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Relationship between patterns of daily physical activity and fatigue in cancer survivors

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A B S T R A C T

Purpose: This study investigated: (1) physical activity behaviour of cancer survivors throughout the day, (2) the relationship between objective and subjective measures of physical activity, and (3) the relationship between daily physical activity and fatigue.
Method: Physical activity was measured objectively using 3D-accelerometry (expressed in counts per minute (cpm)), and subjectively using a Visual Analogue Scale (VAS; 0–10) implemented on a smartphone in 18 cancer survivors (6 male; age 55.7 ± 10.2 yrs; free from cancer, last treatment ≥three months previously), and matched controls. Fatigue was scored thrice daily on a smartphone (0-10 VAS).
Results: Mean daily physical activity of cancer survivors did not deviate from controls (1108 ± 287 cpm versus 1223 ± 371 cpm, $p = .305$). However, in cancer survivors physical activity significantly decreased from morning to evening ($p < .01$) and increased levels of fatigue throughout the day were reported ($p < .01$). Furthermore, a positive correlation was found between levels of fatigue and the magnitude of the decline in physical activity from afternoon to evening ($p < .05$). Objective and subjective measured physical activity showed low correlations.
Conclusions: This study demonstrated imbalanced activity patterns in cancer survivors. Also, the more a survivor felt fatigued, the greater the decline in activity behaviour throughout the day. The low correlation between objective and subjective physical activity suggests low awareness in cancer survivors about their daily physical activity performed. Ambulatory monitoring provides new insights in both patterns of physical activity and fatigue, which might be a valuable tool to provide activity management more efficiently during treatment of fatigue.

Introduction

Cancer-Related Fatigue (CRF) often interferes with the performance of daily activities (Curt et al., 2000), can have devastating social and economic consequences (Flechner and Bottomley, 2002) and may even hinder the chance of remission or cure as a result of its demotivating effects (Morrow et al., 2002). Not surprisingly, CRF is perceived by both patients and caregivers as a highly distressing and debilitating symptom.

It is generally believed that physical activity (PA) is important in the treatment of CRF (Cramp and Byron-Daniel, 2012). Existing guidelines state that improvements to a patient's level of physical fitness and normalization of levels of daily activity, a process termed activity management, are important treatment goals for CRF management (Donnelly et al., 2010; Mitchell et al., 2007; Smith and Toonen, 2007). Moderate PA is associated with the alleviation of cancer-related symptoms such as fatigue (Cramp and Byron-Daniel, 2012), and the beneficial effect of activity management on fatigue in patients undergoing cancer treatment has been demonstrated in several randomized controlled studies (Barsevick et al., 2004; Ream et al., 2006; Yates et al., 2005).

Most of the studies examining PA and fatigue in cancer survivors have used retrospective outcome measures, such as questionnaires, to capture the extent and the nature of PA. Although these measures provide a general idea of the amount of PA performed,

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previous studies involving cancer survivors demonstrated a discrepancy between PA measured retrospectively with questionnaires and PA measured using objective measures such as accelerometers (Goedendorp et al., 2010; Grossman et al., 2008; Rogers et al., 2009; Servaes et al., 2002). A likely explanation for the discrepancy is that questionnaires are prone to recall bias. When people are asked to recall past behaviour, only a part of that behaviour will be recalled, depending on the question asked, the frequency, severity, or impact of the behaviour in question (Shiffman et al., 2008). For example, for PA behaviour it is known that light or moderate PA is difficult to measure using questionnaires (van Poppel et al., 2010); one is likely to forget 'normal', daily PA, but will recall high intensity bouts of activity.

