Sex-specific response to physical activity changes using e-health behaviour change interventions: A Systematic review and Meta Analysis

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ABSTRACT

Sex-specific response to physical activity changes using e-health behaviour change interventions: a systematic review

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Background: Non-communicable diseases (NCDs) account for 70% of deaths globally every year. Cancer, diabetes, cardiovascular diseases, and chronic pulmonary diseases are four commonly caused NCDs. These NCDs usually occur due to modifiable risk factors such as poor diet, alcohol intake, and physical inactivity. Physical activity (PA) has benefits on reducing NCDs and the overall wellbeing of adults. E-health behaviour change interventions with PA outcomes, even though aimed at helping adults increase their PA, may differ in responses between men and women.

Objective: The aim of this systematic review was to synthesise the current evidence on sex-differences in PA changes after an e-health behaviour change intervention.

Methods: Electronic databases PubMed, Web of Science, PsycInfo, and Cochrane were searched to retrieve papers published in peer-reviewed journals. Articles were included, that provided descriptions of interventions that employed e-health delivery modes such as Internet, email, and short messaging services (SMS), included PA as one of their outcomes and focused on healthy adult populations.

Results: In total 18 studies were included in the current systematic review. Of the 18 studies, 14 studies were analysed in both meta-analysis and qualitative synthesis. These 14 studies measured PA subjectively and had usable outcome data. In all, the group comparison showed no significant sex-effect ($p=0.685$) on changes in PA, post-intervention, whereas comparisons of pooled effects

of men and women at follow-up showed a significant effect (p=0.008) indicating greater increases in PA among women over the long-term (mean follow-up = 23.5, SD = 12.7 weeks).

Conclusions: E-health behaviour change interventions lead to significant increases in PA, at both post-intervention and follow-up among men and women, with greater increases at follow-up among women compared to men. Clinically, it means that both men and women maybe able to maintain sustained increase in PA using e-health behaviour change interventions.

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This thesis has been prepared for the fulfilment of master's degree requirement. The thesis consists of a general introduction section, an objective of the thesis and a manuscript section. The manuscript is formatted under the guidelines for the *Journal of Medical Internet Research (JMIR)* (The instructions to authors for *JIMR* are complied in the appendix and they can also be found at https://www.jmir.org/content/author-instructions). The manuscript is still in preparation and has not yet been submitted.

This thesis does not consist of a separate discussion section as all the important discussion are done under the manuscript discussion. No new information is left to be discussed that requires a separate discussion section in this thesis.

AUTHOR CONTRIBUTIONS

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Chapter 1: Introduction

Introduction:

1.1. Non-communicable chronic diseases:

Non-communicable chronic diseases (NCDs) are medical conditions that develop slowly and last for a long period of time [1]. There are five common types of NCDs: cardiovascular diseases, cancers, respiratory diseases, diabetes, and obesity [2, 3]. In Canada, at least four out of five working age Canadian adults (i.e., 34-64) are living with a NCD [4]. Approximately 62% percent of the Canadian population (over 18 years) suffer from at least one major type of NCD, and this proportion is expected to rise by 17% in the next twenty years [5]. Therefore, NCDs are a serious concern for Canada and the world [5, 6]. Together these account for over 80% of NCDs leading to early deaths [7]. Among these deaths, over 85% of deaths (15 million) occur in men and women between the age group of 30-69 years [8].

1.2. Causes of NCDs:

The majority of NCDs are caused by modifiable risk factors, i.e., they can be controlled to reduce their effect, through changes in daily lifestyle [9]. Physical inactivity, unbalanced diet, excess alcohol, and tobacco consumption are some of the most important modifiable risk factors for NCD's, and reduction of these risk factors in our daily lives can lead to both the prevention and reduction of NCDs [10].

Physical inactivity is defined as performing insufficient amounts of physical activity, i.e., not meeting the specified guidelines of physical activity, 150 min/week of moderate to vigorous PA in the bouts of 10 minutes for each week, for adults [11]. In contrast, sedentary behaviour, according to the Sedentary Behaviour Research Network, is defined as any waking behaviour with an energy expenditure less than 1.5 METs (metabolic equivalent method) while in a sitting or reclining posture [12]. Both terms (physical inactivity and sedentary behaviour) are often used

interchangeably; However, there is evidence that sedentary behaviour and physical inactivity are two different constructs, which independently lead to the development of NCDs [13]. The current review, focuses on physical inactivity, as reducing physical inactivity can help in preventing NCDs such as cancer, diabetes, cardiovascular diseases, respiratory diseases [14].

In Canada, it has been estimated that physical inactivity accounts for 30% of the mortality in adults [15]. Currently, 82% of adults in Canada do not meet the required physical activity levels, i.e., 150 min/wk. of moderate to vigorous physical activity (MVPA), and this number is only expected to rise in the coming years [16]. Various conditions like asthma, COPD, stroke, etc. are also exacerbated due to physical inactivity [17]. For example, a systematic review by Thompson et al. found that physically inactive COPD patients exhibited a lower mean FEV_1 [17]. Furthermore, it added that physical inactivity was associated with increased systemic inflammation in COPD patients. A review by Taylor et al, supported the idea that physical inactivity is a highly prevalent and important risk factor for the development of chronic heart disease and stroke [18]. Physical inactivity as a risk factor, also contributes to developing cancer. A review done by Lindsay et al, estimated that physical inactivity leads to 20% of the cancer cases among American adults [19]. These reviews help to reinforce the idea that physical inactivity is a risk factor for one or more NCDs.

1.3.Physical activity in adults:

1.3.1. Definitions:

Physical activity is defined by Casperson et al. as “any bodily movement produced by skeletal muscles that results in energy expenditure” [20]. It includes daily activities like household activities, occupational activities, etc. [20]. Terms like exercise and physical fitness are used interchangeably with physical activity; however, all the three terms are different [18]. Exercise is

"planned structured, repetitive, bodily movements to improve and maintain overall physical and mental wellbeing" [20]. Exercise is not equivalent to physical activity but is a subset of physical activity. Finally, physical fitness is defined as "the ability to carry out daily tasks with vigour and alertness without undue fatigue and ample energy to enjoy leisure time activity and to meet unforeseen emergencies" [21]. Physical fitness is an element or attribute that people develop or achieve, which can be independent of their physical activity [22]. Therefore, understanding, and carefully describing these three terms is important.

1.3.2. Measurements of PA:

PA is measured in various ways, both subjectively and objectively. Subjective measures of PA are captured through self-reported surveys and questionnaires [23]. Objective measures of PA, can be captured using devices such as accelerometers and pedometers [24]. Within the subjective and objective measures, PA can be defined as various intensities of PA such as, light, moderate and heavy. The intensity is the level of energy expenditure while performing a PA [25]. These intensities are then expressed in various units such as min/week, kcal (kilocalories), METs (Metabolic Equivalent Method), or MET-min/wk [26].

1.3.3. PA guidelines:

Most developed countries have set minimum recommended levels of PA that the population should engage in [11]. For example, the Canadian Society for Exercise Physiology developed the Canadian Physical Activity guidelines which states that "Adults (18-79 years) should do at least 150 minutes of moderate-to-vigorous activity per week that is at least 10 minutes or more in duration" [27, 28]. These align with the recommendation of the World Health Organisation (WHO), that adults aged 18-64 should do at least 150 minutes of moderate-intensity PA throughout the week or at least 75 minutes of vigorous-intensity PA throughout the week or an

equivalent combination of moderate-and vigorous intensity activity [14] both the guidelines, emphasize on the main benefits of PA to health , in term of increases in MVPA, Hence this study also has measured change in PA as MVPA.

1.3.4. Impacts of PA:

Regular PA leads to increased energy levels and improved health related outcome in adults and helps in maintaining functional mobility in older adults [29]. It also benefits the physiological, and psychological well-being of humans in general [30]. These benefits then help in preventing NCDs and the occurrence of premature death [31]. However, despite the numerous benefits, most adults in Canada and the world, lack adequate PA [29].

1.3.5. Physical activity interventions:

In order to help adults increase and maintain their physical activity levels, different types of interventions have been used [32]. Most physical activity interventions have been developed to be delivered face-to-face, i.e., in person consultations [33]. These interventions help in encouraging adults to become more physically active [33, 34]. However, they also have some limitations, as face-to-face behaviour change interventions targeting PA are unable to reach widely distributed populations [35]. For example, a study that compared face-to-face vs online intervention modes, stated that, individuals that lived in rural area, faced transport and accessibility issues for the face-to-face intervention, which were not experienced by individuals living in urban areas, the potential of e-health platform was considered as practical and cost-effective to overcome these kinds of barriers [36]. Several studies (both interventions and systematic reviews) that compared both face-to-face and online interventions have stated that both modes were equally efficacious in changing PA, though the effects of face-to-face interventions seemed to have short-term benefits compared to e-health interventions, which

seemed to change PA over a longer period of time. It would seem that this was mainly due to the convenience and availability of e-health interventions [37-42].

Several previous studies have tried to identify the various barriers which reduce participation rates in behaviour change intervention targeting PA [43]. A recent systematic review identified barriers for insufficient physical activity among older adults (55 yrs. and above) [44]. Around 40% of studies in the review identified "little or no time" to perform physical activity as a key barrier and participants reported that competing priorities (e.g., work, family, etc.) made it difficult to make time for daily physical activity [44]. Affordability of the physical activity programme was also a major barrier, with 24% of the studies indicating that participants were hesitant to bear the expenses associated with interventions and/or equipment required for the interventions [45]. In addition to the 55 years and above age group, barriers to physical activity across various age groups, i.e., children, young adults, adults, seem to be similar (e.g., elevated cost, unsafe environment, and poor access to facilities), as per previous systematic reviews that assessed barriers in all groups [45, 46].

1.3.6. Use of e-health health behaviour change interventions to change physical activity:

Internet usage has been rapidly increasing, as a large number of people have access to it [47]. In Canada, 89% of the population over 18 years of age have access to the internet through various means such as smartphones, laptops, computers, etc. [48]. Around 72% of adults use the internet to browse health-related information and 52% use smartphone for the same purpose [49]. The term 'e-health' consists of a combination of communication technologies, like the internet, computers, and smartphones, to educate or assist in making improvements in health [50]. By using the internet, participants can automatically monitor and limit the information they wish to receive and save their time [51]. Functions such as text messages and software applications

(apps) can help to tailor interventions according to various factors such as age, sex, education level, etc. [52]. Wise use of internet and mobile applications in health have made it easier to implement behaviour change strategies [53]. E-health can provide the potential to reach large numbers of participants, at a considerably lower-cost [54]. It also increases the access and exposure of the intervention by instantaneously delivering the intervention to participants [55]. Hence, these qualities of an e-health platform might provide a solution to participation limitations seen in face-to-face interventions.

E-health behaviour change interventions comprise of at least one or more behaviour change techniques, which are irreducible, replicable, and observable components of an intervention [56]. They are the proposed "active ingredients" of a behavioural intervention that are designed to redirect causal processes that regulate behaviour (e.g., goal setting, self-monitoring, decision making, and performance feedback) [56]. They help to carry sustained behaviour change process in the participant. E-health interventions provide the participants with tools to track and self-monitor their progress, goals and activities undertaken by them in an online simulated environment [57]. Previous e-health studies based on behaviour change theories (self-determination, self-efficacy, goal orientation, etc.) showed greater increase in PA compared to a control group [37, 58, 59].

