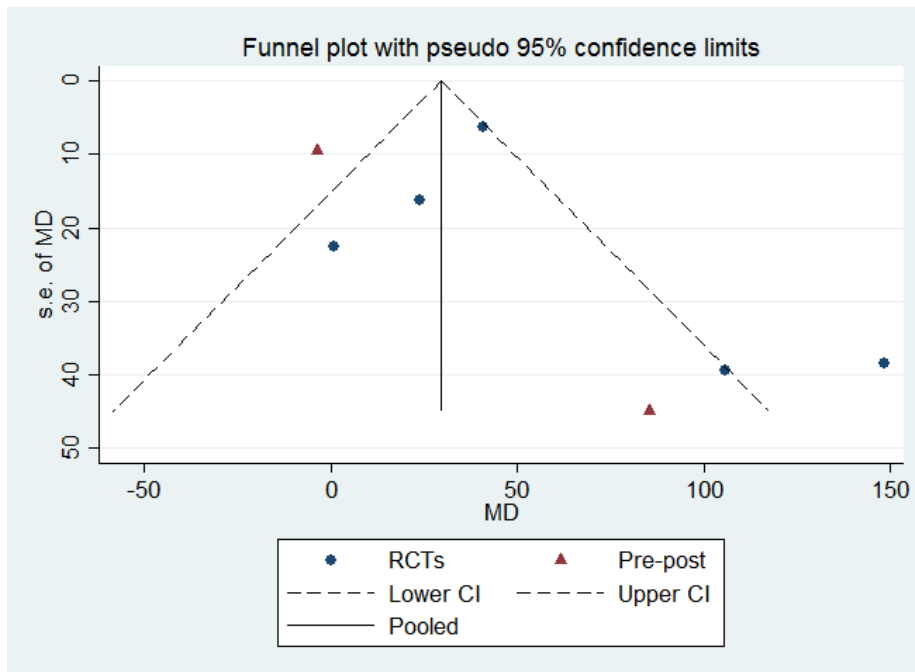
CINAHL (EBSCOhost)

S90	S62 AND S86 AND S89
S89	S87 OR S88
S88	cancer patient*
S87	(MH "Cancer Survivors") OR "cancer surviv*" OR (MH "Cancer Patients")
S86	S63 OR S64 OR S65 OR S66 OR S67 OR S68 OR S69 OR S70 OR S71 OR S72 OR S73 OR S74 OR S75 OR S76 OR S77 OR S78 OR S79 OR S80 OR S81 OR S82 OR S83 OR S84 OR S85
S85	(MH "Medical Informatics")
S84	(MH "Health Informatics+")
S83	(MH "Technology+")
S82	(MH "Health Care Delivery+")
S81	(MH "Instant Messaging")
S80	"email"
S79	SMS
S78	"mobile health"
S77	(MH "Text Messaging") OR "text messag**"
S76	(MH "Computers, Hand-Held+")
S75	"computer**"
S74	(MH "Mobile Applications") OR "mobile app**"
S73	"smartphone**"
S72	mobile phone*
S71	(MH "Cellular Phone+") OR (MH "Smartphone+") OR "cell phone**"
S70	"web 2.0"
S69	"website**"
S68	"web portal" OR (MH "Web Browsers")
S67	"web based"
S66	"ehealth"
S65	"mhealth"
S64	(MH "Telemedicine+") OR "telemedicine" OR (MH "Telehealth+")
S63	(MH "Internet+") OR "internet"
S62	S2 OR S4 OR S6 OR S8 OR S10 OR S12 OR S14 OR S16 OR S18 OR S20 OR S22 OR S24 OR S26 OR S28 OR S29 OR S31 OR S33 OR S35 OR S37 OR S39 OR S41 OR S43 OR S45 OR S47 OR S49 OR S51 OR S53 OR S55 OR S57 OR S59 OR S61
S61	(MH "Health+")
S60	(MH "Health+")
S59	(MH "Health Promotion+")
S58	(MH "Health Promotion+")
S57	(MH "Behavior Modification+")
S56	(MH "Behavior Modification+")

S55	(MH "Eating Behavior+")
S54	(MH "Eating Behavior+")
S53	(MH "Food Intake+") OR (MH "Energy Intake")
S52	(MH "Food Intake+") OR (MH "Energy Intake")
S51	(MH "Diet Therapy+")
S50	(MH "Diet Therapy+")
S49	(MH "Education, Physical Therapy") OR (MH "Physical Education and Training+") OR (MH "Physical Therapists")
S48	(MH "Education, Physical Therapy") OR (MH "Physical Education and Training+") OR (MH "Physical Therapists")
S47	weight loss
S46	weight loss
S45	weight reduction
S44	weight reduction
S43	body weight
S42	body weight
S41	(MH "Weight Control") OR "weight control" OR (MH "Body Weight Changes+")
S40	(MH "Weight Control") OR "weight control" OR (MH "Body Weight Changes+")
S39	(MH "Sitting") OR "sitting"
S38	(MH "Sitting") OR "sitting"
S37	"intervention" OR (MH "Intervention Trials")
S36	"intervention" OR (MH "Intervention Trials")
S35	(MH "Self Care+") OR "self management"
S34	(MH "Self Care+") OR "self management"
S33	behavior change*
S32	behavior change*
S31	(MH "Behavioral Changes") OR "behaviour change**"
S30	(MH "Behavioral Changes") OR "behaviour change"
S29	health behaviour
S28	(MH "Health Behavior+") OR "health behavior**"
S27	(MH "Health Behavior+") OR "health behavior**"
S26	(MH "Life Style Changes") OR "lifestyle"
S25	(MH "Life Style Changes") OR "lifestyle"
S24	sedentary time
S23	sedentary time
S22	sedentary behavior
S21	sedentary behavior
S20	"sedentary behaviour"
S19	"sedentary behaviour"

S18	(MH "Life Style, Sedentary") OR "sedentary lifestyle**"
S17	(MH "Life Style, Sedentary") OR "sedentary lifestyle**"
S16	dietary quality
S15	dietary quality
S14	(MH "Diet, Reducing") OR (MH "Diet+")
S13	(MH "Diet, Reducing") OR (MH "Diet+")
S12	"diet**"
S11	"diet**"
S10	exercise therap*
S9	exercise therap*
S8	exercise*
S7	exercise*
S6	"fitness"
S5	"fitness"
S4	(MH "Physical Fitness+") OR "physical fitness" OR (MH "Exercise+")
S3	(MH "Physical Fitness+") OR "physical fitness" OR (MH "Exercise+")
S2	(MH "Physical Activity") OR "physical activity" OR (MH "Physical Fitness+")
S1	(MH "Physical Activity") OR "physical activity" OR (MH "Physical Fitness+")

Appendix C. Funnel plot illustrating possible publication bias for studies assessing MVPA



Appendix D. The 'Health and Lifestyle after Cancer' survey



HEALTH AND LIFESTYLE QUESTIONNAIRE

This is a survey about health and lifestyle among people who have been diagnosed with breast, prostate or bowel (colorectal) cancer.

The study is being carried out by researchers at University College London in collaboration with London Cancer. It is funded by Cancer Research UK.

There are no right or wrong answers to any of the questions. Please be as honest as possible when answering. Your answers will be confidential and will not be shared with anyone other than the research team.

Once you have filled in the questionnaire, please can you **return it in the freepost envelope provided** – there is no need for a stamp.

By completing this questionnaire you are consenting to your anonymous information being used for research on lifestyle in people diagnosed with cancer.

If you have any questions please contact:
Dr Abigail Fisher or Dr Maggie Heinrich
Health Behaviour Research Centre
Department of Epidemiology and Public Health
University College London

Dr Abigail Fisher:
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T 020 7679 1809
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SECTION 1: ABOUT YOU

This section contains some questions about you to give us some background information.

1 How old are you? years

2 What is your sex? Male Female

3 At what age did you first leave education? years

4 Which educational or professional qualifications do you have? Please tick all that apply.

- | | |
|--|--|
| <input type="checkbox"/> GCSE/School certificate/O-level/CSE | <input type="checkbox"/> Bachelor Degree or equivalent (e.g. NVQ4) |
| <input type="checkbox"/> Vocational qualifications (e.g. NVQ1+2) | <input type="checkbox"/> Masters/PhD/PGCE or equivalent |
| <input type="checkbox"/> A-level/Higher school certificate or equivalent (e.g. NVQ3) | <input type="checkbox"/> Still studying |
| <input type="checkbox"/> Other (please specify) | <input type="checkbox"/> No formal qualifications |

5 What was your employment situation before you were diagnosed with cancer? Please tick one option.

- | | |
|--|--|
| <input type="checkbox"/> Employed full-time | <input type="checkbox"/> Full-time education |
| <input type="checkbox"/> Employed part-time | <input type="checkbox"/> Retired |
| <input type="checkbox"/> Self-employed | <input type="checkbox"/> Unable or too ill to work |
| <input type="checkbox"/> Unemployed and looking for work | <input type="checkbox"/> Voluntary work |
| <input type="checkbox"/> Other (please specify) | |

6 What is your current employment situation? Please tick one option.

- | | |
|--|--|
| <input type="checkbox"/> Employed full-time | <input type="checkbox"/> Full-time education |
| <input type="checkbox"/> Employed part-time | <input type="checkbox"/> Retired |
| <input type="checkbox"/> Self-employed | <input type="checkbox"/> Unable or too ill to work |
| <input type="checkbox"/> Unemployed and looking for work | <input type="checkbox"/> Voluntary work |
| <input type="checkbox"/> Other (please specify) | |

7 What is your current marital status?

- | | |
|--|------------------------------------|
| <input type="checkbox"/> Married/living with partner | <input type="checkbox"/> Separated |
| <input type="checkbox"/> Single | <input type="checkbox"/> Widowed |
| <input type="checkbox"/> Divorced | |

8 Please tick the box which best describes your living arrangement:

- | | |
|---|---|
| <input type="checkbox"/> Alone | <input type="checkbox"/> With other family |
| <input type="checkbox"/> With partner only | <input type="checkbox"/> With friends |
| <input type="checkbox"/> With immediate family (including children) | <input type="checkbox"/> In residential care/nursing home |

9 Which of these best describes your ethnic group?

- | | |
|---|---|
| <input type="checkbox"/> White British | <input type="checkbox"/> Indian |
| <input type="checkbox"/> White Irish | <input type="checkbox"/> Bangladeshi |
| <input type="checkbox"/> Any other White (please specify) | <input type="checkbox"/> Pakistani |
| | <input type="checkbox"/> Chinese |
| | <input type="checkbox"/> Any other Asian (please specify) |

- | | |
|---|---|
| <input type="checkbox"/> Black African | <input type="checkbox"/> Mixed White and Black African |
| <input type="checkbox"/> Black Caribbean | <input type="checkbox"/> Mixed White and Black Caribbean |
| <input type="checkbox"/> Any other Black (please specify) | <input type="checkbox"/> Mixed White and Asian |
| | <input type="checkbox"/> Any other mixed (please specify) |

Any other (please specify) _____

10 Do you use email? Yes No

11 Do you use the internet? (e.g. for health information) Yes No

12 What is your height? _____ ft _____ inches or _____ cm

13 What is your weight? _____ St _____ lbs or _____ kg

14 Is your weight nowadays...

- More than before you were diagnosed with cancer
- About the same as before you were diagnosed with cancer
- Less than before you were diagnosed with cancer

15 Which of the following best describes you at the present time?

- I think I should be trying to lose weight
- I think I should be trying to gain weight
- I don't think I need to change my weight
- Don't know

SECTION 2: YOUR HEALTH

These questions are about your cancer and your general health. This is to help us understand what you have been through and how you are now.

1 Which of these types of cancer have you been diagnosed with? Please tick all that apply.

	Approximate date of diagnosis	
<input type="checkbox"/> Breast month year
<input type="checkbox"/> Prostate month year
<input type="checkbox"/> Bowel (colorectal) month year
<input type="checkbox"/> Other (please specify) month year

Please answer the following thinking about your most recent cancer:

2 At the time of your diagnosis, what stage was this cancer?

1 2 3 4 Don't know

3 Has this cancer spread to any other parts of your body? Yes No Don't know

4 What treatment(s) have you had for this cancer? Please tick all that apply.

<input type="checkbox"/> Surgery	<input type="checkbox"/> Hormone therapy	<input type="checkbox"/> Not sure
<input type="checkbox"/> Radiotherapy	<input type="checkbox"/> Active surveillance	
<input type="checkbox"/> Chemotherapy	<input type="checkbox"/> None	
<input type="checkbox"/> Other (please give details)		

5 How long is it since you completed your main treatment for this cancer?

I am still having my main treatment

It is less than 3 months since my main treatment

It is between 3 and 12 months since my main treatment

It is between 1 and 5 years since my main treatment

On active surveillance

Don't know/can't remember

6 Have you ever had any of the following health problems? Please tick all that apply.

<input type="checkbox"/> Osteoporosis	<input type="checkbox"/> Arthritis
<input type="checkbox"/> Diabetes	<input type="checkbox"/> Angina
<input type="checkbox"/> Asthma	<input type="checkbox"/> Heart attack
<input type="checkbox"/> Emotional or psychiatric illness	<input type="checkbox"/> Heart murmur
<input type="checkbox"/> Stroke	<input type="checkbox"/> Irregular heart rhythm
<input type="checkbox"/> Parkinson's disease	<input type="checkbox"/> Any other heart trouble
<input type="checkbox"/> Alzheimer's disease or dementia	<input type="checkbox"/> Another cancer
<input type="checkbox"/> Lung disease	
<input type="checkbox"/> Other (please give details)	

SECTION 3: PHYSICAL ACTIVITY

These questions are about how active you are and how this might have changed since you were diagnosed with cancer.

1 Over the past month, how many times a week on average did you do the following kinds of exercise for more than 15 minutes during your free time?

a Strenuous exercise (heart beats rapidly) e.g. running, jogging, vigorous swimming, cycling

Times per week: Duration of each session: hours minutes

b Moderate exercise (not exhausting) e.g. fast walking, easy cycling, easy swimming

Times per week: Duration of each session: hours minutes

c Mild exercise (minimal effort) e.g. easy walking, fishing, bowling

Times per week: Duration of each session: hours minutes

d During a typical 7-day period (a week), in your leisure time, how often do you engage in any regular activity long enough to work up a sweat (heart beats rapidly)?

Often Sometimes Rarely/Never

2 Is the amount of physical activity you do nowadays...

- More than before you were diagnosed with cancer
 About the same as before you were diagnosed with cancer
 Less than before you were diagnosed with cancer

3 Which of the following best describes you at the present time?

- I think I should be doing more physical activity
 I think I should be doing less physical activity
 I don't think I need to change my physical activity
 Don't know

4 Think about time you spent sitting on weekdays during the last 7 days. Include time spent at work, home, while doing course work, and during leisure. During the last 7 days how much time did you usually spend sitting on a weekday?

Hours per weekday Minutes per weekday Don't know

5 How many hours of television do you watch on an ordinary day or evening, that is, Monday to Friday?

Hours per weekday Don't know

6 How many hours of television do you normally watch in total over the weekend, that is, Saturday and Sunday?

Hours per weekend Don't know

SECTION 4: DIET AND NUTRITION

These questions are about your diet. They do not cover everything you eat, just a few of the types of foods we are interested in. We know some of these questions are difficult but we would be grateful if you could answer them as best you can.

1 About how many times a week do you eat a serving of the following foods?

	Less than once a week or never	1–2 per week	3–5 per week	6 or more per week
Pasta, rice, noodles, or couscous	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Potatoes, sweet potatoes, yams, or plantains	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Peas	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Beans (including baked), lentils, chickpeas, or other pulses	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Any other vegetables	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fruit (fresh, frozen, canned, dried)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cheese (any except cottage cheese)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Beef (excluding burgers), pork, lamb, or goat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Beef burgers	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bacon, ham, salami, hot dogs, or sausages	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Chicken or turkey (including nuggets/burgers)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fish or shell fish (including tinned and breaded fish but excluding fried/battered fish)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Meat alternatives (e.g. eggs, soya, tofu, Quorn but excluding nuts)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Nuts eaten in a meal as an alternative to meat (e.g. nut roast)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Fried food (e.g. fried/battered fish, chips, fried breakfast, samosas, fried rice, bhajis, puris, fritters)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cakes, pies, puddings, pastries, or Indian sweets	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Biscuits, chocolate or savoury snacks (e.g. crisps, sev, Bombay mix, nuts)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Coconut milk or coconut cream	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

2 How often do you drink the following?

	Never/ rarely	Once a week	2-3 times a week	4-6 times a week	Once a day	Twice a day	3 or more times a day
Regular squash, cordials, fizzy drinks and juice drinks	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sugar-free squash and diet fizzy drinks	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Pure fruit juice (including from concentrate)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Water	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

3 About how many times a week do you have the following breakfast cereals or porridge?

	None	Less than 1 per week	1-2 per week	3-5 per week	6 or more per week
Sugary, Chocolate, Rice or Corn cereals (e.g. Frosties, Coco Pops, Sugar Puffs, Corn Flakes, Rice Crispies, Special K)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Porridge, Ready Brek, Muesli, Multigrain/ Wheat cereals (e.g. Shredded Wheat, Weetabix, Puffed Wheat, Fruit n Fibre, Just Right, Shreddies, Start, Cheerios, Nutri-Grain)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bran cereals (e.g. All-bran, Branflakes, Sultana Bran)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Please use the following examples to help you answer question 4:

Pure vegetable oil or Cooking oil

(e.g. olive, sunflower, soya, corn, rapeseed, Flora Cuisine, Lurpak Cooking Liquid)

Butter (including spreadable), Ghee, Dripping, Solid cooking fats, Lard, Palm oil, Coconut oil

(e.g. Cookeen, Crisp N'Dry solid, Trex)

Half fat butter, Hard/baking margarine

(e.g. Stork Baking Block, Lurpak Cooks Range Baking, Flora Great For Baking, Clover, Willow)

Soft margarine

(e.g. Stork, I Can't Believe It's Not Butter, Clover Light)

Sunflower margarine, Olive margarine, Low fat spread

(e.g. Flora, Vitalite, Flora Light, Bertolli, Bertolli Light, Benecol, I Can't Believe It's Not Butter Light)

4 What sort of fat do you most often use for the following? Please tick one option.

a On bread, potatoes and vegetables?

- Pure vegetable oil or Cooking oil
 Butter/ Ghee etc
 Half fat butter
 Soft margarine
 Sunflower/ Olive margarine
 No fat used or don't eat these foods

b For frying?

- Pure vegetable oil or Cooking oil
 Butter/ Ghee etc
 Half fat butter
 Soft margarine
 Sunflower/ Olive margarine
 No fat used or don't eat these foods

c For baking?

- Pure vegetable oil or Cooking oil
 Butter/ Ghee etc
 Half fat butter
 Soft margarine
 Sunflower/ Olive margarine
 No fat used or don't eat these foods

d For roasting?

- Pure vegetable oil or Cooking oil
 Butter/ Ghee etc
 Half fat butter
 Soft margarine
 Sunflower/ Olive margarine
 No fat used or don't eat these foods

5 About how many rounded teaspoons of margarine, butter or other spread do you usually use in a day (e.g. on bread, sandwiches, toast, potatoes, vegetables)? NB: One rounded teaspoon is roughly the amount used to cover a slice of bread thinly.

Total teaspoons per day

Butter (including 'Lighter', 'Spreadable' and half-fat), Ghee or Margarine

(e.g. Stork, Bertolli, Clover, Clover Lighter, I Can't Believe It's Not Butter, Flora, Flora Buttery, Flora Pro-activ, Benecol, Vitalite, supermarket own brand olive/sunflower spread)

Low fat spread

(e.g. Flora Light, Flora Lighter Than Light, Flora Pro-activ Olive, Flora Pro-activ Light, I Can't Believe It's Not Butter Light, supermarket own brand olive/sunflower light spread, Bertolli Light, Benecol Light, Clover Lighter Than Light)

6 About how many rounded teaspoons of sugar, honey, or syrup do you usually use in a day (e.g. in coffee, tea, milk, bread, cereals, fruit)?

Total teaspoons per day

7 About how much milk do you use in a day (e.g. on cereal and in tea or coffee)?

	None	Less than a quarter-pint per day	About a quarter-pint per day	About a half-pint per day	At least 1 pint per day
Full-fat (whole)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Semi-skimmed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1% fat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Skimmed	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Non-dairy (e.g. rice or soya milk)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

8 About how many pieces of bread, rolls, chapatis etc. do you eat on a usual day?

	None	Less than 1 per day	1-2 per day	3-4 per day	5 or more per day
White	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Brown, granary, half and half, seeded, wheatgerm, or oat	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wholemeal (including wholemeal seeded and wholemeal granary) or wholegrain	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

9 Over the past month, how many portions of fruit did you usually eat? Include fruit eaten at meal times or as a snack. Examples of a serving are 1 apple or banana, a large slice of melon, 2 plums or satsumas, a small bowl of grapes, 2 tablespoons of tinned fruit or ½ tablespoon of dried fruit.