Ambulatory monitoring techniques can provide more accurate and detailed information on daily PA behaviour and fatigue (Broderick et al., 2014). Ambulatory monitoring uses objective methods (e.g. accelerometers), subjective methods (e.g. symptoms scored several times during a day), or a combination of both, to capture behaviour as it occurs in patients' daily life. So far, only a few studies have employed ambulant monitoring, such as accelerometry, to capture PA in cancer survivors (Broderick et al., 2014). The results are surprising, as contrary to the studies using questionnaires, only a minority of these studies report lower levels of PA in cancer survivors as compared with healthy controls (Knols et al., 2009), while the majority report no differences in PA level (Alt et al., 2011; Ferriolli et al., 2012; Grossman et al., 2008). Even so, the expected relationship between PA and fatigue is scarcely observed when evaluated using ambulant monitoring. Only one study reported a significant – but low – correlation between an increase in daily steps and a decrease in fatigue in adult survivors of childhood cancer (Blaauwbroek et al., 2009).

Most of the studies that objectively assessed PA in cancer survivors used parameters that related to the *amount* of PA performed (such as intensity, number of steps, or total amount of daily PA). However, PA is not only a 'multi-dimensional construct incorporating frequency, time, type and duration' (Broderick et al., 2014), but also a behaviourial construct, concerned with patterns of PA within a specific time period (Broderick et al., 2014). To illustrate, for other populations who suffer from chronic disease, it has been reported that not the amount of PA, but PA *behaviour* might be a useful predictor of health outcomes (Evering et al., 2011a,b; van Weering et al., 2009). So far, there are no studies evaluating patterns of PA reported in the cancer literature. Therefore, better insights into both PA behaviour in cancer survivors and its relation to self-reported fatigue are desirable.

When discussing the role of PA behaviour in CRF management, another important aspect is 'awareness'. Awareness is considered essential for effective behaviour change (Pinto and Ciccolo, 2011), and is therefore a prerequisite for treatments that aim to change activity behaviour such as activity management. No previous study could be found that explicitly evaluated awareness of daily PA behaviour in cancer survivors.

Therefore, to explore the potential value of PA behaviour in CRF treatment, this study: (1) assessed PA behaviour throughout the day in a pilot group of cancer survivors; (2) compared objective and subjective ambulatory monitoring techniques to gain insights into the level of awareness of cancer survivors with regard to their daily PA performed; and (3) explored the relationship between specific parameters of daily PA pattern and self-reported fatigue in cancer survivors.

Methods

A cross-sectional study was performed at the Roessingh Center for Rehabilitation, Enschede, the Netherlands. The experimental protocol was approved by the Twente Medical Ethics Committee, and informed written consent was obtained from each participant before enrolment.

Participants and setting

Cancer survivors were recruited from the Roessingh Rehabilitation Center Enschede, the Netherlands. Inclusion criteria were: (1) formerly diagnosed with cancer; (2) completed cancer treatment (i.e. surgery, chemo- and/or radiotherapy) $\geq$3 months previously; (3) ability to read and speak Dutch; and (4) aged 18 or above. The exclusion criteria were: (1) use of wheelchair; (2) terminal or progressive disease; and (3) participation in a rehabilitation program in the previous three months.

For comparison of *daily activity behaviour*, a sample of healthy controls was included in the study. Controls were recruited by asking the patients to ask their spouses to participate. The sample of healthy controls was supplemented with controls selected from a database available at the research center. This database consisted of family members from both patients included in other studies and from employees or students working at the research center. The controls were selected from the database based on their age and sex, so that the two groups were comparable in terms of age and sex. Inclusion criteria for healthy controls were: (1) 18 years or older; (2) subjective report of being healthy; (3) no history of cancer. The same exclusion criteria applied for the controls as for the main cancer survivor group.

Procedures

Eligible cancer survivors and controls were approached by the first and second authors, who provided verbal and written information about the study. Subjects who were willing to participate were asked to fill in an informed consent. On the morning of the first day, the procedure was explained and demographic characteristics were recorded for each participant. After that, participants filled in a questionnaire about fatigue. Instructions were given about the use of the equipment, namely an activity sensor and a smartphone. Instructions covered the correct placement of the accelerometer and the wearing schedule. Participants were asked to wear the accelerometer and smartphone for five consecutive days from 8:00 until at least 22:00, excluding time spent bathing or participating in water activities. Participants were also asked to perform their normal, daily routine, and to not change their physical activity pattern. After instruction, the accelerometer and smartphone were given to the participants, and returned by post or in person to the research center after five days of monitoring.