1.4.Sex and gender differences in e-health and PA:

1.4.1. Definition:

The term 'sex' is defined by the WHO as the "biological and physiological characteristics that define men and women" [60]. Whereas "gender" is defined as the "socially constructed roles, behaviours, activities and attributes that a given society considers appropriate for men and women" [61].

1.4.2. Biological (sex) and psychosocial (gender) differences between men and women:

Biologically, apart from the reproductive standpoint, men and women possess different attributes from one another [62]. For example, men have greater vital capacity, greater lung and heart size, and they have greater muscle mass than women [63]. Hence, owing to the biological differences mentioned above, physical activity responses maybe different among men and women [64]. Psychosocial aspects, especially societal roles mold physical activity behaviours to a great extent [65]. For example, research has repeatedly shown that men and women differ in their motivation towards physical activity, and its forms (sports, exercise), across the life span [66], for example, men were motivated to perform vigorous PA whereas, women performed more walking and biking [67].

1.4.3. Correlation between sex and gender:

Even though there is a defined distinction between sex and gender, both of them are inter-linked[61]. In a social setting, division of labour and associated hierarchical relations are lead by physiological sex, which are then defined as gender roles [68]. These gender roles are then used to differentiate between men and women [69]. It is therefore said that gender is preceded by sex, whereas sex is responsible for formation of gender and it's role in the society [69]. Hence, sex and gender remain inclusive of each other.

1.4.4. Sex differences in preference of PA:

Men and women seem to differ in their PA behaviour [70]. A study that evaluated the difference in physical activity among men and women reported that men preferred to participate in more competitive sports and gym clubs whereas, women were more likely to perform daily physical activities such as biking and walking [71]. Another study stated that, men and women had different preferences for physical activity as women preferred individually structured and

supervised physical activity opportunities, with same sex participants, in a convenient environment, whereas men preferred vigorous, skill-based, and outdoor activities [72].

1.4.5. Sex differences in preferences and participation in e-health interventions and subsequent impacts on PA:

Sex-differences in the use and efficacy of e-health interventions is unclear [70]. Previous studies suggest that women use more internet-delivered health-related information (e.g., diet, nutrition, physical activity, weight loss, etc.) than men [71]. Furthermore, a systematic review found, that of all the participants in e-health interventions, 27% were men and 73% were women, the authors suggested that this disparity in participation was due to the failure to understand the sex-specific needs of men and women [72]. The greater participation of women in e-health interventions may be due to their family and child obligations [73]. Child-care needs, lack of time, inadequate financial resources, and limited transportation are some of the challenges that may have influenced the growing interest of women in e-health interventions [74]. Whereas the inclination of men towards in-person physical activity can be a reason of low participation of men in e-health interventions [75]. A study of men using an e-health behaviour change intervention stated that men expressed a greater preference for in-person, group-based activity as opposed to individualised PA programme [76].

This sex-difference is not just limited to participation, but also evident in PA changes in response to an e-health intervention [77]. An e-health PA study that targeted men and women, stated greater increase in steps-per day in women compared to men [78]. Likewise, a study that assessed MVPA changes in adults, stated that women significantly accumulated greater changes in MVPA (12.9 MET-hours) compared to men (9.3 MET-hours) [79]. However, another pedometer-based study of 37 participants, assessing the impact of pedometer-based

interventions, stated that, while there was an increase of 2000 steps/day post intervention, there was no significant difference between men and women [80].

The above literature, in various ways, suggest differences in sex-specific responses to changes in PA following an e-health intervention. Moreover, it also signifies that women might show greater changes to MVPA/week, compared to men. Studies of interventions targeting only men or women have also mentioned the need to analyse sex-differences [81]. However, to date, no systematic review has been conducted to assess sex-differences in changes in physical activity after participating in an e-health behaviour change intervention. Previous studies have mentioned the need to understand and explore the sex-differences associated with changes in health behaviours as a result of participating in e-health interventions, including PA, as they offer a wide range of tools and customisations [62, 82].

Various aspects of sex-differences has been previously explored, such as biological [83], anatomical [84], cardiological [85], neurological [86], and psycho-social. However, to date, no review has been conducted on sex-specific PA response to e-health behaviour change interventions. Understanding sex-specific response can help us in meeting the sex-specific demands and increase PA in both men and women, in turn reducing the risk factor of physical inactivity responsible for causing NCDs.

Chapter 2: Aim and Hypothesis

Chapter 2: Aim and Hypothesis/Hypotheses

2. Aim:

Sex-differences in the efficacy of general e-health behaviour change interventions on PA outcomes is unclear. For example, an e-health PA study that assessed PA changes, reported greater increase in steps-per day in women participants compared to men [87]. Hence, the aim of this thesis was to synthesise the current evidence on the sex-differences in e-health behaviour change intervention-induced physical activity changes.

2.1. Hypothesis:

Previous studies have mentioned increases in PA among women using e-health interventions, this change in PA may have been due to their family and child-care obligations [81]. Whereas, men have shown greater change in PA using in-person activities such as sports, gym, etc. [88]. Hence, we hypothesized that, compared to men, women will show greater changes in MVPA/week (moderate to vigorous physical activity following the intervention) by using an e-health behaviour change intervention.

Chapter 3: Manuscript

Chapter 3: Manuscript

Sex-specific physical activity changes in response to e-health behaviour change interventions: A systematic review and meta-analysis.

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3. ABSTRACT

Background: Non-communicable chronic diseases (NCDs) account for 70% of deaths globally every year. Cancer, diabetes, cardiovascular diseases, obesity, and chronic lung diseases are the main NCDs. These NCDs usually occur due to modifiable risk factors such as poor diet, alcohol intake, and physical inactivity. Physical activity (PA) has benefits on reducing NCDs and increasing overall wellbeing of adults. E-health behaviour change interventions with PA outcome, even though aimed at helping adults increase their PA, differ in responses between men and women. Women tend to utilize more internet-delivered health-related information (diet, nutrition, PA, weight loss, etc.) than men. Moreover, the later are less likely to utilize internet-delivered health-related information, participate in health modification programmes or engage in intervention research in comparison with women. However, to our knowledge, sex-differences in the impact of e-health behaviour change interventions on PA changes have not been explored.

Objective: The aim of this systematic review was to synthesize the current evidence on sex-differences in MVPA (moderate to vigorous physical activity) changes after an e-health behaviour change interventions.

Methods: The current review was developed according to PRISMA guidelines and registered on PROSPERO. Electronic database PubMed, Web of Science, PsycInfo, and Cochrane were searched to retrieve papers published in peer-reviewed journals. Articles were included if they provided descriptions of interventions that employed an e-health delivery mode (such as internet, email, website, short messaging services), included PA as one of their outcome (both subjective and objective outcomes were included), and focused on a healthy adult population.

Results: In total, 18 studies were included in the current systematic review. Of the 18 studies, 14 studies were analysed in both meta-analysis and qualitative synthesis. These 14 studies measured

PA subjectively and had appropriate outcome measures. Meta-analyses of the 14 studies revealed that e-health interventions lead to increases in PA in both men and women. There was no significant sex-effect of e-health interventions on change in PA post-intervention, standardized difference in means (SMD) for women = 0.177 (95% CI 0.021-0.333; p=0.026) and SMD for men = 0.139 (95% CI 0.698-.536; p=0.00), whereas women had greater increases in PA at follow-up (mean 23.5 weeks, SD = 12.7) compared to men (pooled effect for women = 1.117 (95% CI 0.041-0.237; p=0.001) and for men= 0.422 (95% CI 0.129-0.715; p=0.00).

Conclusions: E-health behaviour change interventions lead to increases in PA, at both post-intervention and follow-up among men and women, with greater increase at follow-up for women compared to men. Clinically, it means that both men and women maybe able to maintain sustained increase in PA.

Review registration: CRD42019127410 (https://www.crd.york.ac.uk/prospero/#recordDetails)

Keywords: E-health, physical activity, men, women.

3.1.Introduction:

Physical activity (PA) has benefits for maintaining the overall well-being of an adult [28]. Casperson et al. defined "physical activity" as any bodily movement produced by skeletal muscles that results in energy expenditure [20]. The Canadian Society for Exercise Physiology developed the Canadian Physical Activity guidelines which states that "Adults (18-79 years) should do at least 150 minutes of moderate-to-vigorous activity per week that is at least 10 minutes or more in duration" [27, 28]. The guideline emphasized the that the benefits of PA on health seem to be driven by increases in MVPA (moderate to vigorous physical activity). In addition to planned leisure-based activities, and PA includes daily activities like household activities, occupational activities, etc. Regular PA leads to increased energy levels and improved health related outcomes in adults and helps maintaining functional mobility in older adults [89]. Also, it significantly reduces the risk of non-communicable chronic diseases, like diabetes, cancer, cardiovascular diseases, obesity, and respiratory diseases, which are responsible for the majority of deaths worldwide [90] . However, despite the numerous benefits of PA, most adults in Canada, and throughout the world, do not engage in adequate levels of PA [5].

Previous research in adults has identified various barriers to PA, that hinder people from being physically active [91]. A recent systematic review identified barriers for insufficient PA among older adults (55yrs and above) [44]. Around 40% of studies in the review identified "little or no time" to perform PA as a key barrier and participants reported that competing priorities (e.g., work, family, etc.) made it difficult to make time for daily PA [44]. In addition, 55% of the total studies mentioned environmental barriers, such as lack of transport, heavy traffic, a lack of neighbourhood safety, inconvenience, and inaccessibility to PA programmes [45]. These barriers were also confirmed for general adult populations, in another systematic review looking at PA

determinants in adults [46]. Hence, there is a growing need for cost-effective solutions which would allow people to participate in PA which reduces these barriers.

In order to help adults, increase and maintain PA, numerous interventions have been used [32]. Generally, interventions have been created using various informational, behavioural, and/or environmental approaches [56, 74]. The majority of these interventions were developed to be delivered face-to-face, requiring participants to be physically present at the venue of intervention [58, 92]. However, such face-to-face formats limit the reach of the interventions, thus restricting participation despite individuals being interested [93].

Ever-increasing use of the internet and smartphones has paved the way for the development of e-health behaviour change interventions [47]. The term ‘e-health’ consists of a combination of communication technologies, like the internet, computers, and smartphones, to educate or assist in making improvements in health behaviours [50]. By the use of the internet, participants can automatically monitor and engage with the information they wish to receive [94]. The strength of e-health interventions lies in the fact that this mode of delivery can reach a larger number of people, with a lower cost compared to face-to-face interventions [95]. E-health interventions provide the participants with tools to track and self-monitor their progress, goals and activities undertaken by them in an online simulated environment [73].