- Less than 1 per week
 1 per week
 2-3 per week
 4-6 per week
 1 per day
 2 per day
 3 or more per day

10 Over the past month, how many portions of vegetables did you usually eat? Include vegetables eaten at meal times or as a snack. Examples of a serving are 2 heaped tablespoons of broccoli or carrots, 3 tablespoons of sweetcorn or peas or a bowl of salad. Please do not include potatoes, sweet potatoes or plantains as a vegetable serving.

- Less than 1 per week
 1 per week
 2-3 per week
 4-6 per week
 1 per day
 2 per day
 3 or more per day

11 Would you say your diet now is...

- Healthier than before you were diagnosed with cancer
 About the same as before you were diagnosed with cancer
 Less healthy than before you were diagnosed with cancer

12 Which of the following best describes you at the present time?

- I think I should have a healthier diet
 I don't think I need to change my diet
 Don't know

SECTION 5: ALCOHOL

These questions are about how much alcohol you drink and how this might have changed since you were diagnosed with cancer.

1a How often do you have a drink containing alcohol?

- Never
 Monthly or less
 2–4 times per month
 2–3 times per week
 4–5 times per week
 Every day

This is one unit of alcohol...



Half pint of regular beer, lager or cider



1 small glass of wine



1 single measure of spirits



1 small glass of sherry



1 single measure of aperitifs

...and each of these is more than one unit



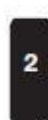
Pint of regular beer/lager/cider



Pint of premium beer/lager/cider



Alcopop or can/bottle of regular lager



Can of premium lager or strong beer



Can of super strength lager



Glass of wine (175ml)



Bottle of wine

1b How many units of alcohol do you drink on a typical day when you are drinking?

- I never drink alcohol
 1–2
 3–4
 5–6
 7–9
 10+

1c How often have you had 6 or more units (for women), or 8 or more (for men), on a single occasion in the last year?

- Never
 Less than monthly
 Monthly
 Weekly
 Daily or almost daily

2 Is the amount of alcohol you drink nowadays...

- More than before you were diagnosed with cancer
 About the same as before you were diagnosed with cancer
 Less than before you were diagnosed with cancer

3 Which of the following best describes you at the present time?

- I think I should drink less alcohol
 I don't think I need to change my alcohol consumption
 Don't know

SECTION 6: TOBACCO

1 Do you smoke/chew tobacco at all nowadays? Yes No

If yes...

Did you ever try to quit before you were diagnosed with cancer? Yes No

Have you tried to quit since you were diagnosed with cancer? Yes No

If no...

Did you ever smoke/chew tobacco regularly? (at least once a day) Yes No

When did you quit smoking/chewing tobacco? month year

2 If you **currently** smoke/chew tobacco, which of the following best describes you at the present time?

I think I should quit smoking/chewing tobacco

I don't think I need to change my smoking/tobacco habits

Don't know

SECTION 7: LIFESTYLE ADVICE

These questions are about the lifestyle advice you received since you were diagnosed with cancer. We are not able to ask about all aspects of lifestyle so we have just focused on a few areas. These questions will help us see what support you are getting and whether anything was missing.

1 In the time since you were first diagnosed with cancer, did a health professional (e.g. doctor/nurse/physiotherapist/dietitian) ever recommend any of the following?

	Yes	No
Doing more exercise	<input type="checkbox"/>	<input type="checkbox"/>
Eating more fruit and vegetables	<input type="checkbox"/>	<input type="checkbox"/>
Avoiding foods or drinks high in fat, sugar or salt	<input type="checkbox"/>	<input type="checkbox"/>
Eating less red or processed meat	<input type="checkbox"/>	<input type="checkbox"/>
Losing weight	<input type="checkbox"/>	<input type="checkbox"/>
Gaining weight	<input type="checkbox"/>	<input type="checkbox"/>
Keeping your weight the same	<input type="checkbox"/>	<input type="checkbox"/>
Reducing the amount of alcohol you drink	<input type="checkbox"/>	<input type="checkbox"/>
Stopping smoking	<input type="checkbox"/>	<input type="checkbox"/>

If yes, do you remember what was suggested? Please provide any details you can in the space below.

.....

.....

.....

.....

.....

If yes, do you remember who gave you the information? Please tick all that apply.

- Oncologist Nurse Dietitian
 Surgeon GP Physiotherapist
 Other (please specify)

If yes, please tick the option which best describes the amount of information you received

- Too much About right Not enough

2 If you had been given the opportunity to have more information/advice/support on making lifestyle changes at the end of your main treatment, would you have taken up the offer?

- Yes definitely Yes probably Probably not Definitely not Not sure Not applicable

SECTION 9: YOUR WELLBEING

These questions are about your general wellbeing. We know that cancer can often affect lots of areas of wellbeing. Unfortunately we do not have space to ask about all of these in this questionnaire so we have just focused on a few areas.

1 In general, I consider myself...

Not a very happy person 1 2 3 4 5 6 7 A very happy person

2 Please circle or mark one number per line to indicate your response as it applies to the past 7 days.

	Not at all	A little bit	Some-what	Quite a bit	Very much
I feel fatigued	0	1	2	3	4
I feel weak all over	0	1	2	3	4
I feel listless ('washed out')	0	1	2	3	4
I feel tired	0	1	2	3	4
I have trouble starting things because I am tired	0	1	2	3	4
I have trouble finishing things because I am tired	0	1	2	3	4
I have energy	0	1	2	3	4
I am able to do my usual activities	0	1	2	3	4
I need to sleep during the day	0	1	2	3	4
I am too tired to eat	0	1	2	3	4
I need help doing my usual activities	0	1	2	3	4
I am frustrated by being too tired to do the things I want to do	0	1	2	3	4
I have to limit my social activity because I am tired	0	1	2	3	4

3 During the past month, when have you usually gone to bed?

Bed time

4 During the past month, how long (in minutes) has it taken you to fall asleep each night?

Number of minutes

5 During the past month, when have you usually gotten up in the morning?

Getting up time

6 During the past month, how many hours of actual sleep did you get a night? (This may be different than the number of hours you spent in bed)

Hours of sleep per night Hours

7 During the past month, how often have you had trouble sleeping because you...

	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
Cannot get to sleep within 30 minutes	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Wake up in the middle of the night or early morning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have to get up to use the bathroom	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Cough or snore loudly	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Feel too cold	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Feel too hot	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have bad dreams	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Have pain	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Other reason(s), please describe, including how often you have had trouble sleeping because of this reason(s)

8 During the past month, how often have you taken medicine (prescribed or 'over the counter') to help you sleep?

- Not during the past month Less than once a week Once or twice a week Three or more times a week

9 During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?

- Not during the past month Less than once a week Once or twice a week Three or more times a week

10 During the past month, how much of a problem has it been for you to keep up enthusiasm to get things done?

- Not during the past month Less than once a week Once or twice a week Three or more times a week

11 During the past month, how would you rate your sleep quality overall?

- Very good Fairly good Fairly bad Very bad

12 How often do you feel you lack companionship?

- Hardly ever or never Some of the time Often

13 How often do you feel left out?

- Hardly ever or never Some of the time Often

14 How often do you feel isolated from others?

- Hardly ever or never Some of the time Often

15 Under each heading, please tick the one box that best describes your health today.**a MOBILITY**

- I have no problems in walking about
 I have slight problems in walking about
 I have moderate problems in walking about
 I have severe problems in walking about
 I am unable to walk about

b SELF CARE

- I have no problems washing or dressing myself
 I have slight problems washing or dressing myself
 I have moderate problems washing or dressing myself
 I have severe problems washing or dressing myself
 I am unable to wash or dress myself

c USUAL ACTIVITIES

- I have no problems doing my usual activities
 I have slight problems doing my usual activities
 I have moderate problems doing my usual activities
 I have severe problems doing my usual activities
 I am unable to do my usual activities

d PAIN/DISCOMFORT

- I have no pain or discomfort
 I have slight pain or discomfort
 I have moderate pain or discomfort
 I have severe pain or discomfort
 I have extreme pain or discomfort

e ANXIETY/DEPRESSION

- I am not anxious or depressed
 I am slightly anxious or depressed
 I am moderately anxious or depressed
 I am severely anxious or depressed
 I am extremely anxious or depressed

Please turn over to the final page ▷

SECTION 10: A FEW FINAL DETAILS

1 Are you currently enrolled in a formal lifestyle programme or trial (e.g. Weight Watchers, NHS smoking cessation)? Yes No

If yes, please specify:

.....

2 Please use the space below to give any other comments you might have.

.....

.....

.....

.....

.....

.....

OPPORTUNITY TO TAKE PART IN A FUTURE TRIAL

We have developed a lifestyle programme for people who have been diagnosed with cancer. In order to test if it is helpful, we are recruiting people like you to take part in a trial. If you take part, you could help us improve the programme and help other cancer patients in the future.

If you think you might be interested in taking part in this trial, **please leave your contact details below** and we will send you further information.

You do not need to commit to taking part at this stage. All information you provide is confidential and will not be shared.

Name:

Telephone:

Email:

Address:

.....

.....

Thank you for taking the time to complete this questionnaire.

Please return it in the freepost envelope provided – there is no need for a stamp.

Appendix E. Patient invitation letter for Study 2

PLEASE INSERT HEADER FOR NHS TRUST

[DATE]

Dear **[PARTICIPANT NAME]**

I am contacting you because following on from your consultation at **[NAME OF NHS TRUST]** you were diagnosed with cancer in 2012 or 2013. I would like to invite you to participate in some voluntary research about lifestyle for people who have been diagnosed with cancer. This research is being funded by Cancer Research UK and involves researchers from University College London and London Cancer.

What will it involve?

I have enclosed a 'Health and Lifestyle Questionnaire' for you to complete. It asks questions about your current health and lifestyle and about the advice you received when you were diagnosed with cancer. This information is very important to us as it will help us improve the care of people diagnosed with cancer.

What am I being asked to do?

We would be very grateful if you could complete this questionnaire and return it to the researchers using the freepost envelope provided (you do not need a stamp). If you prefer you can also complete the questionnaire online at:
https://www.surveymonkey.com/r/ASCOT_MidEssex

Do I have to take part?

No. Taking part is voluntary, if you choose not to do so it will not affect your medical care in any way.

Do I need to leave my contact details?

On the last page of the questionnaire, there is an invitation to take part in a trial. If you would like more information about this trial, please leave your contact details and a researcher will post you some more information. Your details will remain strictly confidential and will not be shared with anyone outside the research team. If you do not want to leave your contact details, you can return the 'Health and Lifestyle Questionnaire' anonymously.

Thank you for your consideration. We look forward to hearing from you.

With kind regards,

[Signature]

[Name of clinician who treated patient]

Appendix F. NHS National Research Ethics Committee – South Central Oxford B (reference 14/SC/1369) approval letter for Study 2



Health Research Authority

NRES Committee South Central - Oxford B

Whitefriars
Level 3, Block B
Lewin's Mead
Bristol
BS1 2NT

Telephone: 0117 342 1333
Fax: 0117 342 0445

05 December 2014

Professor Jane Wardle
1-19 Torrington Place
London
WC1E 6BT

Dear Professor Wardle

Study title: Advancing Survivorship after Cancer: Outcomes Trial
(ASCOT)
REC reference: 14/SC/1369
Protocol number: 14/0409
EudraCT number:
IRAS project ID: 146804

Thank you for your letter of , responding to the Committee's request for further information on the above research and submitting revised documentation.

The further information was considered in correspondence by a Sub-Committee of the REC A list of the Sub-Committee members is attached.

We plan to publish your research summary wording for the above study on the HRA website, together with your contact details. Publication will be no earlier than three months from the date of this opinion letter. Should you wish to provide a substitute contact point, require further information, or wish to make a request to postpone publication, please contact the REC Manager, Mrs Siobhan Bawn, nrescommittee.southcentral-oxfordb@nhs.net.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised, subject to the conditions specified below.

Conditions of the favourable opinion

The favourable opinion is subject to the following conditions being met prior to the start of the

study.

Additional Conditions:

Invitation Letter

The Letter from the Clinician should be made more personal as they have met the individual. This could be achieved with the removal of the phrase 'your records show..' and replacement with ' Following on from your consultation...'

Letter for patients not eligible for ASCOT pilot trial

- Remove the phrase 'has not spread'
 - Correct "feel get in touch" needs correcting to "feel free to get in touch".
- Telephone script for ASCOT intervention
- Correct page 5, paragraph 3 in Walk your way, sentence starting "it's a pedometer..." by removing 'it's'.

You should notify the REC in writing once all conditions have been met (except for site approvals from host organisations) and provide copies of any revised documentation with updated version numbers. The REC will acknowledge receipt and provide a final list of the approved documentation for the study, which can be made available to host organisations to facilitate their permission for the study. Failure to provide the final versions to the REC may cause delay in obtaining permissions.

Management permission or approval must be obtained from each host organisation prior to the start of the study at the site concerned.

Management permission ("R&D approval") should be sought from all NHS organisations involved in the study in accordance with NHS research governance arrangements.

Guidance on applying for NHS permission for research is available in the Integrated Research Application System or at <http://www.rdforum.nhs.uk>.

Where a NHS organisation's role in the study is limited to identifying and referring potential participants to research sites ("participant identification centre"), guidance should be sought from the R&D office on the information it requires to give permission for this activity.

For non-NHS sites, site management permission should be obtained in accordance with the procedures of the relevant host organisation.

Sponsors are not required to notify the Committee of approvals from host organisations

Registration of Clinical Trials

All clinical trials (defined as the first four categories on the IRAS filter page) must be registered on a publically accessible database within 6 weeks of recruitment of the first participant (for medical device studies, within the timeline determined by the current registration and publication trees).

There is no requirement to separately notify the REC but you should do so at the earliest opportunity e.g when submitting an amendment. We will audit the registration details as part of the annual progress reporting process.

To ensure transparency in research, we strongly recommend that all research is registered but for non clinical trials this is not currently mandatory.

If a sponsor wishes to contest the need for registration they should contact Catherine Blewett (catherineblewett@nhs.net), the HRA does not, however, expect exceptions to be made. Guidance on where to register is provided within IRAS.

Clinical trial authorisation must be obtained from the Medicines and Healthcare products Regulatory Agency (MHRA).

The sponsor is asked to provide the Committee with a copy of the notice from the MHRA, either confirming clinical trial authorisation or giving grounds for non-acceptance, as soon as this is available.

It is the responsibility of the sponsor to ensure that all the conditions are complied with before the start of the study or its initiation at a particular site (as applicable).

Ethical review of research sites

NHS sites

The favourable opinion applies to all NHS sites listed in the application, subject to management permission being obtained from the NHS/HSC R&D office prior to the start of the study (see "Conditions of the favourable opinion" below).

Non-NHS sites

The Committee has not yet completed any site-specific assessment (SSA) for the non-NHS research site(s) taking part in this study. The favourable opinion does not therefore apply to any non-NHS site at present. We will write to you again as soon as an SSA application(s) has been reviewed. In the meantime no study procedures should be initiated at non-NHS sites.

Approved documents

The final list of documents reviewed and approved by the Committee is as follows:

<i>Document</i>	<i>Version</i>	<i>Date</i>
Copies of advertisement materials for research participants [Poster alerting patients to ASCOT study]	1	19 November 2014
Evidence of Sponsor insurance or indemnity (non NHS Sponsors only) [Sponsor insurance details]	2	
GP/consultant information sheets or letters [GP letter]	1	02 September 2014
Interview schedules or topic guides for participants [Telephone script for ASCOT intervention]	1	02 September 2014
IRAS Checklist XML [Checklist_29102014]		29 October 2014
Letter from funder [Cancer Research UK grant award letter]		

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Letter from sponsor [Letter from sponsor]		
Letters of invitation to participant [ASCOT pilot trial letter of invitation]	1	02 September 2014
Letters of invitation to participant [ASCOT patient survey letter of invitation]	2	19 November 2014
Non-validated questionnaire [ASCOT patient survey (including validated and non-validated measures)]	3	19 November 2014
Non-validated questionnaire [ASCOT follow-up survey (including validated and non-validated measures)]	3	19 November 2014
Other [CV Sonia Lopes (student)]	1	23 September 2014
Other [CV Abigail Fisher (academic supervisor)]	1	23 September 2014
Other [CV Helen Croker (academic supervisor)]	1	23 September 2014
Other [CV Rose Wilson (UCL research team)]	1	23 September 2014
Other [CV Alison Hill (Principal Investigator)]	1	23 September 2014
Other [CV Allan Hackshaw (statistician)]	1	23 September 2014
Other [CV Sharon Cavanagh (collaborator)]	1	23 September 2014
Other [CV Kathy Pritchard-Jones (collaborator)]	1	23 September 2014
Other [CV Rebecca Roylance (collaborator)]	1	23 September 2014
Other [CV Michael Machesney (collaborator)]	1	23 September 2014
Other [CV John Hines (collaborator)]	1	23 September 2014
Other [CV Krishnaswamy Madhavan (collaborator)]	1	23 September 2014
Other [Letter for patients not eligible for ASCOT pilot trial]	1	19 November 2014
Other [CV Maggie Heinrich (UCL research team)]	1	19 November 2014
Other [Response to REC provisional opinion]	1	21 November 2014
Participant consent form [ASCOT pilot trial patient consent form]	2	19 November 2014
Participant information sheet (PIS) [ASCOT pilot trial patient information sheet]	2	19 November 2014
REC Application Form [REC_Form_29102014]		29 October 2014
Referee's report or other scientific critique report [Cancer Research UK peer reviewer comments and response]	1	23 September 2014
Research protocol or project proposal [Protocol]	7	19 November 2014
Summary CV for Chief Investigator (CI) [Short CV Jane Wardle]	1	23 September 2014
Summary CV for student [CV Kate Williams]	1	23 September 2014
Summary CV for supervisor (student research) [CV Rebecca Beeken]	1	23 September 2014

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

After ethical review

Reporting requirements

The attached document "*After ethical review – guidance for researchers*" gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Adding new sites and investigators
- Notification of serious breaches of the protocol
- Progress and safety reports
- Notifying the end of the study

The HRA website also provides guidance on these topics, which is updated in the light of changes in reporting requirements or procedures.

User Feedback

The Health Research Authority is continually striving to provide a high quality service to all applicants and sponsors. You are invited to give your view of the service you have received and the application procedure. If you wish to make your views known please use the feedback form available on the HRA website:

<http://www.hra.nhs.uk/about-the-hra/governance/quality-assurance/>

HRA Training

We are pleased to welcome researchers and R&D staff at our training days – see details at

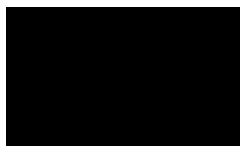
<http://www.hra.nhs.uk/hra-training/>

14/SC/1369

Please quote this number on all correspondence

With the Committee's best wishes for the success of this project.

Yours sincerely



Mr Chris Foy
Chair

Email: nrescommittee.southcentral-oxfordb@nhs.net



NRES Committee South Central - Oxford B

Whitefriars
Level 3, Block B
Lewin's Mead
Bristol
BS1 2NT

Telephone: 0117 342 1333

07 January 2015

Professor Jane Wardle
1-19 Torrington Place
London
WC1E 6BT

Dear Professor Wardle

Study title: Advancing Survivorship after Cancer: Outcomes Trial
(ASCOT)
REC reference: 14/SC/1369
Protocol number: 14/0409
EudraCT number:
IRAS project ID: 146804

Thank you for your letter of 05 January 2015. I can confirm the REC has received the documents listed below and that these comply with the approval conditions detailed in our letter dated 05 December 2014

Documents received

The documents received were as follows:

<i>Document</i>	<i>Version</i>	<i>Date</i>
Interview schedules or topic guides for participants [Telephone script for ASCOT intervention]	2	15 December 2014
IRAS Checklist XML [Checklist_05012015]		05 January 2015
Letters of invitation to participant [ASCOT patient survey letter of invitation]	3	15 December 2014
Other [Letter for patients not eligible for ASCOT pilot trial]	2	15 December 2014

Approved documents

The final list of approved documentation for the study is therefore as follows:

A Research Ethics Committee established by the Health Research Authority

<i>Document</i>	<i>Version</i>	<i>Date</i>
Copies of advertisement materials for research participants [Poster alerting patients to ASCOT study]	1	19 November 2014
Evidence of Sponsor insurance or indemnity (non NHS Sponsors only) [Sponsor insurance details]	2	
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Summary CV for Chief Investigator (CI) [Short CV Jane Wardle]	1	23 September 2014
Summary CV for student [CV Kate Williams]	1	23 September 2014
Summary CV for supervisor (student research) [CV Rebecca Beeken]	1	23 September 2014

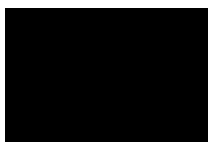
A Research Ethics Committee established by the Health Research Authority

You should ensure that the sponsor has a copy of the final documentation for the study. It is the sponsor's responsibility to ensure that the documentation is made available to R&D offices at all participating sites.