Study measures

For each participant, the following personal information was recorded: age, sex, BMI, and current work status. For survivors, the following information was added: treatment received, location of cancer and months passed since final cancer treatment.

Ambulatory measures – Cancer survivor and controls

Objective PA behaviour was assessed using the MTx inertial 3-D motion sensor (XSens Technologies B.V., Enschede, the Netherlands), which is a tri-axial piezoelectric accelerometer that measures accelerations in the *x*, *y*, and *z*-axis. This sensor was attached to the waist by means of an elastic belt. Data were transmitted wirelessly through a Bluetooth connection and stored on a smartphone. The output measure was calculated following the method described by Bouten et al. (1994), which is highly related to measuring energy expenditure (Plasqui and Westerterp, 2007). The accelerometer data were bandpass filtered through a 4th order Butterworth filter (.11–20 Hz). The absolute value of the acceleration of each of the axes was integrated over time periods of 60 s and summed thereafter. The resulting data was expressed in counts per minute (cpm).

Ambulatory measures – Cancer survivors only

Fatigue was rated three times a day (13:00, 17:00 and 20:00) on a Visual Analogue Scale (VAS) by the cancer survivors, to rate fatigue in the morning, afternoon, and evening, respectively. In a previous study that employed the same activity monitoring method (van Weering et al., 2009), it was shown that especially early in the morning activity data was missing, because patients turned on the system late in the morning. Therefore, it was chosen to schedule morning fatigue rating at 13:00, so sufficient morning activity data would be available to correlate with the morning fatigue scores. Scores could range from 0 ("I am not tired at all") to 10 ("I am totally exhausted"). The VAS has been previously successfully applied and validated in heterogeneous cancer populations (Seyidova-Khoshknabi et al., 2011).

Self-rated level of PA was assessed at the end of each measurement day (20:00). Cancer survivors were asked to rate their level of activity during that day on a VAS, ranging from 0 ("not active at all") to 10 ("maximum level of activity").

Retrospective self-report measures – Cancer survivors only

The Multidimensional Fatigue Inventory (MFI) questionnaire (Smets et al., 1995) was used to measure fatigue retrospectively in cancer survivors, as experienced over the previous days. This 20-item questionnaire covers five dimensions: General Fatigue, Physical Fatigue, Reduced Activity, Reduced Motivation, and Mental Fatigue. The MFI has been previously and successfully validated in cancer patients with various diagnosis sites (Seyidova-Khoshknabi et al., 2011).

Data analysis

Ambulatory measures

Objective PA behaviour (*accelerometer*). Three days per participant with at least 420 minute per day was set as the minimum to be included in the data analysis. Matlab algorithms were written to allow calculation of: PA level per hour, per day part and per whole day. For each group, the mean and standard error of the mean (SEM) per hour were calculated. Only those hours for which at least 30 minute were measured, were included for analysis. The mean PA level per hour was used to calculate PA per day part; morning (8:00–12:00), afternoon (12:00–17:00), and evening (17:00–20:00). Only day parts for which at least 50% of the total data was available were included in the analysis. Finally, mean daily activity was calculated for each participant by averaging the mean activity of all the measurement days. To represent the PA pattern, the change in the PA between day parts was calculated, being the difference in cpm between (a) morning and afternoon ($cpm_{afternoon} - cpm_{morning}$); (b) afternoon and evening ($cpm_{evening} - cpm_{afternoon}$); and (c) morning and evening ($cpm_{evening} - cpm_{morning}$).