Although, e-health is a welcome change and convenient mode for intervention, few studies have investigated the effect of tailored interventions that offer tools and materials customised for specific individuals according to their needs, for example differences between women and men [96]. The term ‘sex’ is defined by the WHO as the “biological and physiological characteristics that define men and women” [60]. Sex-differences in the use and efficacy of general e-health interventions is unclear [70]. Previous studies suggest that women use more internet-delivered

health-related information (diet, nutrition, physical activity, weight loss) than men [73]. This interest of women is seen in terms of participation in e-health behaviour change interventions, for example, three e-health randomised controlled trials that assessed the PA of both men and women, the total number of women participants exceeded over 50% compared to men [87, 97, 98]. It has been suggested that this greater interest of women may be due to their family and child obligations [81]. In addition, a lack of time, inadequate financial resources, and limited transportation are some of the other challenges that may have influenced women toward e-health PA interventions [74]. However, the sex-difference is not just limited to participation but may also be evident in PA changes in response to an e-health intervention [77]. For example, an e-health PA study that assessed PA changes, reported greater increase in steps-per day in women participants compared to men [78], with another study reporting greater increases in min/week of PA in women compared to men [99], in response to an e-health behaviour change intervention, although the improvements were small, it did hint at a sex-difference in PA change [80, 99] .

The aim of this systematic review was to synthesize the current evidence on sex-differences in MVPA changes using an e-health behaviour change intervention. We hypothesized that, compared to men, women would show greater changes in PA in response to such e-health interventions. To our knowledge, this is a first systematic review comparing sex-differences in PA changes using e-health behaviour change interventions.

3.2.Methods:

3.2.1. Protocol and registration:

Our systematic review was conducted in line with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines *(see Supplement 1 for check list)* and was

registered on PROSPERO (registration number: CRD42019127410) https://www.crd.york.ac.uk/prospero/#recordDetails.

3.2.2. Search strategy:

The PubMed, PsycINFO, Cochrane and Web of Science electronic databases were searched. Other sources, such as previous reviews and relevant papers were also screened for additional records. Studies were identified using search terms and keywords, including 'e-health', 'men', 'women', and 'physical activity' (*supplement 2)*. Studies published up to 09 October 2019 in French or English were included. No additional limits (study design or date) were imposed on the search. The specific search strategy was created with the help of a health sciences librarian with expertise in systematic review searching.

3.2.3. Inclusion and exclusion criteria:

We included any e-health interventional study that described PA as one of the behaviour change outcomes; any PA domain (total, recreational, occupational, etc.), intensity (light, moderate, vigorous), and unit of PA (min/week, MET-min/week, steps/day) were considered. Studies needed to report data on PA changes (reported using any intensity, unit, or assessment tool), among men and women over 18 years of age. The studies could be randomised control trials (RCT) or non-randomised trials. PA was defined as '*any bodily movement produced by skeletal muscles that results in energy expenditure'* [20].The term 'e-health' was defined as a combination of any communication technology, like the internet, computers, and smartphones, to educate or assist in making improvements in health behaviours.

Studies were excluded if the target populations were children, pregnant women, and individuals with chronic disease, e.g., stroke, spinal cord injury, respiratory diseases, osteoporosis, arthritis or back problems, heart or cardiovascular condition, and any notable mental health problems,

such as learning disabilities, downs syndrome, and any intellectual disability (chronic and mental diseases classification as per PARQ+ questionnaire [100]). Secondly, studies that included only direct interactivity component (i.e., face-to-face interaction, skype, phone-call, video-coaching, etc.) were excluded. Conference abstracts, theses, and articles published in non-peer-reviewed articles were not included in the review.

3.2.4. Selection and Screening of studies:

The database search and screening phases were conducted independently by two reviewers (PD and NS). Any discrepancies were resolved through discussion with a third reviewer (SB). Prior to the full-text screening, a pilot screening process was done to test and ensure understanding of the process by both reviewers. Studies that met our inclusion criteria were included for data extraction by two independent investigators.

3.2.5. Data extraction:

A data extraction sheet was developed specifically for the current systematic review. We extracted data on study (e.g., first author, year of publication, country, methodology, etc.) and participant characteristics (e.g., sex, age). Data regarding the type and mode of interventions as well as intervention groups were also extracted. Interventions that were focused on for this review, i.e., the interventions with e-health platform without any direct interactivity component (automated-text messages, website, and smart-phone applications) with pre-post intervention results, were named as interventions of interest. Since studies had multiple intervention groups, we grouped them as comparison intervention groups (interventions used as comparison with the interventions of interest) and control group (did not receive any intervention). For this thesis, we only focused on interventions of interest. However, detailed information regarding the comparison interventions was also extracted.

3.2.6. Quality assessment:

Quality assessment was made independently by two investigators (PD and NS) using the modified Downs and Black checklist [101]. This widely used checklist has high internal consistency and good test-retest and inter-rater reliability. The tool is most appropriate for RCTs and intervention studies and covers blinding, allocation of interventions groups, drop-outs, etc. It provides scores as 1= yes, 0= no or unable to determine, and the total score ranges from 0-27 with a higher score reflecting better quality.

3.2.7. Data analysis

Meta-analyses were conducted on data from the e-health intervention group using *pre, post, and follow-up* outcomes (comparison groups were not included in the analysis because we were primarily interested in sex-differences in response to the active intervention and it should be noted that there was a great deal of heterogeneity across the comparison arms). The pooled effect was calculated using the results for the intervention groups, according to sex. Fixed and mixed effects meta-analyses were conducted using Comprehensive Meta-Analysis software (CMA: Version 3.3.070). The primary outcome was MVPA (moderate to vigorous physical activity), as the majority of the studies reported changes in MVPA. Sex-specific pooled standardised mean differences (SMD) with 95% CIs were computed using baseline and post and follow-up means as well as their respective standard deviations (SD). For change scores, CMA requires the pre and post outcome correlation. As these statistics are not usually reported in the studies, we assumed the same correlation among the studies (value of 0.7). An SMD of 0.20, 0.50, and 0.80 were respectively categorised as small, medium, and large effects[102]. Heterogeneity among studies was assessed using Cochrane's Q [37]. Additionally, Higgins I^2 test was also assessed, which provides a measure of degree of inconsistency.

Changes in PA were also measured qualitatively by calculating the percentage of change in MVPA form baseline to post intervention and follow-up, relative to baseline. Post intervention and follow-up means were subtracted from the pre-intervention means. The difference between these means was then converted into a percentage. In order to summarize the percent of change in PA, we categorised it as 5% and 10% change of PA. The 5% and 10% change was considered as a threshold to measure the change in PA and compare among sexes. The 10% change was calculated based on previous literature suggesting this level could be sustained in long-term and translated into daily lives [103] [104].

3.3.Results:

3.3.1. Study selection:

See *Figure 1* for the PRIMSA flow chart. Initial selection yielded a total of 4340 articles after removing duplicates. Of these, 243 full text articles were assessed for inclusion after title and abstract review. Sixty-four full-text articles were included. However, 58 studies did not provide outcome measures of interest stratified by sex. The authors of these studies were contacted and were asked to complete a pre-constructed form (in RedCap) asking for data from their study split by sex. Twelve authors replied and provided the required data. As such, a total of 18 studies were ultimately included in the qualitative analysis. Fourteen studies were included in the quantitative summary (two studies were excluded for not having MVPA as an outcome and two other studies were excluded due to using objective PA measures) [39-58].

Figure 1: Preferred Reporting items for Systematic Reviews and Meta-Analyses flow diagram:

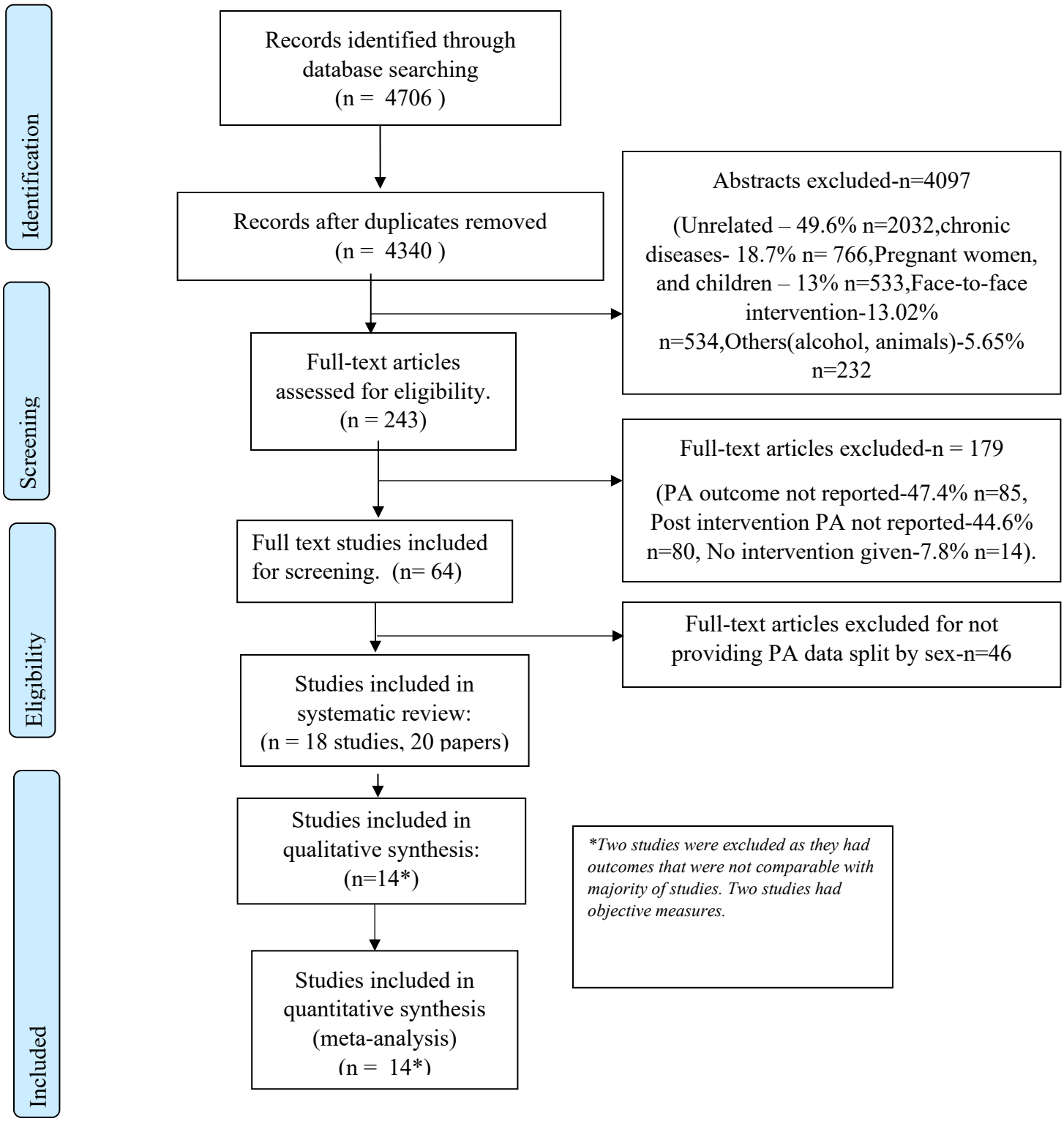

Figure I PRISMA flow diagram

3.3.2. Study characteristics:

As seen in *Table 1*, there was geographical diversity seen across the studies, as six of the 18 studies were conducted in the USA, ten in Europe (four in UK and six in Netherlands), and one study in Iran, China, Malaysia, Australia each. All studies were published between 2005 and 2019.