14/SC/1369

Please quote this number on all correspondence

Yours sincerely



Mrs Siobhan Bawn
REC Manager

E-mail: nrescommittee.southcentral-oxfordb@nhs.net

Copy to: Ms Suzanne Emerton

Appendix G. Sample characteristics for Study 2 with full breakdown of responses

Characteristics	n (%)
Gender	
Male	2553 (43.7)
Female	3265 (55.9)
Missing data	22 (0.4)
Highest level of education	
No qualifications	1709 (29.3)
GCSE/Vocational	1613 (27.6)
A-level	584 (10.0)
Degree or higher	1380 (23.6)
Missing data	554 (9.5)
Ethnicity	
White	5250 (89.9)
Non-white	554 (9.5)
Missing data	36 (0.6)
Internet use	
Yes	3769 (64.5)
No	1982 (33.9)
Missing data	89 (1.5)
Cancer type	
Breast	2788 (47.7)
Prostate	1842 (31.5)
Colorectal	1210 (20.7)
Cancer spread	
Yes	558 (9.6)
No	4499 (77.0)
Don't know	373 (6.4)
Missing data	410 (7.0)
Meeting MVPA guidelines	
Meeting guidelines	1791 (30.7)
Not meeting guidelines	3359 (57.5)
Missing data	690 (11.8)
Perceived need to change PA	
I think I should be doing more PA	2973 (50.9)
I think I should be doing less PA	55 (0.9)
I don't think I need to change my PA	2306 (39.5)
Don't know	377 (6.5)
Missing data	129 (2.2)
Interest in information/advice to increase PA	
Not at all interested	2102 (36.0)
A little interested	829 (14.2)
Somewhat interested	1116 (19.1)
Very interested	1529 (26.2)
Missing data	264 (4.5)
Interest in internet information	
Not at all interested	3230 (55.3)
A little interested	563 (9.6)
Somewhat interested	761 (13.0)
Very interested	687 (11.8)
Extremely interested	208 (3.6)
Missing data	391 (6.7)
Interest in an app	
Not at all interested	4063 (69.6)
A little interested	324 (5.5)
Somewhat interested	431 (7.4)
Very interested	469 (8.0)
Extremely interested	162 (2.8)
Missing data	391 (6.7)

Appendix H. Sample characteristics for breast cancer sample

(n=2,788)

Mean age: 63 years, SD: 13 years, range: 27-97 years

Characteristics	n (%)
Gender	
Male	24 (0.9)
Female	2758 (98.9)
Missing data	6 (0.2)
Highest level of education	
No qualifications	620 (22.2)
GCSE/Vocational	903 (32.4)
A-level	338 (12.1)
Degree or higher	749 (26.9)
Missing data	178 (6.4)
Ethnicity	
White	2476 (88.8)
Non-white	293 (10.5)
Missing data	19 (0.7)
Internet use	
Yes	1993 (71.5)
No	762 (27.3)
Missing data	33 (1.2)
Cancer spread	
Yes	252 (9.0)
No	2214 (79.4)
Don't know/Missing	322 (11.5)
Number of comorbid conditions	
0	933 (33.5)
1	925 (33.2)
2	527 (18.9)
3+	403 (14.5)
Meeting MVPA guidelines	
Meeting guidelines	932 (33.4)
Not meeting guidelines	1577 (56.6)
Missing data	279 (10.0)
Perceived need to change PA	
I think I should be doing more PA	1594 (57.2)
Other	1127 (40.4)
Missing data	67 (2.4)
Interest in information/advice to increase PA	
Not at all interested	891 (32.0)
Interested	1779 (63.8)
Missing data	118 (4.2)
Interest in internet information	
Not at all interested	1429 (51.3)
Interested	1180 (42.3)
Missing data	179 (6.4)
Interest in an app	
Not at all interested	1781 (63.9)
Interested	828 (29.7)
Missing data	179 (6.4)

PA: physical activity

Appendix I. Sample characteristics for prostate cancer sample

(n=1,842)

Mean age: 72 years, SD: 8 years, range 38-95 years

Characteristics	n (%)
Gender	
Male	1831 (99.4)
Female	0 (0)
Missing data	11 (0.6)
Highest level of education	
No qualifications	670 (63.4)
GCSE/Vocational	404 (21.9)
A-level	144 (7.8)
Degree or higher	370 (20.1)
Missing data	254 (13.8)
Ethnicity	
White	1635 (88.8)
Non-white	196 (10.6)
Missing data	11 (0.6)
Internet use	
Yes	1071 (58.1)
No	730 (39.6)
Missing data	41 (2.2)
Cancer spread	
Yes	155 (8.4)
No	1387 (75.3)
Don't know/Missing	300 (16.3)
Number of comorbid conditions	
0	572 (31.1)
1	639 (34.7)
2	376 (20.4)
3+	255 (13.8)
Meeting MVPA guidelines	
Meeting guidelines	538 (29.2)
Not meeting guidelines	1035 (56.2)
Missing data	269 (14.6)
Perceived need to change PA	
I think I should be doing more PA	837 (45.4)
Other	971 (52.7)
Missing data	34 (1.8)
Interest in information/advice to increase PA	
Not at all interested	697 (37.8)
Interested	1065 (57.8)
Missing data	80 (4.3)
Interest in internet information	
Not at all interested	1104 (59.9)
Interested	626 (34.0)
Missing data	112 (6.1)
Interest in an app	
Not at all interested	1410 (76.5)
Interested	320 (17.4)
Missing data	112 (6.1)

PA: physical activity

Appendix J. Sample characteristics for colorectal cancer sample (n=1,210)

Mean age: 70 years, SD: 11 years, range: 26-94 years

Characteristics	n (%)
Gender	
Male	698 (57.7)
Female	507 (41.9)
Missing data	5 (0.4)
Highest level of education	
No qualifications	419 (34.6)
GCSE/Vocational	306 (25.3)
A-level	102 (8.4)
Degree or higher	261 (21.6)
Missing data	122 (10.1)
Ethnicity	
White	1139 (94.1)
Non-white	65 (5.4)
Missing data	6 (0.5)
Internet use	
Yes	705 (58.3)
No	490 (40.5)
Missing data	15 (1.2)
Cancer spread	
Yes	151 (12.5)
No	898 (74.2)
Don't know/Missing	161 (13.3)
Number of comorbid conditions	
0	348 (28.8)
1	429 (35.5)
2	216 (17.9)
3+	217 (17.9)
Meeting MVPA guidelines	
Meeting guidelines	321 (26.5)
Not meeting guidelines	747 (61.7)
Missing data	142 (11.7)
Perceived need to change PA	
I think I should be doing more PA	542 (44.8)
Other	640 (52.9)
Missing data	28 (2.3)
Interest in information/advice to increase PA	
Not at all interested	514 (42.5)
Interested	630 (52.1)
Missing data	66 (5.5)
Interest in internet information	
Not at all interested	697 (57.6)
Interested	413 (34.1)
Missing data	100 (8.3)
Interest in an app	
Not at all interested	872 (72.1)
Interested	238 (19.7)
Missing data	100 (8.3)

PA: physical activity

Appendix K. Logistic regression analyses for interest in internet information and an app for mobile/tablet – complete-case analysis (N=3,616)

Demographic characteristics	Internet information							App for mobile/tablet						
	Interested % (N)	OR	Unadjusted CI	p	OR	Adjusted ^a CI	p	Interested % (N)	OR	Unadjusted CI	p	OR	Adjusted ^a CI	p
Age	-	0.93	0.93-0.94	<.001	0.96	0.95-0.96	<.001	-	0.92	0.91-0.93	<.001	0.94	0.93-0.95	<.001
Gender														
Male	41.6 (609)	1.00	-	-	1.00	-	-	21.2 (311)	1.00	-	-	-	-	-
Female	48.8 (1051)	1.34	1.17-1.53	<.001	0.66	0.55-0.78	<.001	34.3 (738)	1.94	1.66-2.26	<.001	0.87	0.72-1.05	.145
Ethnicity														
White	45.4 (1488)	1.00	-	-	1.00	-	-	27.5 (902)	1.00	-	-	1.00	-	-
Non-White	50.6 (172)	1.23	0.98-1.54	.069	0.73	0.56-0.96	.026	43.2 (147)	2.01	1.60-2.52	<.001	1.33	1.02-1.74	.038
Highest level of education														
No formal qualifications	21.7 (212)	1.00	-	-	1.00	-	-	12.5 (122)	1.00	-	-	1.00	-	-
GCSEs/vocational qualifications	48.9 (575)	3.45	2.85-4.17	<.001	1.43	1.13-1.79	.002	31.4 (369)	3.20	2.56-4.02	<.001	1.17	0.90-1.52	.246
A-levels or equivalent	58.8 (250)	5.16	4.04-6.60	<.001	1.82	1.36-2.43	<.001	38.1 (162)	4.32	3.29-5.68	<.001	1.29	0.94-1.76	.119
Degree or higher	60.1 (623)	5.45	4.48-6.63	<.001	1.90	1.49-2.41	<.001	38.2 (396)	4.34	3.46-5.45	<.001	1.28	0.98-1.68	.074
Internet use														
No	10.3 (99)	1.00	-	-	1.00	-	-	7.1 (68)	1.00	-	-	1.00	-	-
Yes	58.8 (1561)	12.40	9.93-15.48	<.001	6.89	5.41-8.78	<.001	36.9 (981)	7.68	5.93-9.95	<.001	3.55	2.67-4.73	<.001
Number of comorbidities	-	0.87	0.82-0.91	<.001	1.06	0.99-1.13	.105	-	0.83	0.78-0.89	<.001	1.04	0.96-1.11	.361
Cancer spread														
No	45.0 (1448)	1.00	-	-	1.00	-	-	28.0 (901)	1.00	-	-	1.00	-	-
Yes	53.5 (212)	1.41	1.14-1.74	.001	1.06	0.83-1.36	.644	37.4 (148)	1.54	1.24-1.91	<.001	1.14	0.89-1.46	.314
Loneliness	-	1.05	1.01-1.10	.017	1.02	0.97-1.08	.464	-	1.10	1.05-1.15	<.001	1.03	0.98-1.09	.289
Belief that should do more PA														
Other	37.0 (595)	1.00	-	-	-	-	-	21.0 (338)	1.00	-	-	1.00	-	-
“I think I should do more PA”	53.0 (1065)	1.92	1.68-2.20	<.001	1.02	0.85-1.21	.849	35.4 (711)	2.06	1.77-2.40	<.001	1.06	0.88-1.28	.544
Interest in information/advice to increase PA														
Not interested	25.4 (312)	1.00	-	-	-	-	-	12.4 (152)	1.00	-	-	1.00	-	-
Interested	56.4 (1348)	3.80	3.26-4.42	<.001	3.35	2.79-4.02	<.001	37.5 (897)	4.25	3.52-5.14	<.001	3.36	2.71-4.17	<.001
Meeting MVPAs recommendations														
Not meeting recommendations	40.0 (893)	1.00	-	-	-	-	-	24.4 (544)	1.00	-	-	1.00	-	-
Meeting recommendations	55.5 (767)	1.87	1.64-2.15	<.001	1.33	1.12-1.58	.001	36.5 (505)	1.79	1.55-2.07	<.001	1.28	1.07-1.53	.015

^a: Adjusted for age, gender, ethnicity, education, internet use, number of comorbidities, cancer spread, loneliness, belief that should do more PA, interest in information/advice to increase PA, meeting MVPAs recommendations

Appendix L. Pooled logistic regression analyses for interest in internet information and an app for mobile/tablet (10 imputations) – breast cancer survivors only (N=2,788)

Interest in internet information = 46.2%; interest in an app = 32.0%

Demographic characteristics	Internet information							App for mobile/tablet						
	Interested % (N)	OR	Unadjusted CI	p	OR	Adjusted ^a CI	p	Interested % (N)	OR	Unadjusted CI	p	OR	Adjusted ^a CI	p
Age	-	0.94	0.93-0.95	<.001	0.96	0.95-0.97	<.001	-	0.92	0.91-0.93	<.001	0.94	0.93-0.95	<.001
Ethnicity														
White	45.5 (1134)	1.00	-	-	1.00	-	-	30.3 (754)	1.00	-	-	1.00	-	-
Non-White	52.0 (154)	1.30	1.02-1.66	.036	0.79	0.59-1.06	.120	47.0 (139)	2.03	1.58-2.61	<.001	1.20	0.89-1.62	.230
Highest level of education														
No formal qualifications	23.8 (165)	1.00	-	-	1.00	-	-	15.1 (105)	1.00	-	-	1.00	-	-
GCSEs/vocational qualifications	47.3 (452)	2.88	2.56-3.69	<.001	1.17	0.89-1.54	.257	33.3 (318)	2.79	2.10-3.72	<.001	0.97	0.71-1.34	.868
A-levels or equivalent	57.9 (206)	4.40	3.28-5.91	<.001	1.62	1.16-2.25	.004	41.3 (147)	3.94	2.81-5.52	<.001	1.20	0.81-1.77	.359
Degree or higher	59.3 (465)	4.69	3.67-5.99	<.001	1.70	1.28-2.26	<.001	41.1 (322)	3.91	2.94-5.20	<.001	1.16	0.83-1.63	.390
Internet use														
No	16.0 (124)	1.00	-	-	1.00	-	-	10.2 (79)	1.00	-	-	1.00	-	-
Yes	57.9 (1164)	7.30	5.58-9.54	<.001	3.84	2.87-5.14	<.001	40.5 (814)	6.09	4.21-8.81	<.001	2.56	1.71-3.82	<.001
Number of comorbidities	-	0.84	0.79-0.90	<.001	1.06	0.98-1.15	.163	-	0.80	0.74-0.86	<.001	1.03	0.94-1.13	.581
Cancer spread														
No	45.1 (1129)	1.00	-	-	1.00	-	-	30.8 (771)	1.00	-	-	1.00	-	-
Yes	56.4 (159)	1.57	1.21-2.04	.001	1.01	0.75-1.36	.956	43.3 (122)	1.72	1.30-2.27	<.001	1.09	0.80-1.50	.580
Loneliness	-	1.01	0.96-1.06	.805	0.99	0.94-1.05	.779	-	1.05	1.00-1.11	.034	1.02	0.94-1.13	.599
Belief that should do more PA														
Other	37.6 (424)	1.00	-	-	-	-	-	23.7 (267)	1.00	-	-	1.00	-	-
"I think I should do more PA"	52.8 (841)	1.86	1.58-2.18	<.001	0.90	0.73-1.10	.289	38.4 (612)	2.01	1.67-2.42	<.001	0.95	0.76-1.19	.629
Interest in information/advice to increase PA														
Not interested	27.5 (258)	1.00	-	-	-	-	-	13.6 (128)	1.00	-	-	1.00	-	-
Interested	55.7 (1030)	3.33	2.76-4.01	<.001	2.67	2.12-3.56	<.001	41.4 (765)	4.49	3.60-5.58	<.001	3.40	2.63-4.41	<.001
Meeting MVPAs recommendations														
Not meeting recommendations	46.1 (602)	1.00	-	-	-	-	-	30.1 (394)	1.00	-	-	1.00	-	-
Meeting recommendations	46.3 (686)	1.01	0.86-1.19	.888	0.98	0.81-1.19	.850	33.6 (498)	1.17	1.00-1.38	.054	1.13	0.92-1.37	.244

^a: Adjusted for age, gender, ethnicity, education, internet use, number of comorbidities, cancer spread, loneliness, belief that should do more PA, interest in information/advice to increase PA, meeting MVPAs recommendations

Appendix M. Pooled logistic regression analyses for interest in internet information and an app for mobile/tablet (10 imputations) – prostate cancer survivors only (N=1,842)

Interest in internet information = 37.6%; interest in an app = 19.3%

Demographic characteristics	Internet information							App for mobile/tablet						
	Interested % (N)	OR	Unadjusted CI	p	OR	Adjusted ^a CI	p	Interested % (N)	OR	Unadjusted CI	p	OR	Adjusted ^a CI	p
Age	-	0.93	0.92-0.94	<.001	0.96	0.94-0.97	<.001	-	0.92	0.91-0.94	<.001	0.95	0.93-0.96	<.001
Ethnicity														
White	37.0 (609)	1.00	-	-	1.00	-	-	17.6 (290)	1.00	-	-	1.00	-	-
Non-White	43.0 (85)	1.27	0.93-1.73	.134	0.85	0.57-1.25	.399	32.8 (65)	2.28	1.62-3.21	<.001	1.72	1.16-2.54	.007
Highest level of education														
No formal qualifications	22.7 (181)	1.00	-	-	1.00	-	-	12.9 (103)	1.00	-	-	1.00	-	-
GCSEs/vocational qualifications	43.4 (200)	2.60	1.93-3.51	<.001	1.38	0.96-1.99	.086	23.0 (106)	2.02	1.44-2.84	<.001	1.10	0.75-1.61	.636
A-levels or equivalent	46.3 (76)	2.97	1.99-4.41	<.001	1.37	0.87-2.17	.173	20.7 (34)	1.76	1.07-2.89	.025	0.82	0.48-1.38	.447
Degree or higher	56.2 (236)	4.35	3.32-5.71	<.001	2.00	1.43-2.80	<.001	26.7 (112)	2.47	1.77-3.44	<.001	1.10	0.75-1.62	.621
Internet use														
No	13.2 (99)	1.00	-	-	1.00	-	-	8.7 (65)	1.00	-	-	1.00	-	-
Yes	54.4 (595)	7.88	6.02-10.33	<.001	5.55	4.05-7.61	<.001	26.5 (290)	3.83	2.74-5.36	<.001	2.80	1.95-4.02	<.001
Number of comorbidities	-	0.96	0.89-1.03	.270	1.04	0.94-1.14	.480	-	0.94	0.85-1.03	.185	1.02	0.91-1.13	.767
Cancer spread														
No	36.8 (608)	1.00	-	-	1.00	-	-	19.2 (318)	1.00	-	-	1.00	-	-
Yes	45.2 (85)	1.42	1.02-1.98	.039	1.58	1.04-2.41	.031	20.2 (38)	1.04	0.66-1.65	.859	1.11	0.67-1.82	.682
Loneliness	-	1.00	0.93-1.07	.904	1.00	0.93-1.10	.862	-	1.05	0.96-1.14	.300	1.03	0.94-1.13	.541
Belief that should do more PA														
Other	31.6 (307)	1.00	-	-	-	-	-	15.4 (150)	1.00	-	-	1.00	-	-
"I think I should do more PA"	44.6 (373)	1.74	1.42-2.14	<.001	1.01	0.79-1.30	.945	24.1 (202)	1.74	1.36-2.24	<.001	1.12	0.85-1.48	.424
Interest in information/advice to increase PA														
Not interested	20.2 (147)	1.00	-	-	-	-	-	8.5 (62)	1.00	-	-	1.00	-	-
Interested	48.9 (546)	3.76	2.97-4.76	<.001	3.63	2.73-4.84	<.001	26.3 (294)	3.86	2.78-5.37	<.001	3.14	2.21-4.44	<.001
Meeting MVPA recommendations														
Not meeting recommendations	36.0 (319)	1.00	-	-	-	-	-	17.3 (153)	1.00	-	-	1.00	-	-
Meeting recommendations	39.1 (374)	1.15	0.94-1.40	.186	1.46	1.13-1.87	.003	21.1 (202)	1.28	1.00-1.65	.052	1.51	1.14-1.99	.004

^a: Adjusted for age, gender, ethnicity, education, internet use, number of comorbidities, cancer spread, loneliness, belief that should do more PA, interest in information/advice to increase PA, meeting MVPA recommendations

Appendix N. Pooled logistic regression analyses for interest in internet information and an app for mobile/tablet (10 imputations) – colorectal cancer survivors only (N=1,210)