3.3.21. Participants:

Five interventions had only women participants, thirteen interventions consisted of both men and women, and there were no studies with only men participants. Participants' age ranged from 18 to 85 years. The total sample size comprised of 9917 participants, of which 5304 were women and 4613 were men. Regarding the individual interventions' size, 22.2% of the 18 studies had a sample size less than 100, 55.5% had a sample size between 100-1000 and 22.2% comprised a sample size above 1000 participants. A wide range of populations were present across the interventions, such as: students, employees, middle aged adults, and the retired elderly population. Some studies also targeted ethnically diverse populations such as African American women, Muslim women, and Chinese students.

3.3.22. Intervention description:

The duration of the interventions ranged from four weeks to 104 weeks, with 50% of the interventions being 12 weeks. Fourteen interventions used an internet platform, two interventions used SMS texting as their mode for delivering intervention, one intervention used email, and one intervention used both email and SMS for their intervention (see Table 1).

Table 1. General characteristics of included studies (N= Total population).

Author	Country	Study Design	E-health Mode	Population	Duration (weeks)	Assessment Timepoint (weeks)		E-health Intervention	Intervention in comparison	Control group	Target Behaviour
				N, Age, % of female, Description		Post-Intervention	Follow-up (after end of intervention)	e-health only	e-health and/or non-e-health	No intervention	
Hageman 2005	USA	pre-post	Internet	N=31 50-69 yrs W (100%)	8	12	NA	Internet-based newsletter	Standard newsletter	NA	PA
Dunton 2008	USA	RCT	Internet	N=156 21-65 yrs W (100%)	10	12	NA	'Women's fitness planner website'	NA	Waiting list	PA
Slootmaker 2009	Netherlands	RCT	Internet	N= 102 20 - 40 yrs W (60%)	12	12	20	Web-based tailored PA intervention	NA	Printed brochure	PA
Van Wier 2009	Netherlands	RCT	Internet	N=1386 43 ± 8.6 yrs W (33%) IT, bank, police, hospital employees	26	26	NA	Lifestyle intervention	phone group	Self-help materials	PA, Diet
Kelders 2010	Netherlands	RCT	Internet	N=297 40.9 ± 13.8 yrs W (62%)	12	12	NA	'Healthy weight assistant' website	NA	Waiting list	PA, Diet
Robroek 2012	Netherlands	Cluster RCT	Internet	N=924 20-63 yrs W (51.2%)	104	104	NA	Computer-tailored intervention for PA and FVI	NA	face-to-face health check-up	PA, Diet
Peels 2013/ Peels 2014	Netherlands	RCT	Internet	N=1248 18- 50yrs W (51.2%)	16	26	34.7	'Active Plus' computer tailored intervention	print delivered	Waiting list	PA

								‘			
Epton 2014	UK	RCT	Internet	N=1445 18.9 yrs W (58%) under-graduate students	NA	NA	26	‘U@Uni’ web-based intervention	NA	Assessment only	PA, Diet
Kattlemann 2014	USA	RCT	Email	N=1639 18-24 yrs W (67.2%) full-time university students	10	12	52	‘Mini-educational nudges’ e-mail-based intervention	NA	Study material	PA, Diet, Stress Management, Sleep.
Muller 2016	Malaysia	RCT	SMS	N=43 55-70 yrs W (32%)	12	12	24	SMS delivered PA intervention	Non-SMS group	NA	PA
Block 2016	USA	RCT	Internet	N=339 31-70 yrs W (31%)	26	26	NA	‘Alive-PD’ web-based intervention	NA	Usual care	PA , Diet
Alley 2016	Australia	RCT	Internet	N=154 54 yrs (avg) W (75.9%)	8	9	NA	‘My Activity Coach’ computer tailored intervention	Tailoring +video coaching	Waiting list	PA
Joseph 2016	USA	pre-post	Internet	N=25 19-30 yrs W (100%)	12	12	NA	Internet based PA	NA	NA	PA
Duan 2017	China	RCT	Internet	N=493 17-24 yrs W (54%) under-graduate students	4	8	NA	Web-based PA intervention	NA	Screening only	PA, Diet
Blake 2017	UK	RCT	SMS and Email	N=296 19-67 yrs W (13.8%) Hospital employees	12	NA	16	Web and SMS PA intervention	SMS Group	N/A	PA

Author	Country	Study Design	E-health Mode	Population	Duration (weeks)	Assessment Timepoint (weeks)		E-health intervention	Intervention in comparison	Control group	Target Behaviour
				N, Age, % of female, Description		Post-Intervention	Follow-up (after end of intervention)	e-health only	e-health and/or non-e-health	No intervention	
Blake 2017	UK	RCT	SMS and Email	N=296 19-67 yrs W (13.8%) Hospital employees	12	NA	16	Web and SMS PA intervention	SMS Group	N/A	PA
Staffileno 2018	USA	Randomised pre-post Design	Internet	N=26 18-45 yrs W (100%) AA* women	12	12	NA	Tailored web-based PA intervention	DASH group	N/A	PA , Diet
Peyman 2018	Iran	Quasi experimental study	SMS	N=360 18- 33 yrs W (100%)	8	NA	17	Educational web-based intervention	NA	No intervention	PA
Dennison 2018/ Silarova 2019	UK	Parallel Open randomised trial	Internet	N=956 40-84 yrs W (44%)	12	12	NA	'INFORM' web-based lifestyle intervention.	Phenotype +lifestyle; phenotype +genotype +lifestyle.	No intervention	PA, Alcohol consumption, Diet

Table I General characteristics of included studies

*AA= African American , PA= physical activity, RCT= Randomised control trial, FVI= Fruit and Vegetable intake, SMS= Short Messaging Service, NA= Not available

3.3.33. Behavioural theories that underlined PA interventions:

Out of 18 interventions, 14 (77.7%) were based on a single behaviour change theory and six (33.3 %) were based on more than one behaviour change theory. For example, six studies used Bandura's social cognitive theory, four studies used the theory of planned behaviour, three studies used the Transtheoretical model, and two studies used the health action process approach. Other examples of theories included, The Health Belief Model, precaution adoption model, goal setting, feedback theory and self-care behaviour model. *(*see *Supplement 3 for full details)*.

3.3.34. Target behavioural outcome of the studies:

Nine out of eighteen studies had PA as their primary outcome of the study. The remaining nine studies targeted multiple behaviours including PA. Additional behaviours targeted by the interventions included: diet (n=9); sleep (n=1); and alcohol consumption (n=1). There were 11 interventions with pre and post intervention outcomes, four studies with data on pre, post and follow-up outcomes, and three studies with only the pre and follow-up outcomes of the intervention.

3.3.35. PA Outcome measures used:

Included studies reported varied domains, intensities, and units of PA. The domains, intensities and units of PA are mentioned for all the 18 studies included in the review *(Table 2).* Out of the eighteen studies, twelve studies (66.6%) measured total PA, while three studies (16.6%) measured recreational PA, whereas three (16.6%) measured more than one domain of PA (transport, leisure time, occupational, etc.). With regards to intensities, the majority of studies measured walking/light and MVPA (moderate to vigorous physical activity) (i.e., 77.8%) out of the eighteen studies. Minutes/week (44.4%) and MET-mins/week (27.7%), were the two most

frequently used units by most of the studies to report their PA, while 33.3% reported other outcomes (e.g.: Kcal/kg/day, avgsteps/day, hrs/day, mg/min and days/week) *(Table 2)*.

The devices and tools used to measure PA in the studies is presented in Tables 3-5 (*Supplement 4).* Fifteen studies (84%) of the studies measured PA with subjective measures and three studies (16%) of the studies measured PA objectively via pedometer and accelerometer (average steps/day and mg/min).

Table 2: Domain, Intensity and Units of PA, of all studies included in the systematic review :

Author	**Domain**	**Intensity**	**Units**
Hageman, 2005 [105]	Total	MVPA	Kcal/Kg/Day, mins/week
Dunton, 2008 [106]	Leisure time+Transportation	MVPA	mins/week
Slootmaker, 2009 [107]	Total	Light, Moderate, Vigorous	mins/week
Van Wier, 2009 [108]	Total	MVPA	MET-mins/week
$Kelders, 2010 [109]	Total	MVPA	days/week
Robroek, 2012 [110]	Recreational	MVPA +vigorous	mins/week
Peels, 2013/ 2014 [111]	Total	MVPA	mins/week
Epton, 2014 [112]	Total	MVPA	MET-mins/week
Kattlemann, 2014 [113]	Recreational	Vigorous	MET-mins/week
Muller, 2016 [114]	Total	MVPA	MET-mins/week
$Block, 2016 [115]	Leisure time	MVPA	days/week
Alley, 2016 [116]	Total	MVPA	mins/week
*Joseph, 2016 [117]	Total	MVPA	mins/week
Duan, 2017 [98]	Total	MVPA	mins/week
Blake, 2017 [118]	Transport	Walking	hrs/day
	Occupational	Moderate	hrs/day
	Recreational	Vigorous	hrs/day
Peyman, 2018 [119]	Total	MVPA	MET-mins/week
*Staffileno, 2018 [120]	Total	light+MVPA	avg steps/day
*Dennison, 2018/Silarova 2019 [121]	Total	walking+MVPA	mg/min

Table II Domain, intensity & units of PA of included studies

Note: *marked studies measured PA objectively. $ marked studies were excluded from meta-analysis as the outcome units was not aligned with majority of subjectively measured units.

The qualitative synthesis of subjectively measured PA is reported in *tables 3* and *4*. *Table 3* consists of qualitative synthesis of results of the studies with post-intervention self-reported outcomes, whereas *table 4* reports qualitative synthesis of findings from studies with pre-follow-up self-reported outcomes. Two studies have been excluded from the qualitative synthesis and meta-analysis as they were not in alignment with majority of outcome measures. Hence, fourteen studies have been reported across *table 3* and *table 4*.

Table 3: Percent change in MVPA post-intervention using subjective measures:

Table III Percent change in MVPA post-intervention using subjective measures

Pre-post Timepoint: Subjective Measure									
Author, year	**PA**			**Change in women**			**Change in men**		
	Intensity	***Units***	***Questionnaire***	***%***	***5%***	***10%***	***%***	***5%***	***10%***
Hageman, 2005	MVPA	min/week	7 Day PA recall	-28.27	↓	↓	NA	NA	NA
Dunton, 2008	MVPA	min/week	PA inventory	17.91	↑	↑	NA	NA	NA
Slootmaker, 2009	Moderate	min/week	AAQua	-2.62	NC	NC	-10.39	↓	↓
Van Wier, 2009	MVPA+ light	MET-min/week	SQUASH	9.66	↑	↓	15	↑	↑
Robroek, 2012	MVPA	min/week	IPAQ	-1.34	NC	NC	0.68	NC	NC
Peels, 2014	MVPA	min/week	SQUASH	24.81	↑	↑	44.99	↑	↑
Kattlemann, 2014	Vigorous	MET-min/week	IPAQ	15.06	↑	↑	-10.01	NC	NC
Muller, 2016	MVPA+walking	MET-min/week	IPAQ	140.02	↑	↑	213.63	↑	↑
Alley, 2016	MVPA+walking	min/week	AAQua	73.32	↑	↑	212.32	↑	↑
Joseph, 2016	MVPA	min/week	7 Day PA recall	35.51	↑	↑	NA	NA	NA
Duan, 2017	MVPA+walking	min/week	IPAQ	2.37	NC	NC	14.3	↑	↑

* PA-Physical activity, AAQua- Active Australia Questionnaire, IPAQ- International Physical Activity Questionnaire, SQUASH- Short Questionnaire to Assess Health enhancing, NA-not available. *Note: These % change were calculated qualitatively by the research team

Decrease in PA Below -5% = ↓
Between -5 % and 5% = No change (NC)
Increase in PA above 5% = ↑
Decrease in PA Below -10% = ↓
Between -10 % and 10% = No change (NC)
Increase in PA above 10% = ↑

Table 4: Percent change in total MVPA at follow-up using subjective measures.

Pre-Follow-Up Timepoint: Subjective Measure									
Author, year	**PA**			**Change in women**			**Change in men**		
	Intensity	***Units***	***Questionnaire***	**%**	**5%**	**10%**	**%**	**5%**	**10%**
Slootmaker, 2009	Moderate	*min/week*	*AAQa*	120.74	↑	↑	515.05	↑	↑
Peels, 2013	MVPA	*min/week*	*SQUASH*	-1.93	NC	NC	9.44	↑	NC
Epton, 2014	MVPA+walking	*MET-min/week*	*IPAQ*	16.9	↑	↑	-8.04	↓	NC
Kattlemann, 2014	Vigorous	*MET-min/week*	*IPAQ*	-3.6	NC	NC	-6.69	↓	NC
Muller, 2016	MVPA+walking	*MET-min/week*	*IPAQ*	172.66	↑	↑	73.4	↑	↑
Blake, 2017	Moderate	*hour/day*	*GPAQ*	269.69	↑	↑	165.49	↑	↑
Peyman, 2018	MVPA+walking	MET-min/week	IPAQ	263.28	↑	↑	Na	Na	Na

Table IV Percent changein total MVPA at follow up using subjective measures

*For Blake, 2017 study only recreational domain of physical activity was used. PA-Physical activity, AAQua- Active Australia Questionnaire, GPAQ-Global Physical Activity Questionnaire, IPAQ- International Physical Activity Questionnaire, SQUASH- Short Questionnaire to Assess Health enhancing physical activity. NA- Not available.
*Note: These % change were calculated qualitatively by the research team.

For those studies that used objective measures of PA, all three studies measured total domain of PA and MVPA intensity, whereas units of PA differed for each study. The units used by respective studies were mg/min (milligravity/min), avg. steps/day, and min/week. For objectively measured change in PA, only one study demonstrated increase in PA by 60% in women at post intervention. The remaining two studies showed decreases in PA by -42.2% and -4.48% respectively. For studies with men, only one study assessed change in PA in men using accelerometer. PA was shown to be decreased in men by -4.23%, at post-intervention. No study among the four studies that measured change in PA objectively, measured PA at follow-up. The objectively measured PA among men and women present a decrease of 40% in one study, show no change in PA in the second study and demonstrate an increase by 60% in the third study, these three studies depict varying results at post-intervention, which is an interesting contrast to the findings of subjectively measured PA. (*Table 5*).

Table 5: Percent Change in total Physical Activity at pre-post timepoint using objective measures:

Pre-post Timepoint: Objective Measure				
Author, year	**PA**		**Change in women**	**Change in men**
	Units	***Device***	***% change***	***% change***
Joseph, 2016	min/week	Accelerometer	-42.2	NA
Staffileno, 2018	avgsteps/day	Pedometer	60.14	NA
Dennison, 2018/Silarova, 2019	mg/min	Accelerometer	-4.48	-4.23

*NA=not available *Note: These % change were calculated qualitatively by the research team.

Table V Percent Change in total Physical Activity at pre-post timepoint using objective measure

3.3.36. The effects of e-health interventions on subjective MVPA outcomes:

Overall e-health behaviour change interventions in this systematic review showed intervention effects, independent of sex, with increases in MVPA at both post intervention and follow-up. The overall pooled effect for *post* intervention was 0.150 (95% CI 0.067 -0.233; p= 0.001, see *Figure 2*) and the overall pooled effect for follow-up was 0.650 (95% CI 0.410-0.890; p=0.00, see *Figure 3*).

Figure 2: Forest plot of PA changes in men and women post e-health behaviour change intervention.

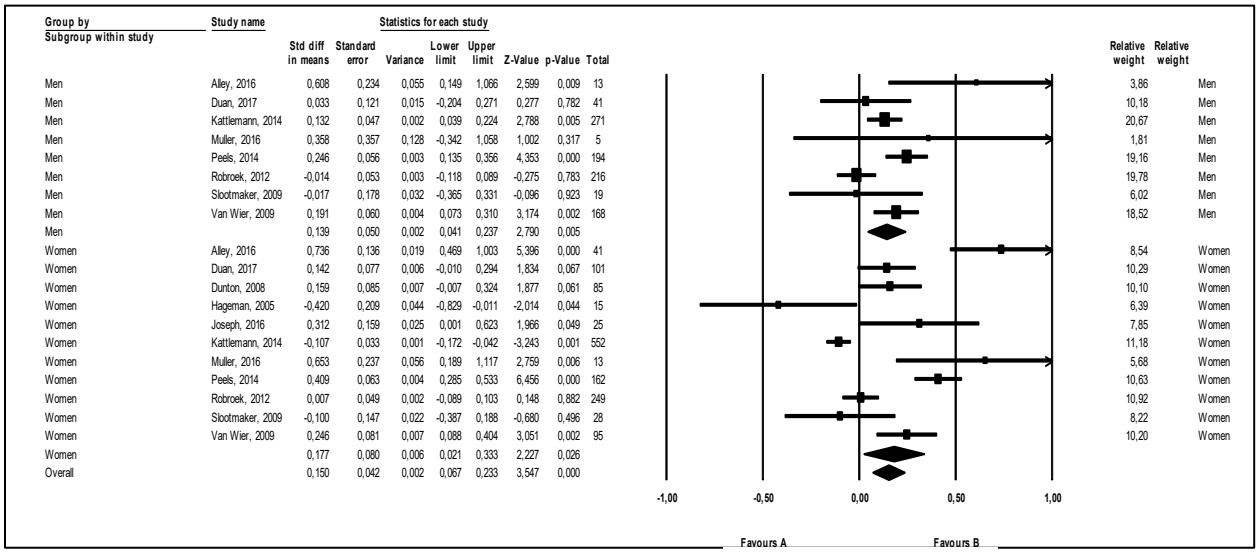

Figure II Forest plot of PA changes in men and women post e-health behaviour change intervention

Figure 3: Forest plot of PA changes in men and women at follow-up.

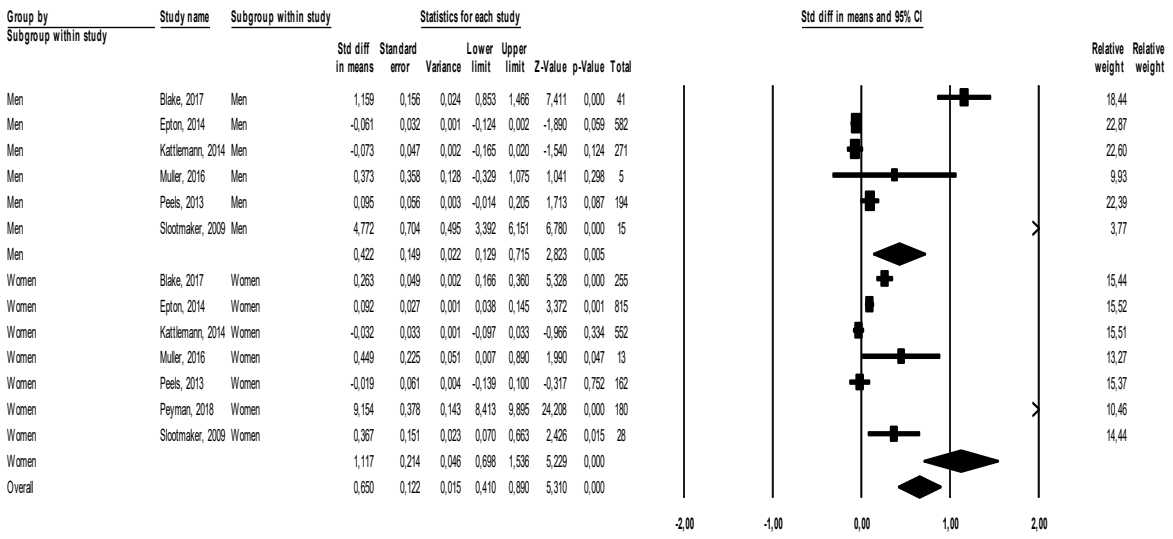

Figure III Forest plot of PA changes in men and women at follow up

3.3.37. Sex-differences:

For the post-intervention data, the pooled estimate effect in women was 0.177 (95% CI 0.021-0.333; p=0.026) and the heterogeneity of these effects was high (Q= 104.7; p = 0.00; and I^2 = 90.4%). The pooled estimate for men was 0.139 (95% CI 0.041-0.237; p=0.001) and the heterogeneity of these effects was moderate (Q= 18.66; p= 0.00; and I^2= 62.4). The comparison between sexes showed no statistical difference (p=0.685), indicating that both men and women showed equivalent increase in post interventions of PA *(Figure 2).*

For follow-up data, the pooled effect in women, was 1.117 (95% CI 0.698-.536; p=0.00) with high heterogeneity (Q=609; p=0.00; I^2= 99%). The pooled estimate for men, was 0.422 (95% CI 0.129-0.715; p=0.00), also with high levels of heterogeneity present (Q=110; p=0.00; I^2 = 95%). The comparison of pooled effects among men and women showed a statistically significant

difference (p=0.008) in the long-term effects of e-health interventions between men and women, with women seeming to have greater increases in PA compared to men *(Figure 3)*.

3.3.38. The effects of e-health interventions on sex-specific relative changes in MVPA

The qualitative data (% change) was calculated for both a 5% and 10% change PA; however, since the majority of the percent change data was above 10% we decided to report only the 10% change in PA for the sake of simplicity. There were eleven interventions reporting MVPA at post intervention for women, 55% of these showed an increase in PA by 10%, whereas 27% showed no change, and 18% of interventions showed a decrease in PA by 10%. In comparison, eight interventions included men, of which 63% showed a 10% increase, 25% showed no change, and 13% showed a decrease in PA by 10% at post intervention time point (*Table 3)*. At follow-up, of the seven interventions in women, 71% showed a 10% increase in PA and 29% showed no change. No interventions in women reported a decrease in PA, at follow-up. Of the six interventions in men, 50% showed an increase of PA by 10% with the remaining 50% showed no change *(Table 4)*.

3.3.39. The effects of e-health interventions on objective PA outcomes:

In this review, three studies objectively assessed PA responses [117, 121-123]. One study that measured steps/day among women (single sex study) via pedometer, demonstrated an increase in PA of 60% post intervention [122], while another study that used accelerometer demonstrated no-change in PA among both men and women post intervention and at follow-up [123]. The third study, which only included women, found a decrease in accelerometer-based PA post intervention *(Table 5)* [117]. Current studies with objective data demonstrate varying results in

PA, at post intervention. This is in contrast to subjective measures, that demonstrate increase in PA among both men and women at post intervention and follow-up time point. Using objective measures along with subjective measures can help us confirm the realistic change in PA in response to behaviour change interventions.