Interest in internet information = 39.1%; interest in an app = 22.3%

Demographic characteristics	Internet information							App for mobile/tablet						
	Interested % (N)	OR	Unadjusted CI	p	OR	Adjusted ^a CI	p	Interested % (N)	OR	Unadjusted CI	p	OR	Adjusted ^a CI	p
Age	-	0.94	0.93-0.95	<.001	0.96	0.95-0.98	<.001	-	0.93	0.92-0.95	<.001	0.95	0.93-0.96	<.001
Gender														
Male	41.4 (290)	1.00	-	-	1.00	-	-	22.7 (159)	1.00	-	-	-	-	-
Female	36.1 (184)	0.81	0.63-1.04	.092	0.71	0.51-0.98	.035	21.8 (111)	0.96	0.70-1.31	.789	0.79	0.55-1.14	.200
Ethnicity														
White	39.2 (449)	1.00	-	-	1.00	-	-	21.6 (247)	1.00	-	-	1.00	-	-
Non-White	37.9 (25)	0.94	0.55-1.60	.815	0.78	0.41-1.49	.451	34.8 (23)	1.95	1.13-3.38	.017	1.70	0.88-3.29	.112
Highest level of education														
No formal qualifications	24.2 (116)	1.00	-	-	1.00	-	-	14.6 (70)	1.00	-	-	1.00	-	-
GCSEs/vocational qualifications	44.2 (148)	2.47	1.78-3.44	<.001	1.19	0.78-1.81	.424	23.3 (78)	1.78	1.20-2.66	.005	0.78	0.47-1.31	.342
A-levels or equivalent	56.8 (63)	4.08	2.52-6.61	<.001	1.98	1.12-3.48	.019	33.3 (37)	2.95	1.74-5.01	<.001	1.23	0.65-2.32	.529
Degree or higher	51.6 (147)	3.34	2.33-4.78	<.001	1.29	0.82-2.04	.272	30.2 (86)	2.54	1.71-3.76	<.001	0.87	0.50-1.49	.596
Internet use														
No	15.1 (75)	1.00	-	-	1.00	-	-	9.3 (46)	1.00	-	-	1.00	-	-
Yes	56.0 (399)	7.21	5.10-10.19	<.001	4.86	3.24-7.29	<.001	31.4 (224)	4.47	2.96-6.76	<.001	2.79	1.70-4.57	<.001
Number of comorbidities	-	0.87	0.80-0.85	.003	1.03	0.92-1.15	.598	-	0.84	0.75-0.95	.005	0.98	0.86-1.13	.806
Cancer spread														
No	39.2 (407)	1.00	-	-	1.00	-	-	21.5 (223)	1.00	-	-	1.00	-	-
Yes	39.0 (67)	1.00	0.69-1.43	.985	0.79	0.50-1.25	.318	27.3 (47)	1.39	0.92-2.11	.117	1.15	0.73-1.82	.541
Loneliness	-	1.00	0.93-1.08	.916	1.02	0.93-1.13	.624	-	1.04	0.95-1.13	.385	1.01	0.92-1.12	.803
Belief that should do more PA														
Other	32.5 (208)	1.00	-	-	-	-	-	17.7 (113)	1.00	-	-	1.00	-	-
"I think I should do more PA"	47.0 (255)	1.83	1.44-2.34	<.001	0.87	0.64-1.19	.386	28.2 (153)	1.83	1.38-2.45	<.001	0.89	0.63-1.26	.516
Interest in information/advice to increase PA														
Not interested	23.7 (129)	1.00	-	-	-	-	-	11.6 (63)	1.00	-	-	1.00	-	-
Interested	51.8 (345)	3.45	2.68-4.46	<.001	3.01	2.21-4.10	<.001	31.1 (207)	3.47	2.45-4.91	<.001	2.73	1.84-4.06	<.001
Meeting MVPA recommendations														
Not meeting recommendations	38.0 (226)	1.00	-	-	-	-	-	22.0 (131)	1.00	-	-	1.00	-	-
Meeting recommendations	40.3 (248)	1.11	0.87-1.41	.419	1.18	0.87-1.60	.280	22.6 (139)	1.04	0.78-1.38	.794	1.00	0.72-1.38	.985

^a: Adjusted for age, gender, ethnicity, education, internet use, number of comorbidities, cancer spread, loneliness, belief that should do more PA, interest in information/advice to increase PA, meeting MVPA recommendations

Appendix O. Publication of Study 3

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Original Paper

Breast, Prostate, and Colorectal Cancer Survivors' Experiences of Using Publicly Available Physical Activity Mobile Apps: Qualitative Study

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Abstract

Background: Physical activity (PA) can improve a range of outcomes following a cancer diagnosis. These include an improvement in experience of side effects of treatment (eg, fatigue) and management of comorbid conditions. PA might also increase survival and reduce recurrence. Digital interventions have shown potential for PA promotion among cancer survivors, but most in a previous review were Web-based, and few studies used mobile apps. There are many PA apps available for general public use, but it is unclear whether these are suitable as a PA intervention after a cancer diagnosis.

Objective: This study sought posttreatment nonmetastatic breast, prostate, and colorectal cancer survivors' opinions of using smartphone apps to promote PA and gathered their views on existing publicly available PA apps to inform a future intervention.

Methods: Each participant was randomly assigned to download 2 of 4 apps (Human, The Walk, The Johnson & Johnson Official 7 Minute Workout, and Gorilla Workout). Participants used each app for 1 week consecutively. In-depth semistructured telephone interviews were then conducted to understand participants' experiences of using the apps and how app-based PA interventions could be developed for cancer survivors. The interviews were analyzed using thematic analysis.

Results: Thirty-two participants took part: 50% (16/32) had prostate cancer, 25% (8/32) had breast cancer, and 25% (8/32) had colorectal cancer. Three core themes were identified. The first theme was that multiple factors affect engagement with PA apps and this is highly personalized. Factors affecting engagement included participants' perceptions of (1) the advantages and disadvantages of using apps to support PA, (2) the relevance of the app to the user (eg, in terms of cancer-related factors, their PA goals, the difficulty level of the app, the way in which they interact with their mobile phone, and the extent to which the app fits with their self-identity), (3) the quality of the app (eg, usability, accuracy, quality of production, and scientific evidence-base), and (4) the behavior change techniques used to promote PA. In the second theme, participants recommended that apps that promote walking are most appealing, as walking removes many barriers to PA. Finally, the participants suggested that PA apps should be integrated into cancer care, as they valued guidance and recommendations from health care professionals.

Conclusions: This sample of breast, prostate, and colorectal cancer survivors was receptive to the use of apps to promote PA. Although no publicly available PA app was deemed wholly suitable, many suggestions for adaptation and intervention development were provided. The results can inform the development of an app-based PA intervention for cancer survivors. They also highlight the wide-ranging and dynamic influences on engagement with digital interventions, which can be applied to other evaluations of mobile health products in other health conditions and other health behaviors.

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KEYWORDS

physical activity; health behavior; cancer survivors; mobile apps; mHealth; digital health

Introduction

The number of people diagnosed with cancer continues to increase and is estimated to reach more than 20 million new cases per year worldwide by 2025 [1]. Earlier diagnosis and improvements in treatment mean that rates of cancer survival are also increasing. However, fatigue [2], pain [3], sleep problems [4], weight gain [5,6], and anxiety and depression [7,8] are common among cancer survivors, and 70% have a comorbid chronic condition [9]. Depending on cancer type and the area at which treatment is targeted, particular groups of cancer survivors are at greater risk of more specific late effects. For instance, lymphedema is common among breast cancer survivors [10], and incontinence is common among prostate and colorectal cancer survivors [11,12]. These sequelae can have a profound negative impact on quality of life (QoL) [13], and interventions to improve outcomes in cancer survivors are urgently required.

There is now strong evidence that physical activity (PA) can improve a range of important cancer outcomes for breast, prostate, and colorectal cancer survivors, 3 of the most prevalent cancer types worldwide [1]. Observational evidence shows that PA might reduce cancer-specific and all-cause mortality and cancer recurrence in breast, prostate, and colorectal cancer survivors [14-16]. PA has also been shown to improve overall health-related QoL, emotional well-being, and social functioning and reduce anxiety, fatigue, pain, and sleep problems in cancer survivors [17]. Therefore, cancer survivors are now advised to meet the same PA guidelines as the general adult population. This includes a minimum of 150 min of at least moderate-intensity PA and 2 instances of strength and resistance-based training per week [18-21]. Where this is not achievable, avoiding inactivity is recommended. However, when PA is measured objectively using accelerometers, as few as 16% of breast cancer survivors meet PA recommendations, and those with the highest level of comorbidity are the least active [22]. People diagnosed with cancer are less likely to engage in PA than people who have never received a diagnosis [23]. In a sample of 631 breast cancer survivors, the self-reported proportion meeting PA guidelines declined from 34% at 2 years post diagnosis to 21% at 10 years post diagnosis [24]. Side effects of treatment and fear about what type of PA, when, and how to start or increase PA safely are often reported as barriers to PA after a cancer diagnosis [25-27]. As a result, PA interventions for people affected by cancer are required.

Face-to-face interventions are time- and resource-intensive, and accessibility can be limited [28,29]. Increasing ownership of smartphones provides an avenue for scalable digital behavior change interventions, including those that aim to increase PA. In the context of cancer, for which age is the strongest risk factor [30], smartphone ownership has, in recent years, risen most rapidly among the older age groups. In the United Kingdom specifically, smartphone ownership increased from 32% to 47%

in people aged over 55 years from 2015 to 2017 [31,32]. In the United States, smartphone ownership is even higher among older age groups (73% among those aged 50-64 years and 46% in people aged over 65 years) [33].

Digital behavior change interventions have been shown to increase PA in the general adult population [34] and our recent meta-analysis of 15 studies showed that digital interventions have the potential to increase cancer survivors' moderate-vigorous PA by approximately 40 min per week [35]. However, of the studies included in this review, the majority used Web-based interventions, and only 2 small feasibility studies evaluated the use of mobile apps in PA promotion [36,37]. Mobile apps have the benefit of being able to deliver behavior change techniques (BCTs) in real time using a device that is usually switched on, usually carried with the person, and often has inbuilt functions to monitor PA and deliver immediate feedback. There are many health and fitness apps aimed at the general population that are currently available on commercial app stores, which might already be appropriate for cancer survivors or could be adapted to increase their suitability. Exploring cancer survivors' experiences of using different types of existing apps is, therefore, a useful way to understand which types of PA apps might be most appropriate or successful, before making potentially large investments into app or intervention development.

Qualitative research methods provide a rich understanding of people's experiences, thoughts, and opinions and seeking the perspectives of intended users is a critical element of digital intervention development [38,39]. Robertson et al conducted focus groups with breast, prostate, colorectal, and endometrial cancer survivors where feedback was collected for potential PA app features and messages [40]; however, the feedback provided was hypothetical. We suggest that by allowing participants to actually experience using different types of apps and BCTs over a period of time provides greater ecological validity. Since the publication of the meta-analysis, Short et al conducted an experiential mixed-methods study where 10 cancer survivors were referred to one of 15 existing PA apps, which were used for a 1- to 2-week period [41]. Although this study explored the participants' experience and preliminary efficacy of the app referral service, it did not explore participants' opinions of using the apps in detail. We see the value in a deeper understanding of participants' perceptions of their preferences for and influences on engagement with PA apps. For the purposes of this study, we use a broad, integrative definition of engagement comprising "1) the extent (e.g. amount, frequency, duration, depth) of usage and 2) a subjective experience characterized by attention, interest and affect" [42].

Therefore, the aim of this study was to seek breast, prostate, and colorectal cancer survivors' opinions of using apps to promote PA and gather their views on existing publicly available PA apps to inform a future intervention.

Methods

Mobile Apps

During our initial scoping of the smartphone app stores, no apps that were specifically designed to promote PA among cancer survivors were identified. This is in line with a previous Australian study exploring the use of PA apps among cancer survivors [41]. Therefore, the PA apps considered for this study were identified from apps that were featured in the “Health and Fitness” section of the British Apple App Store (iOS), along with other apps that the study authors were aware of from previous work in digital health and that might have been suitable for this study. The following criteria were considered in deciding which apps might be suitable for the study:

- **Content:** The apps needed to vary from each other in terms of the type of PA, and their format, features, and BCTs to allow comparison between different types of apps.
- **Typicality:** Although the apps needed to vary in terms of their content, we also felt that the apps chosen should be typical of the various types of popular PA apps that are available (eg, activity trackers and workout programs).
- **Suitability:** The apps needed to be suitable for people who have undergone cancer treatment and, therefore, needed to have the flexibility to cater for different levels of fitness and familiarity with PA. Given the target group, apps that catered for low levels of fitness/familiarity with PA, but with an option to increase this if required, were of interest. Each app was reviewed for its suitability for use by breast, prostate, and colorectal cancer survivors by a physiotherapist specializing in oncology.

- **Stability:** The apps were required to have been launched at least 2 years before the study.
- **Availability:** The apps needed to be available on both iOS and Android devices.

We felt that 4 apps should be included in the study, based on a number of considerations. These included the number of apps required to compare multiple participants’ opinions across several different PA apps, the number of participants required for the study, and feasibility of recruitment and data analysis. Given the consideration of all of the above factors, the 4 chosen apps were “Human,” “The Walk,” “The Johnson & Johnson Official 7 Minute Workout” (J&J), and “Gorilla Workout” (see Table 1 for a description of each of the apps and an assessment of the incorporated BCTs, coded using the BCT Taxonomy (v1) [43] by AR and DK, with discrepancies resolved via discussion). Figures 1-4 show screenshots of the 4 apps.

Recruitment

Participants were recruited via advertisements within community-based cancer support groups (either by verbal descriptions from group leaders at meetings or via posters, flyers, and email mailing lists), Facebook cancer support groups, and charitable organizations (eg, Macmillan Cancer Support’s Cancer Voices and Tackle Prostate Cancer). We initially aimed to recruit 32 participants to attempt to ensure sufficient representation from participants diagnosed with each of the 3 cancer types and so that approximately 16 participants would be allocated to use each of the 4 apps throughout the study. If new themes continued to be identified, we would continue recruitment until saturation was achieved.

Table 1. App characteristics.

App (Developer)	Price	Description	Behavior change techniques
Human (Humanco, Inc)	Free	Encourages users to meet daily 30/60/90/120 min goal of walking, running, and/or cycling measured using mobile phone’s activity tracker. Delivers push notifications when users have not met their goal or during periods of inactivity. Compares activity levels to other app users nearby	1.1 Goal setting (behavior); 2.2 Feedback on behavior; 2.3 Self-monitoring of behavior; 6.2 Social comparison; 7.1 Prompts/cues; 10.3 Nonspecific reward
The Walk (Six to Start)	£2.29 (iOS); £2.59 (Android)	An interactive story-based game where walking unlocks audio clips to hear the next part to the story and other rewards. Time to complete an episode is based on the users’ current physical activity level and walking is measured using the mobile phone’s activity tracker	2.2 Feedback on behavior; 10.3 Nonspecific reward; 10.6 Nonspecific incentive
The Johnson & Johnson Official 7 Minute Workout (Johnson & Johnson Health and Wellness Solutions, Inc)	Free	7-min workouts are created to include aerobic and resistance exercises alternating between upper and lower body, core, and total body exercises. The workouts can be tailored to the users’ current fitness and motivation levels and are provided with detailed video demonstrations and audio guidance	1.4 Action planning; 2.3 Self-monitoring of behavior; 4.1 Instruction on how to perform behavior; 6.1 Demonstration of the behavior; 7.1 Prompts/cues; 8.7 Graded tasks; 9.1 Credible source
Gorilla Workout (Heckr LLC)	£0.79 (iOS); £0.83 (Android)	The default program is tailored to the users’ current fitness level and gradually increases in difficulty. Each exercise has written guidance with an associated video with visual and audio demonstrations. Users can also choose to complete their own selection of exercises (from a list of 43) with the same written/video demonstrations. Daily push notifications are delivered to remind users to complete their workout	4.1 Instruction on how to perform behavior; 6.1 Demonstration of the behavior; 7.1 Prompts/cues; 8.7 Graded tasks

Figure 1. Screenshots of Human.



Figure 2. Screenshots of The Walk.



Participants were required to be aged 18 years or older; to have been diagnosed with breast, prostate, or colorectal cancer; to have finished primary curative treatment (as it is likely that individuals still undergoing primary treatment or with metastatic disease might require additional support and monitoring to be active); to have no known impairment or comorbidity that meant a clinician had advised them not to exercise; and to own a smartphone. Although participants were required to have finished primary curative treatment (surgery, radiotherapy, and chemotherapy), participants still taking maintenance hormone therapy or under active surveillance were eligible. Participants were offered a £10 voucher as an incentive for completion of this study and to reimburse the cost incurred if asked to install an app that was not free to download. Ethical approval for this study was granted by the UCL Research Ethics Committee (reference: 7663/001).

Procedure

Participants took part in an initial short semistructured telephone questionnaire that confirmed participants' eligibility and requested details of the participants' sociodemographic information (age, gender, and ethnicity), cancer diagnosis, and their experience of using digital technologies to support PA. Participants were asked to describe their perceptions of their current participation in PA (eg, what types of PA and how frequently). This was asked as an introductory question to build rapport with the participants at the beginning of the study and to provide context. A Web-based random number generator (Randomizer) was used to allocate 2 apps to each participant to allow comparison of app features and content but to minimize participant burden. Guidance in downloading and installing each app was provided, if required. Participants were asked to spend approximately 2 consecutive weeks using the apps, (approximately 1 week using each) and were able to choose the

order in which they used the apps to which they were allocated over the 2-week period. Participants were asked to try to use each app at least three to four times throughout that app's trial week and record any comments or opinions in log sheets provided. After 2 to 3 weeks, each participant completed an audio-recorded semistructured telephone interview, using the interview schedule (Table 2) as a guide.

Analysis

Telephone interviews were conducted by AR and transcribed verbatim by an external company. A partly deductive and partly inductive approach to thematic analysis was adopted using the stepped approach described by Braun and Clarke [44]. The

deductive approach to thematic analysis involved using the BCT taxonomy [43] as a framework to code any interview data where participants spoke about app features used to promote behavior change. The rest of the data were analyzed using an inductive approach through an iterative reading and rereading of the data. An initial coding framework was developed by AR and revised in collaboration with DK, with discrepancies agreed via discussion. AR applied the final codes that were then incorporated into themes during discussion between all authors. After analysis of these 32 interviews, no new themes were identified and recruitment was concluded. Data analysis was conducted in NVivo 11.

Figure 3. Screenshots of The Johnson & Johnson Official 7 Minute Workout (J&J).



Figure 4. Screenshots of Gorilla Workout.

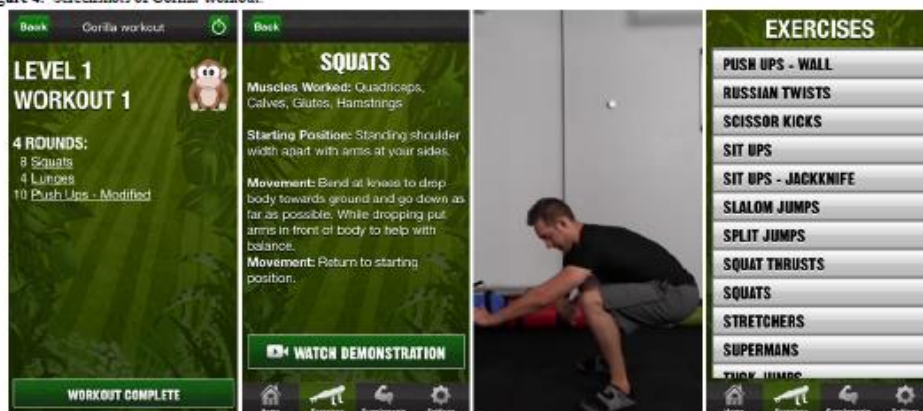


Table 2. Semistructured interview guide.

Discussion point	Details
Recap	Confirm which apps participant was asked to download and try
Download/install	Ask about the participants' ability to find, download, and install each app
First app	Ask participant to start by giving overall opinion of app; Depending on amount of detail provided in overview, ask participant to expand on any points raised in overview, comment on likes/dislikes, comment on specific app features/BCTs ^a (dependent on allocated app)
Second app	Repeat the steps as given for the first app
Appropriateness for cancer	Discuss how appropriate and relevant each of the apps were for their personal circumstances and as a cancer survivor
Adapting for cancer survivors	Discuss how (if at all) the apps could be adapted for cancer survivors. If so, what adaptations/functions to tailor the app would they make
Interest in an app	Discuss participants' interest in a PA ^b app tailored specifically for people who have had cancer
Preferred types of PA	Discuss types of PA that should be promoted to cancer survivors, including intensity, frequency, type of activity, and with relevance to current PA guidelines (ie, 150 min moderate-vigorous PA and 2 sessions of strength and resistance-based exercises per week) and how apps could promote these types of PA (if at all)
Recommendations	Discuss any PA recommendations that were provided to them following cancer diagnosis/treatment and who were they delivered by or where participant looked for them
Intervention communication	Discuss who should direct cancer survivors to a cancer-specific PA app, including when this should be discussed and promoted to patients

^aBCT: behavior change technique.

^bPA: physical activity.

Results

A total of 40 participants began the study, and 32 participants completed telephone interviews. Of those who dropped out, lack of time, family circumstances (eg, bereavement), and not wanting to update their smartphone's operating system or register credit card details with Google Play were the listed reasons. Of the 32 participants who completed the study, the mean age was 60 years (range 37-78 years; SD 11 years) and the other sample characteristics are displayed in Table 3.

Broadly, the core themes demonstrate that multiple factors affect engagement with PA apps and this is highly personalized, that apps that promote walking are most appealing for cancer survivors, and that PA apps should be integrated into cancer care.

Multiple Factors Affect Engagement With Physical Activity Apps, and This is Highly Personalized

Key determinants of engagement appeared to be the users' perceptions of (1) the advantages and disadvantages of using apps to support PA, (2) the relevance of the app, (3) the quality of the app, and (4) the BCTs used to promote PA.

Perceived Advantages and Disadvantages of Using Apps to Support Physical Activity

The participants identified a number of advantages of PA apps, which facilitated engagement with the apps. These included the

convenience that an app offers in terms of equipment required, cost, and not being required to attend a specific exercise facility:

Especially if you can, y'know, the workouts, like the Gorilla workouts that I've looked at so far, they're all just using your own body, where you don't need any special equipment, and all the rest of it...and you don't need to spend £30 a month to join a gym to do it. [Male, aged 68 years, colorectal cancer]

You can just choose when you decide to do it – so you can think, "right, I'm gonna do a little workout now", so y'know, pick your moment, put your phone on and just pick whichever one you want. [Female, aged 52 years, breast cancer]

They also commented that apps could be useful in building confidence or self-efficacy for PA and how this can be important in relation to side effects:

I was left with a lot of tummy problems after my treatment. So in a way you would think that doing a workout at home might suit a lot of people because if their confidence is low, either how they feel about their fitness or that they need to be near the loo or whatever, then being at home should be reassuring, shouldn't it? [Female, aged 47 years, breast cancer]

Table 3. Sample characteristics (N=32).

Sample characteristics	n (%)
Gender	
Female	10 (31)
Male	22 (69)
Ethnicity	
White British	28 (88)
White-other	1 (3)
Asian/Asian British	2 (6)
Mixed	1 (3)
Cancer type	
Breast	8 (25)
Prostate	16 (50)
Colorectal	8 (25)
Experience of using digital technology to support PA^a	
Never used	10 (31)
Mobile phone installed PA app (eg, Apple Health and SHealth)	5 (16)
Currently using a PA tracker (eg, pedometer, Fitbit, Garmin, and Strava)	9 (28)
Have used a PA tracker before but not currently using	5 (16)
Using combination of technologies (eg, mobile phone installed PA app + PA tracker)	3 (9)

^aPA: physical activity.

It was also acknowledged that an app-based PA program could be more effective in comparison with printed materials due to the ubiquity of smartphones and the more engaging nature of interacting with the program in real time:

Where apps, of course, have a huge advantage, the days of paper things...exercise sheets, and things which end up in the bottom drawer or in the dustbin, err, apps are better than that, because they're on your phone, and they can be updated, as well...you've always got your phone with you. You haven't always got the list with you. [Male, aged 69 years, prostate cancer]

...it's a bit more interactive and it's there and you can just...I'm gonna press on...whatever this...what's a box jump? For example, and you can press on that and see...see what it is, so it's very, very useful. [Male, aged 69 years, prostate cancer]

Although only 1 participant mentioned the possible benefit of apps in terms of the level of literacy required to interact with the program, it is important to note that this could improve accessibility to a PA intervention through the visual and interactive features of the apps:

I know...it's a nice, simple app. You don't need to be that literate. [Male, aged 60 years, prostate cancer]

However, a number of disadvantages of app-based PA interventions were also raised. These included the possible safety implications of unsupervised PA:

...if somebody isn't getting advice from a professional first and they're just picking up an app and...wanted to get a bit more active and doing it at home, I think that something like this could be actually be quite risky. [Female, aged 43 years, breast cancer]

I think you'd have to be careful that people did it properly and that they did it at the right time and didn't...you know, didn't overdo it...some people think, 'ooh, well I'm doing exercise, it must be doing me good,' but it might not be...cause they're doing it too early, or they're doing it wrong...Because there's no supervision, there's no guarantee, is there?...That would be more for strength-based things, really [compared to walking]. [Female, aged 59 years, breast cancer]

Participants also experienced a number of technical issues (eg, impact on battery life, mobile data usage, and smartphone memory):

[Human] does drain your battery quite quickly because you have to use, erm, location services all the time...if it was gonna be a regular thing I wouldn't use it every day then just because the fact that it does drain your battery. [Female, aged 37 years, colorectal cancer]

There were also concerns around data security and access to or usage of personal data:

...of course, with the freebies, as we know, what you're doing is you're signing up to allow them to track your

location, other things you might be doing...nothing's really free. [Male, aged 69 years, prostate cancer]

Perceived Relevance of the App

The participants described a number of factors that influenced their opinions of the perceived relevance of the apps used in this study. The participants described greater engagement with the apps that were perceived as most relevant to them. In relation to cancer, the participants acknowledged that they were a heterogeneous group who will differ in terms of their PA ability and that a successful app must be able to be tailored for this diversity to ensure it feels relevant to the user's ability:

Everybody who's had cancer will have a different level of fitness anyway even after cancer, and they'll have a different level of motivation and a different starting point so that's why that 7 minute app is good...you can choose...depending on where your starting point is. [Female, aged 52 years, breast cancer]

The participants also highlighted that each individual's experience of cancer, treatment, and side effects differs and that a PA app to be used by cancer survivors must acknowledge the potential barriers that patients who have been diagnosed with various types of cancer and experienced different types of treatment and side effects might experience:

...depending on what treatment you've had, in terms of, umm, certainly operations, and scars and whether you've got adhesions or...weakened muscles in various places...it's all going to vary, from one cancer to another...there's a lot of variation and, err, that needs to be covered. [Male, aged 68 years, colorectal cancer]

[Gorilla Workout] came up with something like...I can't remember what it said, but something like, "Don't be a slacker, get... you know, get working," or something, and I was like, "Err...hang on a minute." Like, if I'm feeling crap and I'm feeling fatigued, that is not what I want to see. [Female, aged 38 years, breast cancer]

Furthermore, the participants also described that the types of PA that might feel appropriate or relevant to a cancer survivor could vary depending on where the patient is in their cancer journey (eg, diagnosis, treatment, recovery, and survivorship):

I had prostate cancer, and I had an operation. And, if you're looking at an app to try and get patients who've had cancer, y'know, back and fit again, I'm not sure that these exercises [on J&J and Gorilla Workout] were the right ones. I personally felt, that if I were being... had this been about six years ago [around time of treatment], they were too physical. I needed gentler exercises. [Male, aged 70 years, prostate cancer]

However, there were also several noncancer-specific factors that influenced the perceived relevance of the app to the participants. These factors included the extent to which the app(s) aligned with the participants' PA goals:

I suppose it depends what you're trying to get out of it and, for me, it's looking at trying to regain a level of fitness, because I've probably lost it over the last four months or so. And I see the Seven Minute Workout as the one that will specifically do that whereas, [Human] is just monitoring what I will tend to do anyway. [Male, aged 65 years, prostate cancer]

The extent to which the difficulty level of the app was suitable for the user also affected perceived relevance. This was particularly apparent for the strength- and resistance-based training apps:

[Human] was, as I say, very easy. It doesn't cause you any difficulties or problems. So I think anybody can use it. You know, it doesn't really matter how fit you are or how unfit you are, it's not going to be a problem...[with Gorilla Workout] I found, even on the easy level, that some of the exercises were impossible...Level 1 is you can perform 0-10 push-ups, but they still kind of think you're gonna be able to do some. It's, like, I can't do any. And I don't think I'm ever gonna be. [Female, aged 43 years, breast cancer]

Um, and then [J&J] had things like press-ups and the plank. I mean, I just thought it was a joke, to be honest...I had a go on a couple of different days. Um, but it was, it was just much too difficult...I felt quite demoralised when they were so difficult. But yeah, something that's, um, you know, much more gentle to build up from, um, I think is quite a nice idea. [Female, aged 47 years, breast cancer]

The participants also described that the way they interact with their mobile phone affects the perceived relevance of certain types of PA apps, namely activity trackers that require you to carry the smartphone to measure PA behavior:

[Human] assumes your phone is always on you...mine never is, unless I go out. So, it stays on the hall table...So of course, if it's left on the hall table, you're not moving around at all. So it'll say, "You're pretty inactive," y'know, "How about a walk around the block?" and you think, err, I've been doing the housework all morning. I'm exhausted. [Male, aged 65 years, prostate cancer]

Finally, in terms of the participants' self-identity and their perception of whether the app fits with this identity affected their opinion of its perceived relevance:

And it is a man, isn't it, doing the exercises?...[J&J] was quite masculine, I think...I know it's a silly thing but even if it, if there was a choice of having a woman or a man to watch, you know. [Female, aged 47 years, breast cancer]

And of course, umm, on both of them [J&J and Gorilla Workout]...the videos, err, show the sort of slim, fit young, ultra-fit, young men doing it. You think, "Gosh, I...I haven't looked like that for about 40 years." [Male, aged 69 years, prostate cancer]

Perceived Quality of the App

The participants described several factors that affected their perceived quality of the apps to promote PA. The participants expressed greater engagement with the apps that were perceived to be higher quality, although they did not necessarily agree which those apps were. The factors affecting perceived quality differed between users.

Primarily, the users described the importance of ensuring that an app is easy to use and intuitive to foster engagement from the first usage:

...the bottom line is that...[The Walk's] not intuitive...Perhaps I should have looked for a help area, or something, if I wanted to make full use of it, but then I also think, if an app is gonna be good, then it, it needs to lend itself to the user...with Human, again, I didn't look out for any help areas. It's just, you start using it, it tells you what, what's going on, what you've done, and you can interpret it quite easily. [Male, aged 51 years, prostate cancer]

The participants described the importance of ensuring that an app, which tracks PA behavior, does so accurately:

...the main issue I had was that [Human] would record activity, but it would get it wrong. So when I was out on a bike ride, umm, it had me doing a mixture of walking, cycling, umm or running...so I just felt that it didn't really work that well for me. [Male, aged 68 years, colorectal cancer]

Furthermore, the participants' description of how well produced the app was affected their perceived quality of the apps:

I kept getting a bit confused with the voices. They weren't different enough in the story. Mainly, as I say, because, um, it was a bit frenetic and people were noisy and speaking quickly and it was a bit jumpy...and just the production of [The Walk], you know...it was a bit jumbled and thrown together almost. [Female, aged 65 years, breast cancer]

The J&J app provided an explanation of the scientific evidence-base behind the recommended exercises and workout program, and this was described as increasing the perceived quality and credibility of the app to benefit health:

I did like the mass of support documentation you could delve down into to find out why the exercises were what they were, and the, umm, sort of, a bit of medical stuff behind it...I felt [J&J] was more medical-oriented...it was looking at your total body, total welfare – and I thought that it felt very professional...I felt the regime was based on good scientific basis. [Male, aged 70 years, prostate cancer]

Opinions of Behavior Change Techniques Used to Promote Physical Activity

Opinions of BCTs used to promote PA within the apps were sought during the interviews and grouped into the following categories: "video demonstrations," "prompts/cues (reminders)," "goal setting, self-monitoring, and feedback on behavior," and

"incentives, rewards, and gamification." Participants' views toward each of these strategies varied considerably, and their opinions on these BCTs determined the extent to which the participants engaged with the apps to which they were allocated.

Video Demonstrations

The use of video demonstrations to illustrate how to perform specific exercises correctly was well received:

...the method of presentation, brilliant. [J&J] was very clear...the bloke was there doing it with you...because you can sort of follow along, without just trying to remember how you should be doing it, and you can look at him to see how he's got his legs, straight or bent a bit. [Male, aged 51 years, colorectal cancer]

Prompts/Cues (Reminders)

There was mixed feedback on the use of push notifications/reminders to prompt users to engage in PA and how effective they were. This depended on the users' opinion on reminders, their tone, and how appropriate they were in terms of the time or context in which they were delivered:

...mixed feelings about the sort of constant reminders [Human] gave you...it's quite good in some respects, because it does make you think, "Oh, yeah. Okay. I'll just go and have a quick walk to the end of the road and back." Err...But then when...three or four are coming, you're thinking, "Oh god, would you shut up?"...I didn't mind "Oh, what about a quick walk after lunch?" that sort of thing...they were quite positive. [Female, aged 65 years, breast cancer]

...there was at least one of those prompts on Human, that actually we followed it. It said something like, "Let's go for a walk," and we said, "do you know what? Let's do that"...on other occasions, er, we said, well, actually, it's dark so we're not...you tend to start ignoring it 'cause it might not be appropriate at that time...so it wasn't a bad thing – but it wasn't always the right thing at the right time. [Male, aged 65 years, prostate cancer]

Goal-Setting, Self-Monitoring, and Feedback on Behavior

These BCTs were grouped as they are frequently used alongside each other to promote PA. For instance, the Human app presents the daily 30-min PA goal, facilitates self-monitoring of progress toward the goal by presenting data collected by the smartphone's activity tracker, and then presents feedback on their behavior to indicate whether that goal was met or not. Therefore, it is difficult to separate out the participants' opinions of each of these BCTs individually; however, the participants generally responded positively to this approach to promote PA:

[Human] does show you like summaries and averages. It gives you some interesting information so you can see whether you're doing better or worse than you were doing yesterday and that kind of thing...it's nice to have a target and a challenge to work on. [Female, aged 43 years, breast cancer]

I could see that I was actually walking more than I thought. So it all adds up...I think it is interesting to monitor because you can actually see how much you're doing, and...how quickly actually you reach your target. So you could think, like, "Oh, instead of half hour walking, maybe I could increase it to 45 minutes" or an hour if you want to push yourself. So I think that's definitely a benefit to monitor it...for me, just the data it was interesting and nice to see what I'm actually doing, and be more aware, and in that sense actually that...that already motivated me...to walk a bit extra instead of the bus...so in that sense...I did walk more with the app. [Female, aged 54 years, breast cancer]

Some participants also discussed their positive experience of these types of BCTs using other digital technologies to support PA before this study:

I've just got the [Apple] Health one on my iPhone, which we check the steps every day. So because that's nicely how many steps you've done, how far you've done, and that 10,000 steps...we've both taken that on-board as a very good target...[which is] good because you could have a look and say, "Oh, crikey. I haven't done enough today" or "I haven't done enough this week," or whatever. [Male, aged 69 years, prostate cancer]

I find the, you know, the completion of the steps quite satisfying...if I've got to the evening and I'm on, you know, nine thousand and something, I want to make sure I've got that to 10,000 if I walk up and down the stairs a few times, and then actually when you go over, you know, you do feel quite pleased with yourself...[Fitbit] would plot how many days you'd done, how many steps and what your average was for the week and what your average was for the month and that was quite rewarding, because you do feel like you are achieving something. [Female, aged 47 years, breast cancer]

Incentives/Rewards and Gamification

There was mixed feedback on the use of incentives/rewards and gamification to increase engagement with the app and PA. This type of BCT was most prevalent in The Walk; however, participants were generally put off using this app by some of the usability issues mentioned above and the extent to which the app was perceived as relevant to them:

[The Walk's] trying to show you where, you could possibly take alternate...you could select to do a slightly longer walk, and have the chance of getting more points from other things. Like picking up packages, but I haven't really looked at that. [Male, aged 60 years, prostate cancer]

Many of the participants said they felt that the gaming aspect to the app was inappropriate for them and they did not find it interesting:

I'm not interested in doing that, you know. I mean, even listening to [The Walk], it just got boring...I

listened to it as I was walking along and I thought this is not for me really, you know, there was people missing here and people hiding there. I didn't know what it was talking about really. I'm not into that sort of thing. [Male, aged 71 years, prostate cancer]

Apps That Promote Walking Are Most Appealing for Cancer Survivors

In acknowledging cancer survivors' varying needs (above), and incorporating their personal experience of cancer with their experience of using the apps in this study, the participants generally agreed that a walking-based app would be most appealing for cancer survivors. Walking was perceived to be safe, accessible, and achievable for the vast majority of people regardless of their ability, cancer type, treatment type, side effects, or where they are in their cancer journey. They also said that walking was enjoyable, which increased the likelihood that it would be sustainable and consequently effective:

First thing to do when you're coming back from the surgery, or any kind of treatment, I think walking is probably the safest way to introduce yourself back into [an] exercise routine. [Male, aged 51 years, prostate cancer]

I couldn't use my upper body because of the surgery and then I had the chemo and I just couldn't go to the classes, so...but what I did do was walking, because I thought even if I can't do anything else you can always walk...if you really talk about something people can do right after or maybe even during treatment, I think walking is the easiest, the safest and the best way to start. [Female, aged 54 years, breast cancer]

However, they did acknowledge the need to ensure that participants are engaging in PA that is of high enough intensity to meet the PA recommendations:

People might be having a 10 minute dawdle round the garden centre and think that they've done their exercise...I can see the sort of, the, the challenge with getting the balance, um, between the...it being achievable but also being effective isn't it? [Female, aged 47 years, breast cancer]

Some participants recognized the importance of resistance training:

I think walking is very good, but equally I think it's overall, y'know, a balanced body strength and, and flexibility's important. So, I think it's worth persevering with that approach as well. [Male, aged 68 years, colorectal cancer]

However, others reported that they did not enjoy or want to do these types of exercises:

I like the walking better than the exercises...the workouts and that sort of thing...I would hate to get...right into the heavy stuff, er, and tiring myself out, you know, cause we are getting older. [Male, aged 70 years, prostate cancer]

I don't like doing exercise, and yet, as I mean in doing strengthening exercise and that sort of thing to build my muscle up, but I don't mind walking. [Male, aged 70 years, colorectal cancer]

Physical Activity Apps Should Be Integrated Into Cancer Care

The participants agreed that routinely discussing PA and being directed toward onward support (including apps) within the cancer care pathway would ensure everyone diagnosed with cancer receives support. The participants discussed who would be best placed to direct them toward a PA app and when and how this should be introduced:

Patients Should Be Directed to Physical Activity Apps

Participants said that discussions around PA, including being directed toward resources to support behavior change (apps or otherwise), should be discussed with patients as a routine part of cancer care:

I think...there being some sort of formal introduction to the possibility of doing this, then rather it being sort of left for you to find it by yourself...that's what your expert's for. [Male, aged 69 years, prostate cancer]

I don't think a lot of people would bother to go out and look, to see what apps they can find to do exercise. So, I think, if you're gonna do one, I think you've got to encourage somehow, you've got to encourage people to say, or to go, "Oh, that looks good. I'll use that one." [Male, aged 70 years, prostate cancer]

Health Care Professionals' Recommendations Are Valued

There was a general consensus that the medical team, in particular the Clinical Nurse Specialist (CNS), would be best placed to discuss PA and possible interventions with patients. Participants reported feeling that they had built a relationship with their nurse and medical care team over the course of treatment and that they would trust the advice they provided as safe, accurate, and beneficial for their recovery:

The specialist nurses – so you always have a breast care specialist nurse who looks after you and if they started talking about it and telling you it was a good thing to do – I would have, I would have definitely done it...because you develop such a relationship with the specialist nurse who's in charge of your case. [Female, aged 52 years, breast cancer]

The nurses. I was assigned a support nurse...She was very good at giving me advice, and support...If she had said to me, "Look, there's a jolly good app. You will need some ex...you need to get back into fitness again, you've had a big op...have a look at this one." I'd have taken that. [Male, aged 70 years, prostate cancer]

This was also discussed in the context of the fear and uncertainty that is often raised when trying to increase PA post cancer and the potential for inaccurate and potentially unsafe information but that they would trust the medical team and CNS:

I didn't go to any of the support groups although I think they're a good idea, because people do get, you know, a lot from them. I do think it's dodgy if you haven't got a professional person there, because, as I found just sitting in...in the waiting room, um, you know, people have misconceptions...they've got their own ideas about their own treatment and their own health, and um, they start feeding people with, as I say, wrong information and wrong facts...so I was sort of aware that I'd just listen to what [the nurses] told me. [Female, aged 65 years, breast cancer]

Some participants discussed the impact that receiving PA recommendations and feedback from trusted health professionals had on their subsequent participation in PA:

I had one of my check-ups with my consultant, and she said it might be a good time to introduce a tiny little bit of gentle exercise...and so from that point I then got a Fitbit and starting doing 10,000 steps a day, and by the next time I saw her I'd lost a stone and, um, she was very pleased really. [Female, aged 47 years, breast cancer]

Other participants acknowledged that people seek information from different sources, in different ways, so having the information and direction toward an app available via a range of channels might be beneficial:

I think if you want to promote an app like this, it's, er, it's a good idea maybe to go, er, yeah, do it via various channels, so both a Clinical Nurse Specialist, er, the oncology physios, or charities, like, er, like Prostate Cancer UK or Breast Cancer Care. [Female, 54 years, breast cancer]

Physical Activity Should Be Recommended Before and After Treatment

Participants suggested that PA interventions should be discussed at diagnosis or before treatment as a way to help manage or reduce side effects during treatment and after treatment to promote recovery and self-management:

I think if it...if it came as part of the pre-treatment package then I think that would be fantastic, 'cause you're already kind of...yes, you're in a state of shock, but if you're being given stuff to help and start playing with it before you actually start your treatment...because once you're in it, it's quite hard...and then another option, definitely after you finish treatment. Like, if you're feeling fatigued around radiotherapy time or after, definitely then. [Female, aged 38 years, breast cancer]

What I've been trialling out [Human] that should be in your initial pack. So you...once you're diagnosed with the cancer, then you're given the pack and everything else, what to expect and go through, and I think it should be at that stage, as early as possible...that's the time you need that information. [Male, aged 54 years, colorectal cancer]

Discussion

Principal Findings

The sample of breast, prostate, and colorectal cancer survivors interviewed in this qualitative study was receptive to the idea of apps to increase PA but highlighted that it is important to acknowledge the varying needs and preferences of this heterogeneous group. Participants recognized that the impact of cancer on each individual in terms of cancer type, treatment, prognosis, and experience of side effects can be very different, and successful app-based PA interventions must account for that diversity. The results demonstrate the subjective and dynamic nature of engagement with digital interventions and revealed factors that affected engagement for each individual (eg, their perceptions of the advantages and disadvantages of using apps to promote PA, relevance of the app, the quality of the app, and of the BCTs used to promote PA).