3.3.310. Study Quality:

Studies included in the review, showed certain variations in quality scores, with the average score being 17.5 (range: 15-21). No individual study received a score of 26 or above, indicating high quality of studies. The general quality of the studies was moderate. Overall, the majority of studies did not: report, adverse effects (85%); adequately adjust for cofounding in the analysis (80%); mention characteristics of participants lost at follow-up (65%); blind those measuring main outcomes (85%); nor blind the study participants (90%) *(*See *Supplement 5* for full details*).*

3.3.311. Adverse effects:

The majority of studies (17) failed to report any adverse effects in their studies. Reporting of adverse effects is important to determine positive and negative impact of findings of the respective studies.

3.4. Discussion:

The current systematic review aimed to explore sex-differences in the impact of e-health behaviour change interventions on PA, where we hypothesised that women would demonstrate greater change in PA compared to men. This review found that, at post-intervention, there was an overall increase in MVPA with no differences between women and men. The pooled estimate effect in women at post intervention was 0.177 (95% CI 0.021-0.333; p=0.026), whereas pooled estimate effect in men at post intervention was 0.139 (95% CI 0.698-.536; p=0.00),

demonstrating a small effect at post intervention. In contrast, while both women and men increased PA at follow-up, women obtained a greater increase in PA relative to men. The pooled effect in women at follow-up was 1.117 (95% CI 0.041-0.237; p=0.001) demonstrating a large effect, and in men it was 0.422 (95% CI 0.129-0.715; p=0.00) showing a medium effect. We also assessed PA in a qualitative manner by determining the relative percent change in PA among men and women. This qualitative assessment supported the findings of the meta-analysis and confirmed that both men and women showed increase in PA post intervention, 63% of men and 55% of women increased their PA by 10%, whereas more women (71%) showed an increase of at least 10% in PA compared to men (50%) at follow-up.

The greater increase in PA at follow-up among women compared to men might be due to various factors that helped women participants of the included studies to perform better. Women may have liked the idea of receiving an individualised PA intervention, through which they could not only monitor but also set a daily target of activities they wish to do during the day [2]. E-health interventions are often target-based or goal oriented, incorporating incremental activities in e-health behaviour change interventions, such as increasing difficulty in resistance exercise with varying weights, etc. [73]. A study of different barriers to PA (leisure time) between men and women parents stated that, men managed to take time out from their everyday lives (apart from work and parenting) to perform PA, whereas women felt guilty to be active leaving their expected priorities (professional work, daily chores, child care etc.) behind [91]. Furthermore, the same study also added that, women expressed time constraints to perform PA, as they found it difficult to incorporate timely or routine PA in their schedule [91]. Availability of e-health behaviour change interventions, specifically for PA may have allowed women to incorporate their PA around their daily roles and responsibilities such as child-care, and work and household

responsibilities [106, 120, 124]. This ability to perform and incorporate regular PA in their daily schedule might have helped not only in reducing the feeling of guilt but also to develop an intrinsic motivation to begin and maintain long-term PA [125]. A systematic review that assessed long-term PA in women mentioned that the majority of women maintained long-term PA primarily due to intrinsic motivation along with aided tools such as tailored interventions, regular feedback, etc. [126]. Another aspect that may have contributed to women's greater exercise at follow-up could be health based appearance; although it is more of a gender-based issue, women have expressed their need, to be active and maintain PA to appear 'in shape' or remain physically attractive [127]. A study that assessed the role of gender in PA, stated that women often face pressure due to gender role expectations and beauty norms [128], as previous studies have demonstrated that women, especially middle aged to older adults, expressed the feelings of embarrassment in public, fear of being judged and body dissatisfaction, for participating in an in-person PA intervention [129-132].

Men also demonstrated maintained increases in PA at post-intervention, and seemingly less increases in PA at follow-up than women. The increase in PA among men may have been due to varied reasons. Seven included studies specified that men were active at baseline, as they already met the recommended national guidelines [87, 94, 98, 108, 117, 133-135]. An active baseline meant that men might have experienced a ceiling effect [133]. With already meeting the guidelines, particularly MVPA, there is little room left for improvement among men [87]. This may have lead to a relatively slow increase in long-term PA in comparison to women. A study by Caspersen et al. stated that men are more likely to be involved in high intensity PA, particularly high intensity vigorous activities (weightlifting, resistance training, etc.) and on-field sports (soccer, basketball, etc.) since young adulthood, which gradually declined during adulthood [20].

Another study that measured PA in middle-aged men mentioned that increasing assimilation of adult work and family roles, although typically seen more relevant in women, affected PA in men as well, there was a 7 yr. activity decline as men transitioned from young (18-29 yrs) adulthood to middle-age (40-65 yrs) [75]. However, a key difference is that men still found time in their work-schedule to perform their PA whereas women expressed fear of being judged for performing PA over their other responsibilities (e.g., chores, work, child care, etc.) [75].

Another reason for an increase in PA among men maybe the social activity component. A study of PA maintenance in men stated that men looked forward to community based-activities, in particular with same age-peers [136]. In a study that assessed PA change (only in men) found that they performed PA more for social interaction, team spirit and enjoyment, than health-related reasons [137]. While men appreciated the novelty brought by e-health behaviour change interventions initially, they still preferred activities that include social interaction and team spirit to maintain their PA [10]. Since this current review assessed only non-interactive interventions, this missing social interactivity component may have resulted in a smaller increase in PA among men, compared to women at follow-up. A previous systematic review also supported this claim and stated that *'team spirit and social interaction'* motivated men to increase and maintain their PA, compared to women [11]. Even though women supported the idea of 'social interactivity and team support,' they still preferred e-health strategies and programmes to improve their PA at their convenience [93]. Hence, a lack of social interactivity component and ceiling effect of PA, may have leads to smaller increase in PA among men compared to women.

3.4.1. Differences in PA change using objective and subjective outcome measures:

In this review, three studies used objective outcome measures whereas fifteen studies used subjective measures of PA. Subjectively measured PA showed increases at both post-

intervention and follow-up among both men and women. In contrast, out of the three objectively measured studies, one study showed increases in PA post intervention [122], while the other study showed no change (according to the percent change categorization for 5%) in PA at post intervention and follow-up (see Table 5) [121, 123]. Interestingly, the third study used objective measures in combination with subjective measures, showing a 35.5% increase in PA using the subjective measure, while a -42.2% decrease in PA via objective measures at post intervention; this specific study enables us to understand the discrepancy between subjective and objective measures [117]. Subjective measures are valid, self-reported and self-administered, they are inexpensive and commonly available. However, they are also biased (social desirability, recall bias, etc.) [94, 117], often over reporting and less accurate than objective measures [138]. Thus, validating the intervention effects with objective measures would help us understand the realistic change in PA. Previous studies and studies in this systematic review, have mentioned that the results of subjective measures should be used with caution; and stressed the need to incorporate more objective measures in future studies to compare the bias and actual activity of participants [87, 94, 98, 138].

3.4.2. Sex-specific tailoring of future PA behaviour change interventions:

In order to increase and maintain PA changes among men and women, future e-health behaviour change interventions may have to tailor the content to consider the sex-specific needs with regards to men vs women in e-health behaviour change interventions [75]. For long-term increases and maintenance of PA in men, providing a supportive and interactive environment along with regular follow-up and update of their PA change can help them remain active even after cessation of intervention [139]. For women, individualised follow-up, and planning of PA activities to fit their schedules might motivate them to remain physically active [106].

Accommodating PA to fit their daily schedule especially among working women, may reduce the perceived dichotomy between self and beliefs of being a good mother / spouse / employee [140]. An intervention that focuses on incorporating PA into their daily routine and does not interfere in their roles and responsibilities might help in increasing and maintaining PA in women [141].

3.4.3. Strengths and Limitations:

3.4.31. Limitation of the studies in the review:

It should be noted that only one study in the review directly compared sex-differences in PA, which found greater changes in vigorous PA among women compared to men [113]; we had to ask authors to provide us with the required data. This process lead to loss of potential articles which could be included in the review as only 18 authors replied out of the 63 potential articles. Exploring and reporting sex-specific data in behaviour change interventions either in their primary findings or in their supplement can prevent this process. The variability in the type of interventions, age-groups, and PA assessment methods among the studies might make it difficult to assign the findings to a particular type of group. Lastly, seventeen studies in the systematic review failed to report adverse effects of the interventions. When advising men and women to change their PA using e-health behaviour change interventions, it is important to provide details on both positive and potentially negative consequences, taking into account certain factors like previous activity levels and age-specific limitations.

4.3.32. Limitation of the review:

The selected studies were of moderate quality, as assessed by the Downs and Black assessment tool [101], translating into fairly low risk of bias in the studies. We relied on data that were

provided by the authors through our request which inevitably reduced the number of included studies in the review. Our inclusion criteria include studies with English and French language, which means we were not able to include studies published in other languages and, as such, we may have missed other important articles.

4.3.33. Strength of the systematic review:

To date, no other systematic review has explored sex-differences in the efficacy of e-health interventions for PA. This is the first review in this topic. One key strength of the review is that it followed the PRISMA guidelines [142] (see checklist in the *supplement 1*). It provides structure and highlights all the necessary steps in the systematic review. It ensures, that all the steps are carried by the author in a persistent way. The guidelines also, provides the reader the opportunity to contrast the conclusion based on the information reported. In addition, we were able to report on both post intervention and follow-up data providing an assessment of the short-term and long-term changes in PA.

3.4.4. Implications for future research:

The current findings can help future e-health interventions that ought to adapt behaviour change interventions and suggests more research is required to better understand the specific needs of men and women. Based on the current findings, future research should compare the sex-differences in behaviour change interventions with direct interactivity component (skype vs automated messages, phone-call vs website based, etc.). Moreover, assessing sex-differences across various age-groups (adults, middle-aged and older adults) can help us identify specific changes to PA behaviour across age-groups. Incorporating current findings, to modify sex-specific aspects to change PA should be considered for future behaviour change intervention.

3.4.5. Conclusion and Clinical implications of the study

E-health behaviour change interventions lead to increases in PA, at both post-intervention and follow-up among men and women, with greater increase at follow-up for women compared to men. Current findings confirm the sex-differences to PA change using e-health interventions. Clinically, this study confirms that men and women do show sex-specific response to changes in PA and participants would benefit from tweaking the interventions according to the sex-specific responses. For example, one study in the review included a PA monitor along with web-based tailored PA advice [87]. They also included a social platform that enabled encouragements within participants. This sex-specific response can enable both men and women to perform increased long-term PA.

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5. Appendix:

5.1. Supplement 1: Instructions for Authors of JMIR

Here are some quick links to how your manuscript should look at the time of submission. Components are detailed in the expected format of your manuscript. Please also refer to Instructions for Authors of JMIR for more information related to submissions, and Guide to JMIR Online Interface (PPT to come) for help with using our online system.

Authors' information/metadata

Heading/heading styles

Type of Paper

Length of paper

Title

Keywords

Trial registration

Introduction

Methods

Results

Discussion

Other components

Figures

Tables

Footnotes

Textboxes

Multimedia Appendices

CONSORT-EHEALTH

Acknowledgements (previously Authors' Contributions)

Conflicts of Interest

Abbreviations

URLs

Field codes/citation formatting

References:

- Formatting
- Published works
- Journal
- Book
- Web
- Conference proceedings
- WebCite archive

Original Paper

Enter information for authors (including designations, affiliations, correspondence, contributions) in the online metadata form. Do not use periods after initials and include degree designations and affiliations for all authors. Trial registration numbers are also filled in on the metadata forms online.