Participants recommended that walking would be the most appealing form of PA to recommend using an app and could be recommended at any stage across the cancer trajectory. This was because it was described as feeling safe, achievable, accessible, and enjoyable, regardless of cancer type, treatments received, or ability and could be used to increase confidence and fitness before incorporating strength/resistance-based training as recovery progresses. In terms of the strength/resistance-based training apps in this study (J&J and Gorilla Workout), there was a perception that even the beginner levels of these apps were too difficult and potentially unsafe, given the age, fitness level of many of the participants, in addition to their experience of side effects and recovery from cancer treatment. However, the participants were receptive to the format of these types of apps, with detailed video demonstrations illustrating how to perform each exercise. Activity tracking/walking-based apps did not provoke the same level of unease and the participants said that they felt that these need not be tailored specifically toward people who have had cancer. Although most participants recognized the benefit of strength- and resistance-based training, there was a consensus that apps that promote this type of PA would need to be tailored more specifically toward specific cancer types (eg, with regard to location of surgery) and for people with a lower starting level of ability, confidence, and familiarity with these types of exercises. Some participants also described strength and resistance training as unenjoyable and that they would be unlikely to adhere to these types of regimes. This illustrates the need to increase awareness about other ways of incorporating the strength and resistance training element of the PA recommendations in a way that is more enjoyable or feasible and might be more appealing to this group (eg, yoga, carrying shopping bags) compared with specific workout routines.

The participants suggested that to effectively direct cancer survivors toward an app-based PA intervention, this should be integrated within the existing cancer care pathway and recommended by their health care professionals, particularly CNSs. They described being directed toward an app within the medical setting as providing an opportunity to increase knowledge about the cancer-specific benefits of PA from a

trusted source. The participants recommended that discussing PA/directing to ongoing support would be most beneficial before or after treatment, and particularly if it was highlighted as a way to alleviate side effects and promote recovery. They also felt that recommending walking specifically would be appropriate at any point after diagnosis for the majority of cancer survivors.

There is ongoing debate about the most appropriate, feasible, and effective way to support cancer survivors to increase PA within routine cancer care [45-49]. The results of our study support the use of existing PA apps to support low-risk moderate intensity PA (eg, walking) that could help cancer survivors to achieve the recommended minimum of 150 min of at least moderate-intensity PA per week [18-21]. However, one of the main issues of concern for the participants in this study was the lack of supervision and the potential for harm, particularly regarding the resistance training apps, especially for patients who are unfamiliar with these types of exercises or who might require specialist support. Although patients might receive more appropriate and tailored support if delivered and supervised by appropriate allied health professionals (eg, clinical exercise physiologists and physiotherapists) in specialist facilities [48] where adherence to the regimen can be monitored, there are issues regarding access and uptake [50]. A recent UK study found that despite national guidelines recommending that prostate cancer survivors treated with androgen deprivation therapy should receive 12 weeks of supervised exercise training, only 17% of National Health Service (NHS) trusts are able to provide this [51]. This reflects the lack of availability of these programs and the difficulty of implementation in routine care, particularly if uptake is poor. Future work should aim to better understand the potential for apps to support PA, which is likely to require greater involvement and supervision from exercise oncology specialists (eg, resistance training) and with greater adaptation/tailoring based on the individual's type of cancer, experience of treatment (eg, surgery, hormone therapy, chemotherapy, or radiotherapy) and associated consequences of treatment and side effects (eg, stoma, cachexia, or lymphedema). Greater supervision is also likely to be required for people with advanced/metastatic disease.

However, as highlighted by the participants in this study, there is little debate about the value that patients place on the recommendations provided by their clinical team, particularly the CNS and consultants [51-53]. Despite this, few cancer survivors receive PA recommendations or referrals to exercise programs within routine care [51,54]; health professionals report little discussion about PA with their patients and low awareness of PA recommendations for cancer survivors [52,55-57]. Therefore, it is crucial that oncology staff are supported to have discussions about PA with patients, direct them toward behavioral support to increase PA, and refer to specialist programs, where available. The implementation of recommendations to appropriate PA apps in cancer care requires greater exploration.

Most research in PA and cancer has been overrepresented by female cancer survivors' and primarily by women who have had breast cancer. For instance, in a meta-analysis exploring the effects of PA after cancer conducted by Fong et al [58], 25 of the 39 included studies were conducted exclusively in breast

cancer patients. Although only 6 of the 15 studies included in our review exploring the impact of digital interventions on PA in cancer survivors were conducted exclusively with breast/endometrial cancer survivors, the other 9 studies were all overrepresented by female participants [35]. However, in this study, 69% (22/32) of our sample were male, driven by the 50% of our participants with prostate cancer. It would be interesting to explore the demographic characteristics or particular cancer types for which PA apps are most appealing on a larger scale.

Our approach, enabling participants to experience searching for, downloading, and using selected apps *in the wild* for a period of time, proved to be a time- and resource-efficient method, allowing us to understand how cancer survivors actually experience different types of apps and BCTs. We suggest this provides greater ecological validity than previous studies in the area that have, for instance, sought feedback of hypothetical app features and example text messages from slideshows shown to focus groups of cancer survivors [40]. Digital health research has come to appreciate the importance of usability, design, and tailoring for engagement [38,59]; however, recent reviews have conceptualized engagement with digital health interventions more broadly [42,60]. These reviews have highlighted factors such as personal agency and motivation, personal life and values, the engagement and recruitment approach, and the quality of the digital health intervention [60] and the delivery method (eg, aesthetics/design, ease of use, personalization, and message tone), content (eg, BCTs such as feedback and reminders), the population (eg, demographic characteristics, personal relevance, and self-efficacy), and both the social (eg, norms and social cues) and physical (eg, health care system, location, and time) settings as being important for engagement [42]. Our methodology has allowed us to demonstrate these broader influences on engagement, and we suggest that this methodology could be useful in the development and evaluation of other mobile health (mHealth) products for other health conditions and other health behaviors.

But, how should we respond to the demand from participants for highly tailored interventions that feel relevant to each individual user? Will it be more appropriate to identify/develop a number of PA apps that are suitable for different groups of cancer survivors and from which they could choose the one they think is most suited to them rather than attempting to develop one app that is flexible enough to meet all needs and preferences of a heterogeneous group of individuals? Should we focus on making apps that are cancer specific, or choosing among existing noncancer-specific apps and focusing on how the app is introduced to the individual? In light of this challenge, Short et al [38] have developed a PA app referral scheme to select the most appropriate publicly available, noncancer-specific PA app for a cancer survivor based on a referral matrix, taking into account the participant's fitness level, PA interests, app preferences, and personality characteristics [41]. This novel

approach to evaluation of multiple PA apps within a referral scheme takes advantage of the large number of appropriate and relevant publicly available PA interventions, while offering flexibility, choice, and tailoring to the users' needs and preferences.

Limitations

This study should be viewed in light of a number of limitations. The sample was self-selecting. This led to a high proportion of participants who were already physically active and who were interested in technology and their health and recovery. We did not quantify the participants' current level of PA; however, none of the participants reported being completely inactive. Although this study intended to explore initial opinions of the use of PA apps among cancer survivors, we need to understand the views of those who are inactive or engaging in very little PA, who might feel less confident in engaging in PA or using apps, and who might be unaware of the benefits of PA postcancer diagnosis. Our approach to recruitment means we cannot estimate the number of eligible people who saw the advertisements versus those who responded. Although the participants in this study were able to use the selected apps for between 2 and 3 weeks, a more realistic experience than discussing hypothetical app features in a single session, this does not completely reflect *real-life* app usage or engagement. Participants did not choose the apps, and we did not assess experiences in the longer term. This might be amplified by the fact the participants knew they were taking part in a research study and so might have been more inclined to persevere with some of the apps they disliked and may have discontinued using otherwise.

Conclusions

In conclusion, this sample of breast, prostate, and colorectal cancer survivors were receptive to the use of apps to promote PA but felt that for apps to be effective among this group, they must feel relevant to the individual. This includes accounting for the needs of those who have been diagnosed with different types of cancer, experienced different types of treatment and side effects, and have different levels of PA ability. Walking was highlighted as the most appealing type of PA to promote via an app as it is perceived as safe, achievable, accessible, and enjoyable. We suggest it is useful to also consider the impact of the users' perception of the relevance of an app and how an app relates to their self-identity. This can arise from the app features, but might also be affected by how the app is introduced (eg, by a trusted health professional). Digital health research has come to appreciate the importance of usability and its impact on engagement. Our methodology has allowed us to demonstrate the broader and more dynamic influences on engagement with apps, and we believe this work could, therefore, generalize to evaluations of mHealth products for other health conditions and other health behaviors.

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Conflicts of Interest

The authors have no personal financial interests related to the presented work. AF, HWWP, and LS currently work alongside Six to Start (the developers of the app, The Walk, used in this study) on an unrelated research project. HWWP has a current PhD student (unrelated to this study) who was employed by Johnson & Johnson and whose employment ceased before the beginning of this study. HWWP has received consultancy fees from Crystallise, System Analytic, and The HELP Trust and received funding from myownteam and Shift.ms. These relationships/activities were unrelated to the presented work or analyses. All other authors have no conflicts of interest to declare.

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Abbreviations

BCT: behavior change technique
 CNS: clinical nurse specialist
 J&J: the Johnson & Johnson Official 7 Minute Workout
 mHealth: mobile health
 NHS: National Health Service
 NIHR: National Institute for Health Research
 PA: physical activity
 QoL: quality of life

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Appendix P. UCL Research Ethics Committee approval letter –

Study 3

UCL RESEARCH ETHICS COMMITTEE
ACADEMIC SERVICES



12 January 2016

Dr Abigail Fisher
Health Behaviour Research Centre
Research Department of Epidemiology and Public Health
UCL

Dear Dr Fisher

Notification of Ethical Approval

Project ID: 7663/001: A qualitative study of cancer survivors' views and experiences of using physical activity mobile apps

I am pleased to confirm in my capacity as Chair of the UCL Research Ethics Committee (REC) that I have approved your study for the duration of the project until January 2017.

Approval is subject to the following conditions:

1. You must seek Chair's approval for proposed amendments to the research for which this approval has been given. Ethical approval is specific to this project and must not be treated as applicable to research of a similar nature. Each research project is reviewed separately and if there are significant changes to the research protocol you should seek confirmation of continued ethical approval by completing the 'Amendment Approval Request Form': <http://ethics.grad.ucl.ac.uk/responsibilities.php>
2. It is your responsibility to report to the Committee any unanticipated problems or adverse events involving risks to participants or others. The Ethics Committee should be notified of all serious adverse events via the Ethics Committee Administrator (ethics@ucl.ac.uk) immediately the incident occurs. Where the adverse incident is unexpected and serious, the Chair or Vice-Chair will decide whether the study should be terminated pending the opinion of an independent expert. The adverse event will be considered at the next Committee meeting and a decision will be made on the need to change the information leaflet and/or study protocol.

For non-serious adverse events the Chair or Vice-Chair of the Ethics Committee should again be notified via the Ethics Committee Administrator (ethics@ucl.ac.uk) within ten days of an adverse incident occurring and provide a full written report that should include any amendments to the participant information sheet and study protocol. The Chair or Vice-Chair will confirm that the incident is non-serious and report to the Committee at the next meeting. The final view of the Committee will be communicated to you.

On completion of the research you must submit a brief report of your findings/concluding comments to the Committee, which includes in particular issues relating to the ethical implications of the research.

Yours sincerely



Professor John Foreman
Chair of the UCL Research Ethics Committee

Academic Services, 1-19 Torrington Place (9th Floor),
University College London
Tel: +44 (0)20 3108 8216
Email: ethics@ucl.ac.uk
<http://ethics.grad.ucl.ac.uk/>



Amendment Approval Request Form

1	<p>Project ID Number: 7663/001</p>	<p>Name and Address of Principal Investigator:</p> <p>Dr Abigail Fisher Health Behaviour Research Centre; Department of Epidemiology & Public Health, 1-19 Torrington Place, UCL, London, WC1E 7HB</p>
2	<p>Project Title: A qualitative study of cancer survivors' views and experiences of using physical activity mobile apps</p>	
3	<p>Type of Amendment/s (tick as appropriate)</p> <p><input checked="" type="checkbox"/> Research procedure/protocol (including research instruments) <input type="checkbox"/> Participant group <input type="checkbox"/> Sponsorship/collaborators <input type="checkbox"/> Extension to approval needed (extensions are given for one year) <input checked="" type="checkbox"/> Information Sheet/s <input type="checkbox"/> Consent form/s <input checked="" type="checkbox"/> Other recruitment documents <input type="checkbox"/> Principal researcher/medical supervisor* <input type="checkbox"/> Other *</p> <p><small>*Additions to the research team other than the principal researcher, student supervisor and medical supervisor do not need to be submitted as amendments but a complete list should be available upon request.</small></p>	
4	<p>Justification (give the reasons why the amendment/s are needed)</p> <p>The small amendments are needed to broaden our participant recruitment methods to increase interest in the study.</p>	
5	<p>Details of Amendments (provide full details of each amendment requested, state where the changes have been made and attach all amended and new documentation)</p> <p>1) We request permission to use the Facebook Advertising tool to use paid adverts to broaden the audience for potential participants. Please see the attached document with the proposed adverts in the different formats that they can appear to Facebook users. Those who click on the link are taken to a UCL Opinio online survey where they can read further details about the study and leave their contact details if they wish to receive further information for the research team, where they will then receive a phone call/email with more details and the information sheet/consent form to obtain informed consent as usual. Please also see (https://opinio.ucl.ac.uk/s?s=44303) and the attached screenshot of the survey page where participants leave their contact details if they are interested.</p> <p>2) We also request permission to use Macmillan Cancer Voices as another option for participant recruitment. This is an online service where people affected by cancer can browse opportunities for research/activities that they wish to take part in. We have received permission from Macmillan Cancer Voices to advertise our study using this process, where we must upload a description of the opportunity being advertised. Macmillan Cancer Voices has specified that our Participant Information Sheet meets their criteria for the description they require, however they did request that we made some small changes - such as highlighting that all participants receive a £10 voucher for taking part regardless of whether they are asked to download an app with a fee or not, highlighting that they can take part from their own home and that the study is being carried out independently of Macmillan Cancer Support. We have made these changes to the attached Participant Information Sheet which has been approved by Macmillan Cancer Voices however this differs very slightly to the initial information sheet that we received ethical approval for. We therefore request permission to use this slightly amended information sheet for the purposes of the Macmillan Cancer Voices online advert.</p>	

	<p>3) We also request permission to offer Marks & Spencers vouchers as an additional choice for the type of voucher that participants can receive for taking part. This has been included in a new version of the information sheet (attached).</p> <p>4) We also request to ask participants who complete the study if they would like us to store their details to contact them in future about participation in related studies. It will be made clear to participants that they are not obliged to do so and that this will not affect their participation in the current study.</p>
6	<p>Ethical Considerations (insert details of any ethical issues raised by the proposed amendment/s)</p> <p>1) All identifiable participant information will be held securely within the Data Safe Haven.</p> <p>2) There are no further ethical considerations as a result of this amendment.</p> <p>3) There are no further ethical considerations as a result of this amendment.</p> <p>4) Participants who complete the study will be asked on a voluntary basis if they are interested in future related studies and it will be made clear whilst asking that they are not obliged to give permission if they are not interested. Any participants' details who do give permission, will be stored securely within the Data Safe Haven.</p> <p>There are no further ethical issues raised by the proposed amendments.</p>
7	<p>Other Information (provide any other information which you believe should be taken into account during ethical review of the proposed changes)</p> <p>Not applicable</p>
	<p>Declaration (to be signed by the Principal Researcher)</p> <ul style="list-style-type: none"> • I confirm that the information in this form is accurate to the best of my knowledge and I take full responsibility for it. • I consider that it would be reasonable for the proposed amendments to be implemented. • For student projects I confirm that my supervisor has approved my proposed modifications. <p>Signature: </p> <p>Date: 22/06/16</p>
	<p>FOR OFFICE USE ONLY:</p> <p>Amendments to the proposed protocol have been <i>approved</i> by the Research Ethics Committee.</p> <p>Signature of the REC Chair, Professor John Foreman: </p> <p>Date: 29/6/2016.</p>

Appendix Q. Participant Information Sheet for Study 3

Information Sheet for Participation in Research Studies

You will be given a copy of this information sheet.

Title of Project: **A qualitative study of cancer survivors' views and experiences of using physical activity mobile apps**

This study has been approved by the UCL Research Ethics Committee (Project ID Number): 7663/001

Name	Miss Anna Roberts
Work Address	Health Behaviour Research Centre, Department of Epidemiology & Public Health, University College London, WC1E 6BT
Contact Details	Email: anna.roberts.15@ucl.ac.uk ; Tel: 020 7679 1723

We would like to invite adults who have been diagnosed with breast, prostate and bowel cancer to participate in this research project.

Details of Study: An increasing amount of research suggests that physical activity can benefit people affected by cancer in a number of ways. This includes improving overall health and wellbeing as well as reducing fatigue, pain, anxiety, depression and even the risk of cancer returning. However, we are aware of many of the challenges faced by people affected by cancer and that this may reduce the amount of physical activity they feel they are able to do. We hope to develop a way to support people who've been diagnosed with cancer to increase their physical activity in a way which is specifically tailored to meet their needs and which considers these challenges. The use of smartphones, tablets and mobile technology is rising and physical activity mobile applications (apps) are popular. However there is no physical activity app specifically tailored to meet the needs of people who've had cancer. We would like to gain feedback about whether you feel that a mobile application (or 'app') for a smartphone or tablet would be an effective way to promote physical activity and we would like to know how we could make this work most effectively for you.

Who would we like to be involved? We are looking for adults (over the age of 18) who have been diagnosed with breast, prostate or bowel cancer, who have finished their main treatment and who own an iOS (iPhone) or Android (e.g. Samsungs, Sony, HTC, LG, Nexus) smartphone. We would particularly like to involve people who do not feel they are as active as they should be or who struggle to be more physically active. We would like to emphasise that you don't have to be regularly physically active to take part, but we ask that any participants who have an existing musculoskeletal, cardiovascular or respiratory problem that limits your ability to do physical activity not to take part. Furthermore, please do not take part if your GP or a health professional has advised you not to take part in any physical activity.

What will happen if you decide to take part? The researchers have chosen 4 existing physical activity apps which are currently available to download by the public but that we feel may be appropriate for people who have had a cancer diagnosis. If you wish to take part, a researcher will telephone you to speak about the study and ask you a few short questions about physical activity. We will then tell you which 2 of these apps we would like you to download onto your smartphone and try out for approximately 2 weeks. The apps you will be asked to download will be selected at random. Whilst you are on the telephone, guidance can be provided if you need any help to download the apps or would like an introduction about how to use them.

We would like you to spend one week using each app, and to try to use each app at least 3 times. This is to allow you time to experience using each of them and form your opinions about what you like and dislike about them. Each time you use the apps, we would like you to complete a brief log sheet to record which app you used, the length of time you spent using it and any comments/thoughts about the app that will help you to remember your opinions about the apps when we contact you afterwards. If you would like to take any digital photographs throughout this 2 week period which may also help as a prompt for your thoughts and experiences of physical activity or the apps, please feel free to do so. You may share any photographs (via email) with the researcher before the follow-up telephone interview or you can keep them as prompts for yourself. After approximately 2 weeks, we will telephone you again to discuss your opinions and experiences of using the 2 apps you downloaded.

Some of the apps that we have suggested are free and some have a small one off fee (between £0.79-£2.29). You may or may not be randomly allocated to download one of the paid apps. However, when you have tested the apps for 2 weeks and completed the telephone call afterwards, we will send you your choice of a £10 Love2Shop high street gift voucher, Marks and Spencer voucher or iTunes/Google Play voucher. This is to refund the cost of any of the apps you may have downloaded and as

a 'thank you' for taking part.

The telephone interviews will be audio recorded so they can be transcribed into a written format and reviewed later on. During the telephone interview we will speak about physical activity, and about the apps you tested. This will include talking about things like the content, features, usability, format and acceptability of the apps and what you liked/disliked about them. We will also talk about features you might like to see in a physical activity app for people affected by cancer that were not necessarily included in the apps you used.

How long will the study last? The first time we speak to you on the telephone will take approximately 20 minutes. Here we will tell you which apps we'd like you to download and go through some initial information. We will then ask you to try both the apps for approximately 2 weeks. After this we will arrange a telephone call for us to go through your feedback about the apps you used and this will take approximately 30-40 minutes.

What are the risks involved with this study? We anticipate the risks involved in this study to be minimal. We are aware that talking about a cancer diagnosis may be distressing and it is possible that some sensitive topics may be discussed during the telephone calls. We would like to remind you that you can choose to share as much or as little information as you feel comfortable with. The researchers have a specific schedule of topics to be discussed during the telephone call and so we will keep the discussions focused on the physical activity apps and how appropriate they are for people who have been diagnosed with cancer. All of the possible apps that you could be asked to download have been reviewed by an Oncology Physiotherapist to ensure the exercises that are recommended are safe and appropriate to do for people who've been diagnosed with cancer. However, if you feel any pain or discomfort whilst taking part in any physical activity during this study, please do not continue and contact your GP or medical professional.

Possible benefits of taking part in the study: If taking part in this study helps you to be more physically active, you may experience some of the benefits associated with increased physical activity that were mentioned above. We hope to use this information to help us think about ways we can help people be physically active following a cancer diagnosis. Your feedback will be used in the development of a future physical activity intervention which is specifically tailored to the needs of people who have had cancer.

Anonymity and confidentiality: Your personal/contact details, the audio recordings of the telephone calls and any digital photographs you may choose to share with the researcher will be stored securely and confidentially, in accordance with the Data Protection Act 1998. Any direct quotes from the telephone interviews that are used in publications of the findings of the study will be anonymised and it will not be possible to identify any participants from the quotes used. Any photographs you share with the researcher will not be published and will only be used as prompts in the telephone calls.

Other important information:

- On the consent form you will be asked if you are happy to be contacted about participation in future related studies. Your participation in this study will not be affected should you choose not to be re-contacted.
- We will provide you with a written summary of the findings of the study (unless you choose not to receive this information by indicating your preference on the consent form).

What if I have further questions, or if something goes wrong? If this study has harmed you in any way or you wish to make a complaint about the conduct of the study, you can contact UCL using the details below for further advice and information:

Dr Abi Fisher

Email: abigail.fisher@ucl.ac.uk; Tel: 020 7679 1722

Health Behaviour Research Centre, Research Department of Epidemiology & Public Health,
1-19 Torrington Place, University College London, WC1E 7HB.

Please discuss the information above with others if you wish or ask us if there is anything that is not clear or if you would like more information. It is up to you to decide whether to take part or not; choosing not to take part will not disadvantage you in any way. If you do decide to take part you are still free to withdraw at any time and without giving a reason. If you do decide to take part, please sign the consent form provided with this information sheet and return it to the researcher.

All data will be collected and stored in accordance with the Data Protection Act 1998.

Thank you for reading this information sheet and for considering taking part in this research.

Appendix R. Participant Consent Form for Study 3

Informed Consent Form for Participation in Research Studies

Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research.

Title of Project: **A qualitative study of cancer survivors' views and experiences of using physical activity mobile apps**

This study has been approved by the UCL Research Ethics Committee (Project ID Number): 7663/001

Thank you for your interest in taking part in this research. Before you agree to take part, the person organising the research must explain the project to you.

If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you to decide whether to join in. You will be given a copy of this Consent Form to keep and refer to at any time.

Participant's Statement

I

- have read the notes written above and the Information Sheet, and understand what the study involves.
- understand that if I decide at any time that I no longer wish to take part in this project, I can notify the researchers involved and withdraw immediately.
- consent to the processing of my personal information for the purposes of this research study.
- understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the Data Protection Act 1998.
- understand that my participation will be audio recorded and that anonymised quotes may be used in reporting the findings of this study - I consent to the use of this material as part of the project.
- understand that any digital photographs I share with the researcher will not be published and will only be used as shared prompts during the follow-up telephone call.
- understand that the information I have submitted will be published as a report and I will be sent a summary of the findings (unless I tick the box below). Confidentiality and anonymity will be maintained and it will not be possible to identify me from any related publications of the findings.
- understand that I if I complete the study, I will receive a £10 Love2Shop high street gift voucher, Marks and Spencer voucher or iTunes/Google Play gift voucher of my choice.
- agree that the research project named above has been explained to me to my satisfaction and I agree to take part in this study.

If you DO NOT wish to receive a written summary of the findings of this study, please tick:

If you DO NOT wish to be contacted about participation in future related research studies, please tick:

Print name: _____

Signed: _____

Date: _____

Appendix S. Initial coding frame for Study 3

Initial codes

Feedback from 4
trialled apps

Advantages of an
app

- Convenience
- Confidence
boosting
- Interactivity

Disadvantages of an
app

- Lack of supervision
- Technical difficulties
- Data security /
privacy

Behaviour change
techniques

- Instructions and
video demonstrations
- Goal setting, self-
monitoring and
feedback on
behaviour
- Gamification,
rewards and
incentives
- Reminders
- Social support and
social comparison

Factors affecting
engagement with the
apps

- Perceived relevance
to the individual user
 - App meets their PA
goals + preferences
 - Difficulty level
 - Location
 - Relationship with
smartphone &
technology
 - Sociodemographic
characteristics
 - Identity as a cancer
survivor
- App characteristics
 - Usability
 - PA tracking
accuracy
 - Quality of production
 - Price
 - Novelty effect
 - Opinion of
behaviour change
techniques / app
features

Feedback for
intervention
development

Need for flexibility,
tailoring &
personalisation in PA
apps

- For variation (prevent boredom)
- Ability, fitness level & familiarity with PA
- Personal preference of type, duration, frequency, timing of PA
- Impact of cancer diagnosis, side effects, treatment, where in cancer pathway

Factors that could
increase motivation
to be active

- Emphasising benefits of PA after cancer
- Harnessing the 'teachable moment' of cancer diagnosis

Non-cancer specific
barriers to PA

- Time
- Mind-set / personal motivation
- Accessibility
- Confidence

Preference for
walking

- Safety
- Accessibility
- Achievable
- Enjoyable

Intensity of PA
Strength &
resistance training
Factors affecting
implementation

- How to direct users to an app

- Method of communication
- When should it be recommended – where in pathway
- How should it be recommended


- Importance of healthcare professional recommendations
- Reflections on PA recommendations received (or lack of)

Impact of cancer in
relation to health
behaviours &
lifestyle

How side effects
have affected PA,
weight, diet, lifestyle
& health
Fear & uncertainty
around health
behaviours

Appendix T. UCL Research Ethics Committee approval letter –

Study 4

<p>UCL RESEARCH ETHICS COMMITTEE OFFICE FOR THE VICE PROVOST RESEARCH</p>	
<p>14 November 2017</p> <p>Dr Abigail Fisher Department of Behavioural Science and Health UCL</p> <p>Dear Dr Fisher</p> <p><u>Notification of Ethics Approval with Provisos</u> <u>Project ID/Title: 7663/002: Specialist oncology nurses' opinions of recommending physical activity apps to cancer survivors</u></p> <p>I am pleased to confirm in my capacity as Co-Chair of the UCL Research Ethics Committee (REC) that I have ethically approved the data collection element of your study until 14th November 2018 on condition that participants are not identified by virtue of their status as an NHS staff member but instead via their membership of a professional organisation such as the Royal College of Nursing and other non-NHS routes.</p> <p>The Participant Information Sheet should be revised to include the researcher's status as well as your own. The participant documentation should also be compliant with the new General Data Protection Regulation (GDPR) which comes into effect in May 2018 given that you are collecting personal data beyond this date. Please find enclosed GDPR compliant annotated template participant information sheet and consent form which you should compare against your own adding in some of the mandatory information. For example, a privacy notice should be included in the participant information sheet.</p> <p>Ethical approval is subject to the following conditions.</p> <p><u>Notification of Amendments to the Research</u> You must seek Chair's approval for proposed amendments (to include extensions to the duration of the project) to the research for which this approval has been given. Ethical approval is specific to this project and must not be treated as applicable to research of a similar nature. Each research project is reviewed separately and if there are significant changes to the research protocol you should seek confirmation of continued ethical approval by completing an 'Amendment Approval Request Form' http://ethics.grad.ucl.ac.uk/responsibilities.php</p> <p><u>Adverse Event Reporting – Serious and Non-Serious</u> It is your responsibility to report to the Committee any unanticipated problems or adverse events involving risks to participants or others. The Ethics Committee should be notified of all serious adverse events via the Ethics Committee Administrator (ethics@ucl.ac.uk) immediately the incident occurs. Where the adverse incident is unexpected and serious, the Joint Chairs will decide whether the study should be terminated pending the opinion of an independent expert. For non-serious adverse events the Joint Chairs of the Ethics Committee should again be notified via the Ethics Committee Administrator within ten days of the incident occurring and provide a full written report that should include any amendments to the participant information sheet and study protocol. The Joint Chairs will confirm that the incident is non-serious and report to the Committee at the next meeting. The final view of the Committee will be communicated to you.</p>	
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Final Report

At the end of the data collection element of your research we ask that you submit a very brief report (1-2 paragraphs will suffice) which includes in particular issues relating to the ethical implications of the research i.e. issues obtaining consent, participants withdrawing from the research, confidentiality, protection of participants from physical and mental harm etc.

In addition, please:

- ensure that you follow all relevant guidance as laid out in UCL's Code of Conduct for Research: <http://www.ucl.ac.uk/srs/governance-and-committees/resgov/code-of-conduct-research>
- note that you are required to adhere to all research data/records management and storage procedures agreed as part of your application. This will be expected even after completion of the study.

With best wishes for the research.

Yours sincerely



Dr Lynn Ang
Joint Chair, UCL Research Ethics Committee

Encs.

Cc: Anna Roberts

Appendix U. Participant Information Sheet for Study 4

Information Sheet for Participation in Research Studies

You will be given a copy of this information sheet.

Title of Project: **Specialist oncology nurses' opinions of recommending physical activity apps to cancer survivors**

This study has been approved by the UCL Research Ethics Committee (Project ID Number): 7663/002

Researcher Name: Anna Roberts

Work Address: Department of Behavioural Science & Health, UCL, Gower Street, WC1E 6BT

Contact Details: Email: anna.roberts.15@ucl.ac.uk; Tel: 020 7679 1723

We would like to invite breast, prostate or colorectal cancer Clinical Nurse Specialists to participate in this research project.

Details of Study:

Physical activity can improve quality of life and reduce the most common side effects of cancer treatment such as fatigue, pain, sleep problems, anxiety and depression. There is also emerging evidence to suggest that physical activity may reduce cancer-specific and all-cause mortality and could reduce the risk of cancer returning. We are exploring the possibility of using an app to promote walking as a form of physical activity to people affected by breast, prostate and colorectal cancer after completion of curative treatment within the NHS. We would like to gain your feedback about whether you think this is feasible, and if so, how this could be implemented most effectively within the NHS. To do this, we will ask you to take part in a telephone discussion where we will ask you a number of questions about your thoughts and opinions about this.

Who would we like to be involved?

We are recruiting Clinical Nurse Specialists (CNS) who are involved in the care of people diagnosed with breast, prostate and/or colorectal cancer. This is because our current programme of work is focusing on breast, prostate and colorectal cancers as these are 3 of the 4 most common cancers in the UK and the cancer types where there is the strongest evidence for the benefits of physical activity post-diagnosis. Whilst we are aware that all oncology-based health professionals have a role in the promotion of physical activity to their patients, our previous research with patients has shown that they think that their assigned CNS is who they would want to signpost them to a physical activity app around the completion of the treatment.

What will happen if you decide to take part?

If you wish to take part, a researcher will contact you to arrange a convenient time for you to take part in the study. The telephone discussions will last approximately 30 minutes and will focus on your opinions of signposting breast, prostate or colorectal cancer survivors towards a physical activity app at the end of treatment, whether you feel this could be implemented successfully within the NHS and if so, how that may be most effective. The discussions will be audio-recorded and transcribed into a written format and reviewed later on.

If you are able and wish to, we will ask you to download and very briefly use an app called Active 10 (developed by Public Health England) in advance of the discussion. If you are unable to download/use the app, we will send you some screenshots to look at before the telephone discussion. This is because we may conduct a pilot study to promote physical activity among breast, prostate and colorectal cancer patients using this app. As health professionals who are directly involved in their care and whose opinions are valued by their patients, we would therefore value your opinions about this app.

Once you have completed your interview, we will send you your choice of a £25 Marks and Spencer or Amazon gift voucher as a token of our appreciation for your participation in this study.

What are the risks involved in this study?

We anticipate the risks involved in this study to be minimal. We would like to remind you that you can choose to share as much or as little information as you feel comfortable with. The researchers have a specific schedule of topics to be discussed during the telephone call and so we will keep the discussion focused on your opinion about using apps to promote physical activity following the completion of cancer treatment and how this could be implemented successfully in the NHS. Any information you provide will not be shared outside of the research team involved in the study.

Possible benefits of taking part in the study:

We hope to use the information you provide to help us think about ways we can help people be physically active following a cancer diagnosis. Your feedback will be used in the development of a future physical activity intervention which is specifically tailored to the needs of people who have had cancer. We believe that this is not possible without involving the health professionals who are involved in their care, who can offer valuable insight into how to make this most effective and implemented successfully. We would also be happy to offer advice and information about physical activity and cancer and how this can be discussed with patients in return for your participation in this study.

Anonymity, confidentiality and data protection:

Your personal/contact details (i.e. name, email address, telephone number, the type of cancer your patients have been diagnosed with) and the audio recordings of the interviews will be stored securely and confidentially, in accordance with the General Data Protection Regulation (GDPR) for the purposes outlined in the study description above. We would also like to send you the results of this study and may contact you about future opportunities to take part in research. This could be as a research participant or as a key stakeholder who is involved in the treatment of patients with cancer, who we can ask for advice when we design new projects. We treat the secure storage of your identifiable data very seriously and hold all of this data within a secure system called Data Safe Haven. It has been certified to the ISO27001 information security standard and conforms to NHS Digital's Information Governance Toolkit. We will share the audio file of the interview with an external transcription company, through their secure file transfer system, so that they can provide us with a written transcript of the interview, which will then be anonymised. Any direct quotes from the discussions that are used in publications of the findings of the study will be anonymised and it will not be possible to identify you or the hospital that you work in.

Your rights:

You can request an electronic copy of the data that we hold about you and have the right to withdraw your permission for us to hold this data at any time (simply email anna.roberts.15@ucl.ac.uk). We will contact you again in 3 years' time to ask if you are still happy for us to hold this data and if we are unable to reach you we will delete it.

The UCL Data Protection Office provides oversight of UCL activities involving the processing of personal data, and can be contacted at data-protection@ucl.ac.uk. UCL's Data Protection Officer is Lee Shailer and he can also be contacted at data-protection@ucl.ac.uk. Your personal data will only be processed for the purposes outlined above. The legal basis that would be used to process your personal data will be your confirmation that we have permission to do so by way of signing the attached consent form.

If you are concerned about how your personal data is being processed, please contact UCL in the first instance at data-protection@ucl.ac.uk. If you remain unsatisfied, you may wish to contact the Information Commissioner's Office (ICO). Contact details, and details of data subject rights, are available on the ICO website at: <https://ico.org.uk/for-organisations/data-protection-refom/overview-of-the-gdpr/individuals-rights/>.

Other important information:

- You are free to withdraw from this study at any time and without having to give any reason.
- We will provide you with a written summary of the findings of this study (unless you choose not to receive this by indicating your preference on the consent form).

What if I have further questions, or if something goes wrong?

If you have any further questions, you wish to make a complaint or if this study has harmed you in any way, you can contact UCL using the details below for further advice and information:

Anna Roberts – PhD Researcher

Email: anna.roberts.15@ucl.ac.uk; Tel: 020 7679 1723
Department of Behavioural Science & Health, UCL, Gower Street, WC1E 6BT

Dr Abi Fisher – Lecturer in Physical Activity and Health

Email: abigail.fisher@ucl.ac.uk; Tel: 020 7679 1722
Department of Behavioural Science & Health, UCL, Gower Street, WC1E 6BT

Please discuss the information above with others if you wish or ask us if there is anything that is not clear or if you would like more information.

It is up to you to decide whether to take part or not; choosing not to take part will not disadvantage you in any way. If you wish to take part, please sign the consent form provided with this information sheet and return it to the researcher. If you do decide to take part you are still free to withdraw at any time and without giving a reason.

All data will be collected and stored in accordance with the General Data Protection Regulation.

Thank you for reading this information sheet and for considering take part in this research.

Appendix V. Participant Consent Form for Study 4

Informed Consent Form for Participation in Research Studies

Please complete this form after you have read the Information Sheet and/or listened to an explanation about the research.

Title of Project: **Specialist oncology nurses' opinions of recommending physical activity apps to cancer survivors**

This study has been approved by the UCL Research Ethics Committee (Project ID Number): 7663/002

Thank you for your interest in taking part in this research. Before you agree to take part, the person organising the research must explain the project to you.

If you have any questions arising from the Information Sheet or explanation already given to you, please ask the researcher before you to decide whether to join in. You will be given a copy of this Consent Form to keep and refer to at any time.

Participant's Statement

I

- have read the notes written above and the Information Sheet, and understand what the study involves.
- understand that if I decide at any time that I no longer wish to take part in this project, I can notify the researchers involved and withdraw immediately, without having to provide a reason for withdrawal.
- consent to the processing of my personal information for the purposes of this research study.
- understand that I can request an electronic copy of the data that the researchers hold about me and that I have the right to withdraw my permission for the researchers to hold this data at any time by emailing: anna.roberts.15@ucl.ac.uk
- understand that such information will be treated as strictly confidential and handled in accordance with the provisions of the General Data Protection Regulation.
- understand that my participation will be audio-recorded and I consent to the transfer of this audio file to an external company to provide a written transcript of the interview
- consent to the use of the audio recording and written transcript of the interview as part of this project.
- understand that the information I have submitted will be published as a report and I will be sent a summary of the findings (unless I tick the box below). Confidentiality and anonymity will be maintained and it will not be possible to identify me from any related publications of the findings.
- understand that if I complete the study, I will receive a £25 Marks and Spencer or Amazon gift voucher of my choice.
- understand that if I accept the £25 voucher, some of my personal details may be passed to UCL Finance for administration purposes.
- agree that my data, after it has been fully anonymised, can be shared with other researchers [to satisfy Research Council funded projects as Research Councils have changed their guidance regarding data sharing].
- agree that the research project named above has been explained to me to my satisfaction and I agree to take part in this study.