Title of Your Manuscript Should Describe the Intervention: Study Design

Abstract

Background:

Objective:

Methods:

Results: Be sure to include relevant statistics here, such as sample sizes, response rates, *P* values or Confidence Intervals. Be specific (by stating the value) rather than general (eg, "there were differences between the groups").

Conclusions:

Trial Registration: In accordance with ICMJE recommendations, **RCTs must have been registered in a WHO accredited trial registry**. Please mention the ClinicalTrials.gov registration identifier, the International Standard Randomized Controlled Trial Number (ISRCTN), or a comparable trial identifier at the end of the abstract ("Trial Registration: ClinicalTrials.gov NCT123456"), as well as when you first mention the trial in the manuscript. When mentioning related trials (e.g. in the Introduction or Methods section) the trial registration number should also be added in brackets. **ICMJE member journals require, as a condition of consideration for publication, registration in a public trials registry at or before the onset of patient enrollment. This policy applies to any trial which started enrollment after July 1, 2005. JMIR authors must add an explanation to the methods section of their manuscript if a RCT meeting these criteria has not been registered**. The JMIR editor reserves the right to reject any paper without trial registration without any further consideration or peer-review.

Keywords: Provide 3 to 10 author-selected keywords or short phrases separated with semicolons (;) that will assist indexers in cross-indexing the article and that may be published with the abstract.

Introduction

This section can include background information such as theories, prior work, and hypotheses.

If this section is quite lengthy, use of subheadings (use Word Heading 3) are encouraged to break up the material logically, e.g. Background, Prior Work, Goal of This Study etc. Subheadings should be consistent; therefore a subheading for the first part of the Methods section, for example, is also necessary (see below).

Generally, a typical paper contains between 3000 and 6000 words, but there are no rigorous restrictions. Papers should be written in accordance with the American Medical Association Manual of Style: A Guide for Authors and Editors. 9th ed. Baltimore, Md: Williams & Wilkins; 1998.

Please do not include URLs within the manuscript. A reference should be created for the URL and included in the reference list. Please use WebCite to capture the website as soon as possible, as they often expire after the intervention and become inaccessible.

Methods

Recruitment

Notice that the first subheading immediately follows the last heading. Subheadings under subheadings are also possible (see Statistical Analysis).

Statistical Analysis

Power

Notice that the next Heading Style (Heading Style 4 in this case) is used. Click on the different headings to see their Heading Style in the "Home" ribbon under "Styles". Always have at least 2 of the same subheading level in a section.

Data Exclusion

Try to avoid having only one sentence after a subheading. For example, describe the key findings of a Table that you refer to in that sentence.

Results

User Statistics

These are only examples of possible headings. Please feel free to use different headings to best describe your results.

Evaluation Outcomes:

Please make reference to your Textboxes (Textbox 1), Tables (Table 1), Figures (Figure 1), and Multimedia Appendices (Multimedia Appendix 1) in parenthesis. Please see the examples below for how they should be formatted. Please note the punctuation used in all components, including the caption/title, footnotes etc.

Figures and Multimedia Appendices are uploaded online, while Textboxes and Tables are not uploaded and remain in the body of the manuscript, appearing in the order they are mentioned after the first mention of each Table.

Textbox 1. The caption/title is placed here in a sentence format (capitalization of every word is unnecessary).

The formatting is actually a 1x1 Table, not an actual "textbox". Textboxes have no footnotes. Bullet points or numbered lists are allowed in textboxes.

Table 1. The table caption/title is placed here in a sentence format (capitalization of every word is unnecessary).[a-e]

	Main heading 1	Main heading 1	Main heading 1
	Main heading 2	Main heading 2	Main heading 2
Subheading			
(leave blank)	data	Data	data
(leave blank)	data	Data	data
Subheading			
(leave blank)	data	Data	data
(leave blank)	data	Data	data
Subheading			
(leave blank)	data	Data	data
(leave blank)	data	Data	data

[a]Not all elements are necessary for every table, simply omit the irrelevant sections for your table and keep the formatting of the rest. For further details, please refer to the main Instructions for Authors of JMIR document.

[b]Footnotes are labeled in superscript lower case a-z. Other symbols are not used.

[c]Astericks (*) can only be used if exact *P* values cannot be provided for a specific reason, and are listed after the superscript a-z footnotes.

[d]please be conscious of the overall width of the table. Tables will be automatically fitted/resized to the width of a US Letter Small page in portrait configuration during typesetting. Overcrowded Tables or Tables that are too crowded WILL look squished, and should be avoided if possible.

[e]longer headings can be abridged within the Table, with a full explanation in a footnote.

Figure 1. Captions/titles are inserted online. Try to use Times New Roman for text within the Figure to match the font of the final typeset manuscript when possible. These should be .jpeg or .png files. Please prepare Figures with good resolution – Figures that are predominantly graphics/pictures should have dpi close to 300, while those that are text-dominant can have lower resolution (usually dpi 200). Try to use combinations of color and symbols/line styles to define and refer to different categories. This will help with readability if Figures are printed/viewed in black and white.

Discussion

Principal Results

Limitations

Comparison with Prior Work

Conclusions

Acknowledgements

Please include all authors' contributions, funding information, financial disclosure, role of sponsors, and other acknowledgements here. This description should include the involvement, if any, in review and approval of the manuscript for publication and the role of sponsors. Omit if not applicable.

Conflicts of Interest

Disclose any personal financial interests related to the subject matters discussed in the manuscript here. For example, authors who are owners or employees of Internet companies that market the services described in the manuscript will be disclosed here. If none, indicate with "none declared".

Abbreviations

JMIR: Journal of Medical Internet Research

RCT: randomized controlled trial

Multimedia Appendix 1

Multimedia appendices are supplementary files, such as a PowerPoint presentation of a conference talk about the study, additional screenshots of a website, mpeg/Quicktime video/audio files, Excel/Access/SAS/SPSS files containing original data (very long tables), and questionnaires. See https://jmir.zendesk.com/hc/en-us/articles/115003396688 for further information. Do not include copyrighted material unless you obtained written permission from the copyright holder, which should be uploaded together with your Publication Agreement form as supplementary file.

The Multimedia Appendices must be uploaded online, accompanied by a caption. CONSORT-EHEALTH checklists are always uploaded as Multimedia Appendices. Although this is primarily intended for randomized trials, the section of the checklist describing how an intervention should be reported is also relevant for manuscripts with other evaluation designs.

Before submission, authors of RCTs must **fill in the electronic CONSORT-EHEALTH questionnaire at http://tinyurl.com/consort-ehealth-v1-6** with quotes from their manuscript (if you wish to comment on the importance of the items from the checklist for reporting, please also rate each item on a scale between 1-5). BEFORE you press submit, please generate a pdf of the form with your responses and upload this file as supplementary file entitled CONSORT-EHEALTH V1.6.

References

1. Number references using 1., 2., 3. etc (no square brackets) corresponding to the square bracketed references (eg, [1], [2,3], [4-7]) in the body of the manuscript.
2. DO NOT use italics, periods after authors' initials, and periods after journal abbreviations.
3. DO use a semicolon (;) after a journal title before the year, put volume number in parenthesis, and use a colon (:) before the page numbers.
4. Titles should be in sentence case (do NOT capitalize the first letter of every word). Do not use the footnotes tool to generate the reference list.

5. **Cite only *published* or *accepted* ("in print") works**. *Submitted* papers (not *accepted*) documents not widely available (personal emails, letters), or oral communications (unless they are published abstracts) should NOT be cited as references. Cite these in the main body of text as **"personal communication by NAME, DATE"** after obtaining permission from the communicator to quote his communication.
6. **Remove OLE elements** from reference management softwares such as Endnote and Reference Manager. Select the entire document (Ctrl+A or Command A), remove field codes (*Ctrl+Shift+F9* or *Command+6*). This is important for correct parsing of your reference list

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12. **For books, please add the ISBN, if known** (no blanks). (http://isbndb.com/; examples below)
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5.2. **Supplement 1:** PRISMA guidelines

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	25
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	26
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	28
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	23
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	30
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	31
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	32
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Supp 2
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	32
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	32

Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	32
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	32
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	32
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	32

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	32
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	n/a
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	34
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	36
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	n/a
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	41-48
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	41-46
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	49
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	n/a
DISCUSSION			

Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	52
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	53
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	55
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	n/a

5.3.Supplement 2: Search Strategy for PubMed database

Search	Query	Items found
#27	Search **(((((((((online[Title/Abstract] OR web[Title/Abstract] OR internet[Title/Abstract] OR electronic[Title/Abstract])) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))) AND (((intervention[Title/Abstract] OR tutorial[Title/Abstract] OR e-health[Title/Abstract] OR m-health[Title/Abstract] OR diary[Title/Abstract] OR app[Title/Abstract] OR application[Title/Abstract])) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))) AND (((((male OR males OR female OR female OR women OR men OR woman OR man OR gender) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))) AND (((exercise[Title/Abstract] OR "Physical activity"[Title/Abstract] OR "exercises"[Title/Abstract] OR "exercise"[Title/Abstract])) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))** Sort by: **Best Match**	379

Search	Query	Items found
#33	Search **(((((((online[Title/Abstract] OR web[Title/Abstract] OR internet[Title/Abstract] OR electronic[Title/Abstract])) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))) AND (((intervention[Title/Abstract] OR tutorial[Title/Abstract] OR e-health[Title/Abstract] OR m-health[Title/Abstract] OR diary[Title/Abstract] OR app[Title/Abstract] OR application[Title/Abstract])) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))) AND (((((male OR males OR female OR female OR women OR men OR woman OR man OR gender) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))) AND (((exercise[Title/Abstract] OR "Physical activity"[Title/Abstract] OR "exercises"[Title/Abstract] OR "exercise"[Title/Abstract])) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat])) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat])** Sort by: **Best Match**	379
#26	Search **(((((((online[Title/Abstract] OR web[Title/Abstract] OR internet[Title/Abstract] OR electronic[Title/Abstract])) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))) AND (((intervention[Title/Abstract] OR tutorial[Title/Abstract] OR e-health[Title/Abstract] OR m-health[Title/Abstract] OR diary[Title/Abstract] OR app[Title/Abstract] OR application[Title/Abstract])) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))) AND (((((male OR males OR female OR female OR women OR men OR woman OR man OR gender) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))) AND (((exercise[Title/Abstract] OR "Physical activity"[Title/Abstract] OR "exercises"[Title/Abstract] OR "exercise"[Title/Abstract])) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))** Sort by: **Best Match** Filters: **Publication date from 2018/07/01 to 2019/02/25**	379
#25	Search **(((male OR males OR female OR female OR women OR men OR woman OR man OR gender) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))) AND (((exercise[Title/Abstract] OR "Physical activity"[Title/Abstract] OR "exercises"[Title/Abstract] OR "exercise"[Title/Abstract])) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))** Sort by: **Best Match** Filters: **Publication date from 2018/07/01 to 2019/02/25**	14930
#24	Search **(exercise[Title/Abstract] OR "Physical activity"[Title/Abstract] OR "exercises"[Title/Abstract] OR "exercise"[Title/Abstract])** Sort by: **Best Match** Filters: **Publication date from 2018/07/01 to 2019/02/25**	29451
#23	Search **male OR males OR female OR female OR women OR men OR woman OR man OR gender** Sort by: **Best Match** Filters: **Publication date from 2018/07/01 to 2019/02/25**	399509

#22	Search **male OR males OR female OR female OR women OR men OR woman OR man OR gender** Filters: **Publication date from 2018/07/01 to 2019/02/25**	197172

Search	Query	Items found
#12	Search **(male[Title/Abstract] OR males[Title/Abstract] OR females[Title/Abstract] OR female[Title/Abstract] OR women[Title/Abstract] OR men[Title/Abstract] OR woman[Title/Abstract] OR man[Title/Abstract] OR gender[Title/Abstract])** Filters: **Publication date from 2018/07/01 to 2019/02/25**	125983
#21	Search **((((online[Title/Abstract] OR web[Title/Abstract] OR internet[Title/Abstract] OR electronic[Title/Abstract])) AND ("2018/07/01" [PDat] : "2019/02/25"[PDat]))) AND (((intervention[Title/Abstract] OR tutorial[Title/Abstract] OR e-health[Title/Abstract] OR m- health[Title/Abstract] OR diary[Title/Abstract] OR app[Title/Abstract] OR application[Title/Abstract])) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))** Filters: **Publication date from 2018/07/01 to 2019/02/25**	5732
#20	Search **(intervention[Title/Abstract] OR tutorial[Title/Abstract] OR e-health[Title/Abstract] OR m-health[Title/Abstract] OR diary[Title/Abstract] OR app[Title/Abstract] OR application[Title/Abstract])** Filters: **Publication date from 2018/07/01 to 2019/02/25**	73129
#19	Search **(online[Title/Abstract] OR web[Title/Abstract] OR internet[Title/Abstract] OR electronic[Title/Abstract])** Filters: **Publication date from 2018/07/01 to 2019/02/25**	36806
#14	Search **(((((online intervention[Title/Abstract] OR e-health[Title/Abstract] OR m-health[Title/Abstract] OR online tutorial[Title/Abstract] OR web[Title/Abstract] OR electronic diary[Title/Abstract])) AND ("2018/07/01" [PDat] : "2019/02/25"[PDat]))) AND (((male[Title/Abstract] OR males[Title/Abstract] OR females[Title/Abstract] OR female[Title/Abstract] OR women[Title/Abstract] OR men[Title/Abstract] OR woman[Title/Abstract] OR man[Title/Abstract] OR gender[Title/Abstract])) AND ("2018/07/01" [PDat] : "2019/02/25"[PDat]))) AND (((exercises[Title/Abstract] OR physical activity[Title/Abstract] OR physical exercises[Title/Abstract])) AND ("2018/07/01"[PDat] : "2019/02/25"[PDat]))** Filters: **Publication date from 2018/07/01 to 2019/02/25**	74
#18	Search **(((online intervention[Title/Abstract] OR e-health[Title/Abstract] OR m-health[Title/Abstract] OR online tutorial[Title/Abstract] OR web[Title/Abstract] OR electronic diary[Title/Abstract])) AND (male[Title/Abstract] OR males[Title/Abstract] OR females[Title/Abstract] OR female[Title/Abstract] OR women[Title/Abstract] OR men[Title/Abstract] OR woman[Title/Abstract] OR man[Title/Abstract] OR gender[Title/Abstract])) AND (exercises[Title/Abstract] OR physical activity[Title/Abstract] OR exercise[Title/Abstract] OR physical exercises[Title/Abstract])**	748

#17	Search **(((health behaviour OR health behavior intervention OR physical activity OR physical exercises OR exercises[All Fields])) AND (online intervention OR web OR internet OR e-health OR m-health OR electronic)) AND (male OR female OR men OR women OR gender OR sex)** Filters: **Publication date from 2018/07/01 to 2019/02/25**	4240
#13	Search **(exercises[Title/Abstract] OR physical activity[Title/Abstract] OR physical exercises[Title/Abstract])** Filters: **Publication date from 2018/07/01 to 2019/02/25**	8996

Search	Query	Items found
#11	Search **(online intervention[Title/Abstract] OR e-health[Title/Abstract] OR m-health[Title/Abstract] OR online tutorial[Title/Abstract] OR web[Title/Abstract] OR electronic diary[Title/Abstract])** Filters: **Publication date from 2018/07/01 to 2019/02/25**	9217
#10	Search **((#7) AND #8) AND #9** Filters: **Publication date from 2018/07/01 to 2019/02/25**	112
#9	Search **#4** Filters: **Publication date from 2018/07/01 to 2019/02/25**	17567
#8	Search **#3** Filters: **Publication date from 2018/07/01 to 2019/02/25**	125983
#7	Search **#2** Filters: **Publication date from 2018/07/01 to 2019/02/25**	9217
#6	Search **((#2) AND #3) AND #4** Filters: **Publication date from 2018/07/01 to 2019/02/25**	112
#5	Search **((#2) AND #3) AND #4**	748
#4	Search **(exercises[Title/Abstract] OR physical activity[Title/Abstract] OR exercise[Title/Abstract] OR physical exercises[Title/Abstract])**	336412
#3	Search **(male[Title/Abstract] OR males[Title/Abstract] OR females[Title/Abstract] OR female[Title/Abstract] OR women[Title/Abstract] OR men[Title/Abstract] OR woman[Title/Abstract] OR man[Title/Abstract] OR gender[Title/Abstract])**	2952339
#2	Search **(online intervention[Title/Abstract] OR e-health[Title/Abstract] OR m-health[Title/Abstract] OR online tutorial[Title/Abstract] OR web[Title/Abstract] OR electronic diary[Title/Abstract])**	97477

5.4.Supplement 3: Behaviour change theories used in individual papers, included in systematic review.

Author :	**Behaviour Change Technique used in the studies included in systematic review.**
Hageman, 2005	Pender's health promotion model based on Bandura social cognitive theory
Dunton 2008	The Health Belief Model , The Transtheoretical Model
Slootmaker 2009	Bandura's social cognitive theory
Van Wier 2009	Principle's on Behavior therapy
Kelders 2010	Transtheoretical model
Robroek 2012	Social Cognitive Theory
*Peels 2013	I-Change Model, transtheoretical model, the health action process approach , the precaution adoption model , the self-regulation theory , the self-determination theory.
*Peels 2014	I-Change Model, transtheoretical model, the health action process approach , the precaution adoption model , the self-regulation theory , the self-determination theory
Epton 2014	Theory of planned behaviour
Kattlemann 2014	Dick and Carey's Model for Instructional Design.
Muller 2016	Behaviour change technique
Block 2016	Social Cognitive Theory, The theory of planned behaviour, Behavioural economics, Positive Psychology
Alley 2016	Theory of planned behaviour, Communication theory
Joseph 2016	Social Cognitive Theory
Duan 2017	Health Action Process Approach Theory
Blake 2017	Theory of planned behaviour
Staffileno 2018	Social cognitive theory
Peyman 2018	Self-care behaviour
×Dennison 2018	Goal setting, feedback, tips on overcoming barriers
×Silarova 2019	Goal setting, feedback, tips on overcoming barriers

Multiple Publications that consisted same studies = * = Peels 2013 and 2014, Same Trial with multiple authors = × = Dennison 2018, Silarova = 2019

5.5.Supplement 4: Devices and measures used to measure PA across eighteen studies

Author name	Outcome measure									
	MVPA Minutes/week	**hrs/day**	**mins/week**	**aerobic activity (days/week)**	**days/week**	**mg/min**	**Kcal/kg/Day**	**MET-mins/week**	**Avg Steps/day**	**Walking (min/week)**
Dunton	x PA inventory									x PA inventory
Hageman	x Modified 7day activity recall						x 7 day activity recall			
Staffileno									x pedometer	
Peyman								x IPAQ		
Block				x block qstnr						
Peels x2					x SQUASH					
Alley			x AAQua							
Epton								x IPAQ		
Duan	x IPAQ-C									
Kelders					x DSHPA					
Slootmaker			x AAQua (Light, mod and Vig)							
Blake		x GPAQ (moderate and Vig PA)								
Robroek	x IPAQ		x IPAQ (Vig)							
Van Wier								x SQUASH		
Muller								x IPAQ		
Kattlemann								x IPAQ (Vig)		

Joseph			x accelerometer & 7 day activity recall							
Silarova /Dennison						x accelerometer				
Total Sum	**3**	**1**	**4**	**1**	**4**	**2**	**1**	**5**	**1**	**1**

LEGEND	FULL NAME	REFERENCE
PA inventory	Physical Activity Inventory Questionnaire	Hopkins, W. G., Wilson, N. C., & Russell, D. G. (1991). Validation of the physical activity instrument for the Life in New Zealand national survey. *American journal of epidemiology*, *133*(1), 73-82.
Modified 7day activity recall	Modified 7 day activity recall	Hellman, E. A., Williams, M. A., & Thalken, L. (1996). Modifications of the 7-day activity interview for use among older adults. *Journal of Applied Gerontology*, *15*(1), 116-132.
AAQua	Active Australia Questionnaire	Brown, W., Bauman, A., Chey, T., Trost, S., & Mummery, K. (2004). Method: comparison of surveys used to measure physical activity. *Australian and New Zealand journal of public health*, *28*(2), 128-134.
block qstnr	Block Questionnaire	Freudenheim, J. L. (1993). A review of study designs and methods of dietary assessment in nutritional epidemiology of chronic disease. *The Journal of nutrition*, *123*(suppl_2), 401-405.
IPAQ-C	International Physical Activity Questionnaire-Chinese.	Macfarlane, D. J., Lee, C. C., Ho, E. Y., Chan, K. L., & Chan, D. T. (2007). Reliability and validity of the Chinese version of IPAQ (short, last 7 days). *Journal of Science and Medicine in Sport*, *10*(1), 45-51.
IPAQ	International Physical Activity Questionnaire	Craig, C. L., Marshall, A. L., Sjöström, M., Bauman, A. E., Booth, M. L., Ainsworth, B. E., ... & Oja , P. (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine & science in sports & exercise*, *35*(8), 1381-1395.
GPAQ	Global Physical Activity Questionnaire.	Bull, F. C., Maslin, T. S., & Armstrong, T. (2009). Global physical activity questionnaire (GPAQ): nine country reliability and validity study. *Journal of Physical Activity and health*, *6*(6), 790-804.
SQUASH	Short Questionnaire to Assess Health enhancing Physical Activity	Wendel-Vos, G. W., Schuit, A. J., Saris, W. H., & Kromhout, D. (2003). Reproducibility and relative validity of the short questionnaire to assess health-enhancing physical activity. *Journal of clinical epidemiology*, *56*(12), 1163-1169.
DSHPA	Dutch Standard for Healthy Physical Activity	Wendel-Vos, G. W., Schuit, A. J., Saris, W. H., & Kromhout, D. (2003). Reproducibility and relative validity of the short questionnaire to assess health-enhancing physical activity. *Journal of clinical epidemiology*, *56*(12), 1163-1169.