If you **DO NOT** wish to receive a written summary of the findings of this study, please tick:

If you **DO NOT** wish to be contacted about future relevant research opportunities (e.g. as a

participant or as a key stakeholder involved in the treatment of patients with cancer), please tick:

Print name: _____

Signed: _____

Date: _____

Appendix W. Summary Table 7.1: Characteristics of studies

Author, year	Country	Study design	Sample Size	Retention rate at follow-up	Study duration	Women, %	Age in yrs, mean (SD)	Cancer type(s) and other inclusion criteria
Fransham, 2018a/2018b	Australia	RCT	91	89% (91/102)	6 months	52	66 (9)	Any type of cancer (excluding skin), not currently receiving treatment, engaging in less than 20 sessions of PA (<30 mins) in past month
Galiano-Castillo, 2016	Spain	RCT	76	94% (76/81)	6 months	100	48 (9)	Breast cancer (stage I-IIIa), completed adjuvant therapy (except hormone treatment), no recurrence
Golsteijn, 2018	Netherlands	RCT	462 ^a	93% (443/478)	6 months	13	66 (8)	Colorectal or prostate, undergoing/completed treatment with curative intent (<12 months) (except hormone therapy), >6 weeks post-surgery
Kanera, 2017 ^b	Netherlands	RCT	462 ^b	82% (381/462)	12 months	80	56 (11)	Any type of cancer, completed treatment >4 weeks & <56 weeks prior to study, no recurrence
Kenfield, 2019	USA	RCT	64	89% (64/72)	3 months	0	65 (SD not reported)	Prostate (stage \leq TIIIAa) non-metastatic disease (<5 years), completed treatment (\geq 3 months) or on active surveillance
Krebs, 2017	USA	RCT	68	79% (68/86)	3 months	96	60 (11)	Breast or prostate, completed primary treatment (<5yrs), engaging in <150 mins PA/week and/or <5 portions F&V/day
Mayer, 2018	USA	RCT	227	80% (227/284)	6 months	52	59 (14)	Colon, (stage I-III) completed treatment, >6 weeks post-surgery, <12months since diagnosis, no recurrence, <150 mins PA/week
Orlemann, 2018	Germany	RCT	24	Not reported	1 month	Not reported	Not reported	Any type of cancer, no other inclusion criteria
Ormel, 2018	Netherlands	RCT	32	100% (32/32)	3 months	13	34 (11)	Any type of cancer, received systemic treatment with curative intent
Paxton, 2017	USA	Pre-post ^d	71	62% (44/71)	3 months	100	52 (9)	Breast cancer, completed treatment (except hormone treatment) >6 months, self-identify as African American, Hispanic or of mixed ethnicity
Pope, 2018	USA	RCT	20	67% (20/30)	10 weeks	100	53 (9)	Breast cancer (stage 0-III), completed treatment >3 months & <10 years, no recurrence, active Facebook account
Short, 2018	Australia	Pre-post	10	83% (10/12)	1-2 weeks	60	56 (11)	Any type of cancer, completed primary curative treatment, owned iPhone/Android smartphone
Trinh, 2018	Canada	Pre-post	46	65% (30/46)	6 months	0	73 (7)	Prostate cancer (stage I-III), receiving androgen deprivation therapy (continuous and/or intermittent) >6 months, <150 mins PA/week
Uhm, 2017	Korea	RCT	339	95% (339/356)	3 months	100	50 (10)	Breast cancer, aged between 20-70 years, completed treatment
Valle, 2017	USA	RCT	33	94% (33/35)	6 months	100	53 (9)	Breast cancer (stage I-IIIa) < 10 years, completed treatment (except endocrine treatment), BMI \geq 20- \leq 45kg/m ² , self-identify as African American/black, no disease progression/second primary cancers
Villaron, 2018	France	RCT	43	72% (43/60)	2 months	72	50 (14)	Any type of cancer, currently undergoing chemotherapy or systemic treatment as out-patients

^a: Golsteijn et al. report data for up to 462 participants (depending on outcome). Objective physical activity data was available for 420 participants.

^b: Kanera et al. (2017) is a long-term follow-up paper from the intervention described in the systematic review/meta-analysis described in Study 1 (Chapter 3) which reported 6-month follow-up outcomes

^c: Kanera et al. report imputed data for 451 participants for PA outcomes and 462 for diet outcomes

^d: Paxton et al. is treated as a pre-post study due to the lack of true control (participants randomised to either physical activity or diet intervention delivered via same intervention delivery approach).

Appendix X. Summary Table 7.2: Intervention descriptions, outcomes and summary of findings

Author, year	Intervention type	Description of intervention	Approaches to measurement of engagement/ adherence	Control group treatment	Outcomes measured	Description of behavioural results
Frensham, 2018	Website + emails + pedometer	Personalised step targets emailed to participant based on ratings of perceived exertion, affective state and logged daily steps (measured with pedometer). Website includes feedback (average weekly steps), online forum and virtual noticeboard of local events/activities, and healthy eating information.	Intervention participants logged onto website average of 53 times over 12-week programme.	Lifestyle information and pedometer	Objectively measured PA, motivation, barriers self-efficacy, relapse self-efficacy, BMI, waist circumference, blood pressure, physical fitness (6MWT), QoL (generic)	3 months: significant increase in steps per day in intervention vs. control. NS time x condition interaction for physical fitness, blood pressure, BMI, waist circumference. 6 months: no difference in steps per day. NS time x condition interaction for physical fitness, blood pressure, BMI, waist circumference. Significant decrease (intervention) and significant increase (control) in role-emotional domain of QoL between 3 and 6 months.
Galiano-Castillo, 2016	Website, including instant messaging and video conferencing connect participants and research staff	Personally tailored 3x weekly exercise programmes (~90 mins each) including aerobic and resistance exercises delivered using online telerehabilitation system and monitored remotely by research staff	Adherence to sessions was 94% (average 22.5 of 24 possible sessions)	Written basic recommendations for exercise (+access to programme at end of study)	Muscle strength (handgrip, abdominal, back, lower body), QoL (cancer-specific), pain, fatigue	8 weeks (end of intervention): significant improvement in handgrip strength (both affected and non-affected side), abdominal, back & lower body strength, some domains of QoL (global health status, physical, role & cognitive functioning), pain severity, pain interference, fatigue perception in intervention vs. control. 6 months: significant improvement in handgrip strength (affected side only), abdominal, back & lower body strength, some domains of QoL (global health status, physical and cognitive functioning), pain interference and fatigue perception in intervention vs. control.
Golsteijn, 2018	Website + pedometer	Pedometer + tailored PA advice, based on questionnaire data, at baseline, 2 & 3 months via website and mail. Website includes videos, module for goal setting with pedometer, option to consult physical therapist.	Not measured/ reported	Waitlist control	PA (self-report and objective measures), fatigue, anxiety, depression, QoL (cancer-specific)	3 months: Significant improvement in self-reported PA, fatigue and physical functioning in intervention group vs. control. Objective PA not measured at 3 months. 6 months: Significant improvement in self-reported and objectively measured PA, fatigue and depression in intervention vs. control. NS differences in physical functioning, overall QoL, anxiety.

Kanera, 2017 ^a	Website	Automated system to evaluate baseline assessment and select personalised intervention components using 'if-then' algorithms. Users are recommended modules based on assessments but have access to all 8 modules.	Specific modules were recommended to participants based on current behaviours from 8 modules in total. Participants followed mean (SD) 2.23 (1.58) modules. 25% participants followed PA module, and 62% followed diet module.	Waitlist control	PA, diet	Significant increase in moderate physical activity at 12 months. No significant intervention effect remained for vegetable consumption after 12 months.
Kenfield, 2019	Website + Fitbit + text messages	Received personalised recommendations based on self-reported diet, smoking, physical activity comparison with study recommendations. Access to website throughout, fortnightly emails for blogs/recipes added to website. Fitbit activity tracker + access to study-only community group via Fitbit website. Text messages 4/5x per week.	Intervention participants wore Fitbit for median 82 days (with 98% of the days in the 12wk study period) and responded to median of 71% of 60 text messages that requested reply. 75% of intervention participants responded to at least one text in 12wk period. Median total number of website visits was 3.	Usual care (+ access to programme at end of study)	Composite behavioural score (inc. self-reported PA, diet, smoking, range 0-8), objective PA, BMI, waist circumference, waist-hip ratio, metabolic markers, antioxidant markers, QoL (cancer-specific), QoL (generic)	Median (IQR) absolute change in composite score from baseline-12 weeks was 2 (1,3) in intervention participants and 0 (-1,1) in controls. Estimated mean (95% CI) score for intervention arm was 1.5 (0.7-2.3) higher than controls. 81% of intervention participants met at least one new recommendation (not already met at baseline) vs. 66% controls. Outcome statistically significantly improved for composite score, and for cooked tomatoes, cruciferous vegetables, fish and processed meat, but not vegetable fat, vigorous activity/brisk walking, supplement use. NS differences in objectively measured moderate, vigorous, or moderate-vigorous PA, body measurements, metabolic markers, antioxidant markers, almost all QoL measures. Significantly increased report of pain in intervention arm vs. control on bodily pain subscale of SF36 measure of QoL.
Krebs, 2018	DVD	DVD provided generic dietary/physical activity recommendations for cancer survivors and suggestions how to change behaviours. Branching menus on DVD allowed users to tailor information/ feedback.	72% viewed DVD, 50% completed it. Of those who used it, 60% did so more than once.	Usual care (routine health behaviour assessment and advice/brief counselling regarding health maintenance by nurse)	PA, F&V intake	Significance testing not carried out due to feasibility study and lack of power. Feasibility outcomes show increase of 0.18 daily servings for combined F&V intake vs. control group who decreased by -0.10 servings (Cohen's d = 0.25). Both groups decreased PA, and decrease was greater in intervention group vs. control (Cohen's d = -0.11).

Mayer, 2018	Mobile app	Smartphone with intervention app, included weekly goal of 150 mins plus app functions to log PA and set goals; connect with other app users via individual messaging/discussion forum; read information about physical activity and health and support tools for coping/adapting to life after colon cancer. (NB. App was updated throughout recruitment to include a function to facilitate communication with a certified personal trainer via the app, who would promote discussion in forum and answer questions from users. A later update included the function for the personal trainer to post motivational messages, upload exercise videos and provide individually tailored messages to users biweekly.)	Of 180 possible days of use, mean number of days use was 55. Use was greatest in the first week and declined over 6 months of study (data not reported). The tracking function within the app (logging PA and goal setting) was most popular function.	Booklet on cancer survivorship and a pedometer	PA, distress, QoL (cancer-specific)	No significant difference in MVPA, QoL or distress between groups at 6-months. Both groups were classified as insufficiently active at baseline and both moved to moderately active at 6-months.
Orlemann, 2018	Mobile app	Nutrition counselling, nutritional therapy and use of mobile app. Physician/nutritionist configured personalised nutritional goals which were entered into app. Users enter food intake daily (3x/day) and weight /appetite parameters weekly. Charts show whether users met their daily nutritional goals using 'traffic light' system colour-coded diagrams.	Not reported	Nutrition counselling, nutritional therapy without app	Protein, fibre, carbohydrate, fat, total energy intake, muscle mass, fat-free mass, weight	Significance testing was not conducted on percent of nutritional goals reach by app users for each nutrient/total energy. However, percent of users meeting nutritional goals for protein, fibre, carbohydrate, fat, total energy intake was higher in intervention versus control after 4-weeks. Significant increase in muscle mass, fat-free mass and weight in intervention group versus control.

Ormel, 2018	Mobile app	Publicly available app (RunKeeper) for self-monitoring PA. Intervention group instructed to self-monitor PA (e.g. cycling, hiking, running) with RunKeeper. Also requested to keep "training reminder" function within the app turned on.	11 (73%) intervention participants who downloaded app self-reported still frequently using RunKeeper at 3 months.	Usual care (advice to engage in 30mins PA, 5x/week)	PA, SB	6 weeks: Significant increase in self-reported PA of 51% from baseline to 6-week follow-up in intervention group vs. control. No significant difference in sedentary behaviour between groups. 3 months: significant effect described above no longer significant. No significant difference in sedentary behaviour between groups.
Paxton, 2017	Website + emails	Individualised website plus interactive weekly emails making use of goal setting, self-monitoring, rewards, cues to action and repetition. Self-reported diet/PA used to individualise weekly goals. PA intervention: encouraged to meet 150 mins/week recommendation. Diet intervention: could choose between targeting dietary fat/added sugar or F&V intake and encouraged to consume within dietary guidelines.	PA intervention participants visited the website an average of 9.6 of the 12 weeks compared to 10.7 weeks of the diet intervention participants	No control (randomised to PA or diet intervention)	PA, SB, sugar, fibre, F&V, saturated fat, trans fat, carbohydrates	Both PA and diet intervention participants significantly improved PA, but the improvements in the PA intervention group were significantly greater. Moderate intensity PA minutes was almost doubled in PA intervention group vs. diet group participants. Both groups significantly reduced SB but the reduction in the PA intervention group was significantly greater than the diet group (almost 5x less sedentary time in the PA vs. diet intervention groups). F&V intake significantly improved in those randomised to the diet intervention group. Effect sizes were 0.20 for MVPA/week, 0.45 for total sedentary time/week and ranged from 0.25-0.35 for sugar, fibre, F&V, saturated and trans fat intake, but was only 0.08 for carbohydrate intake.
Pope, 2018	Smartwatch + Facebook support group	Smartwatch capable of tracking health metrics (e.g. energy expenditure, steps/day, daily PA duration) and can connect with smartphone. Twice-weekly tips provided via Facebook group (e.g. targeting self-efficacy, outcome expectancy, social support and enjoyment, while reducing barriers) and participants could post PA stats from their smartwatch into Facebook group and participate in group discussion. Also received a non-mandatory strength/aerobic training program delivered via Facebook group.	All intervention participants reported wearing smartwatch 6-7 days/week. Used smartwatch for average 4.55 sessions/week and 54 minute duration.	Control Facebook group (content-identical, including strength/aerobic training program). Instructed to discontinue smartwatch use	Objectively measured PA & SB, weight, body fat, cardiorespiratory fitness, physical functioning, anxiety, depression, fatigue, sleep, ability to participate in social roles/activities, pain, social support, barriers, self-efficacy, enjoyment, outcome expectancy	No significant differences between groups in PA, SB, weight, body fat, cardiorespiratory fitness, physical functioning, anxiety, depression, fatigue, sleep, ability to participate in social roles/activities, pain, self-efficacy, enjoyment, outcome expectancy between groups. Control group showed significantly increased social support and significantly reduced barriers

Short, 2018	Mobile app referral service	Referral to a publicly available app (from choice of 15) in consultation during an initial face-to-face session. Referral based on individual characteristics (e.g. preferred type of PA, workout goals, personality, preferences, willingness to pay for an app). Initial session included support to download app, education of benefits of PA after cancer, PA guidelines for cancer survivors and a goal-setting activity. A mid-week check-up was delivered via telephone call/email.	Not reported	N/A	PA	Average total weekly MVPA increased by 236 minutes between pre- to post-test (Cohen's $d = 0.73$). At baseline, 6 participants reported participating in some resistance training, this increased to 7 at post-test.
Trinh, 2018	Activity tracker + website	Activity tracker used to understand baseline activity (weeks 1-2), followed by progressive release of self-regulatory strategies (e.g. action planning) and targeted changes in sitting time and step count (weeks 3-6), followed by weekly reminders to encourage to continue to use website and practice self-regulatory strategies (weeks 9-12). Aim to increase daily step count by 1000 from previous phase. Incentives were offered for logging into website every day and reaching step goal target. Rewards could be redeemed for variety of items or donated to charity.	Overall adherence rate was 72% (33/46) for total number of logins (i.e. >3 visits each week)	N/A	Objectively measured PA & SB, QoL (cancer-specific), QoL (generic)	3 months: significant reduction in sedentary time and significant increase in MVPA and step count at end of intervention compared to baseline. No significant differences in generic/cancer-specific QoL between baseline/post-intervention 6 months: no significant difference in sedentary time, MVPA, cancer specific or generic QoL between baseline/6months.

Uhm, 2017	Mobile app + pedometer + resistance band	Provided with weekly goal of minutes PA/week based on baseline 2MWT, which could be increased at 6 weeks if achieved this goal every week of first 6 weeks. Intervention participants were instructed to wear pedometer and enter recorded minutes of PA into app weekly. Video clips of prescribed resistance exercises could be viewed via app and record number of sets for each exercise performed.	Not reported	Same exercise protocol but facilitated with a brochure and did not have access to app or pedometer	PA, QoL (cancer-specific) BMI, blood pressure, pulse rate, arm circumference, hand edema, handgrip strength, lower body muscle strength and 2MWT.	No significant differences in any measures between groups at 3 months. Overall, patients in both groups improved in PA, physical function (diastolic blood pressure, pulse rate, handgrip strength, lower body muscle strength, 2MWT) and various domains of QoL regardless of intervention/control group.
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Valle, 2017 ^b	<p>Face-to-face session + mobile app + website + Bluetooth weighing scales + email (INT)</p> <p>Above, + activity tracker (INT+)</p>	<p>INT: Face-to-face session provided education about weight gain in breast cancer, behaviours associated with body weight and health consequences of weight gain. Emphasised daily use of wireless scale as indicator of progress. Scales automatically sync weight data with online account and/or mobile app. Instructed to monitor weight daily and this drove content for tailored feedback messages delivered throughout intervention. Weekly emails included skills/behavioural strategies (e.g. self-monitoring, problem solving, finding social support). Encouraged to make one dietary change (to reduce calorie intake by 100) per day and received recommendation/ exercise plan to gradually increase PA to meet 150 minutes/week recommendation.</p>	<p>Median total days weighed was 106/168 (INT) and 154 (INT+) vs. 11 (control). Over 80% of INT+ participants weighed ≥ 5 days/ week, and 73% wore activity tracker ≥ 5 days/ week. Median total days activity tracker was worn was 162/168 days in INT+. Weighing/activity tracking remained consistent over time in both groups. 90% of INT+ and 100% INT participants reported reading some-all/most of email lessons and reading email feedback.</p>	<p>Received wireless scale (for evaluation purposes and remove any potential effect of novelty of scales) and waitlist control for rest of intervention content</p>	<p>PA, diet (24h recall), BMI, waist circumference, body composition, blood pressure, HbA1c, blood lipids</p>	<p>No significant differences between groups over time in changes in diet and energy expenditure from PA. From baseline to 6-months the INT+ group reported a significant 432 kcal increase in energy expenditure/week. Median weight change from baseline to 3 months was significant among INT and INT+ groups but not control. The proportion of INT+, INT and control participants that were at/below baseline weight was 73%, 54% and 44%, respectively (Cohen's $d = 0.64$). The INT+ group decreased BMI over 6 months (significantly different from control).</p>
		<p>INT+: As above, with activity tracked which also synced with wireless scales and online account/mobile app. Also asked to track PA daily and feedback included whether participants were monitoring activity/ meeting weekly PA recommendation as well as daily self-weighing/weight.</p>				

Villaron, 2018	SMS text messaging + pedometer	Received advice on increasing PA with aid of a recommendation guide with 8 sections for each of 8 weeks of intervention, including examples of exercises and recommendations about PA, walking in particular. Also received motivational SMS text messages sent at the start of every week. Completed online weekly questionnaires reporting weekly number of steps, fatigue, QoL.	Not reported	Usual care + pedometer + completed online weekly questionnaires reporting weekly number of steps, fatigue, QoL.	Objectively measured PA (pedometer), fatigue, QoL (cancer-specific)	No effect of time/group on number of steps walked each week. Significantly improved general fatigue and physical fatigue, activities, motivation, and mental fatigue dimensions of fatigue scale in intervention vs. control group in week 7 & 8. Intervention participants also had significantly higher overall QoL and in some specific domains of QoL (role function and emotional capacity) vs. control group.
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^a: Kanera et al. (2017) is a long-term follow-up paper from the intervention described in the systematic review/meta-analysis described in Study 1 (Chapter 3) which reported 6-month follow-up outcomes

^b: Valle et al. was a 3-arm RCT

PA: physical activity; MVPA: moderate-vigorous physical activity; SB: sedentary behaviour; F&V: fruit and vegetables; QoL: quality of life; BMI: body mass index; NS: non-significant; MWT: minute walk test; HbA1c: glycated haemoglobin