Daily fatigue. For each participant, scores of all measurement days were averaged into overall mean and standard deviation (SD) fatigue scores per day part (morning, afternoon, evening). To describe daily fatigue levels, a VAS fatigue score of $\geq$4 (out of 10) was used to represent a moderate to high level of fatigue (Temel et al., 2006).

Self-rated activity. Scores from all the measurement days were averaged, resulting in a mean score of self-rated activity for each participant, ranging from 0 to 10.

Retrospective fatigue (MFI)

A score for each dimension of the MFI was calculated, with higher scores indicating more fatigue (Smets et al., 1995).

Statistical analysis

IBM's Statistical Package for the Social Sciences (SPSS, 20.0) was used for the statistical analyses of our data. Descriptive statistics were used to summarize the characteristics of the sample. For all statistical analyses, a significance level of $p < .05$ was used. Normality of the outcome measures was tested using P-Plots, and histograms. Friedman's ANOVA was used to test the change in fatigue throughout the day in cancer survivors.

An independent *t*-test was performed to compare differences between survivors and controls in mean daily PA level. Secondly, differences in PA between day parts were tested using repeated measures ANOVA for both groups independently. Thirdly, to test group differences in PA patterns throughout the day (i.e. between day parts), repeated measures ANOVA (RMANOVA) with a grouping factor (survivors versus controls) were performed, with PA per day part being the repeated measure.

Level of awareness was tested by calculating Kendall's Tau correlation between objective PA per day (accelerometer) and self-rated PA (VAS physical activity).

To explore the *relationship between daily fatigue and activity patterns*, correlations (Kendall's Tau) were calculated between objective PA per day part and fatigue per day part.

For all correlations, cutoff scores of $<.3$, $.3 \leq r \geq .8$, and $>.8$ were used to represent low, moderate and high correlations, respectively.

Results

Participants

Forty-four cancer survivors were approached for participation. Twenty-three cancer survivors participated in the study, of whom 18 survivors (6 male; mean age 56.7 ± 10.2 yrs) provided sufficient accelerometer data to be included in the final data-analysis. The most important reasons for exclusion of survivors were no interest in study, current participation in a rehabilitation program or progressive disease. Most survivors were women diagnosed with breast cancer, resulting in twice as many women than men in the study sample. Scores on the domains of the MFI varied between 10 and 13, which is relatively high compared to literature (Schwarz et al., 2003). The sample of healthy controls comprised nine spouses of included survivors, and nine healthy subjects selected from the database. Characteristics of the included survivors and matched healthy controls are presented in Table 1. There were no significant differences found for age, sex, BMI or work status between the survivors and the controls.

Physical activity behaviour

From the included cancer survivors, 85 days (i.e. 94% of all possible measurement days), and from the healthy controls 83 days (92%) were suitable for analysis. Reasons for missing data were technical failure, incorrect use of the system, and insufficient time for PA monitoring. It was found that the mean daily activity level of cancer survivors ($M = 1108$ cpm, $SD = 287$ cpm) did not deviate significantly from daily PA levels in the control group ($M = 1223$ cpm, $SD = 371$ cpm) ($p = .305$). Daily activity patterns of both groups are visualized in Table 2 and Fig. 1. Cancer survivors exhibited a significant decrease of PA during the day ($p = .001$; Greenhouse-Geisser corrected), while the PA level between day parts did not differ significantly in controls ($p = .147$). However, the

Table 1
Characteristics of the study population.

	Cancer survivors ($n = 18$)	Healthy controls ($n = 18$)
Age, mean (SD)	56.7 (10.2)	55.2 (8.2)
Sex, *n*		
Male	6	6
Female	12	12
Body mass index, mean (SD)	25.2 (3.9)	25.3 (2.9)
Employed, *n* (%)		
Yes	8 (44)	12 (67)
Location of cancer, *n* (%)		
Breast	12 (66)	–
Testicular	2 (11)	–
Lung	2 (11)	–
Skin	1 (6)	–
Colon	1 (6)	–
Treatment, *n* (%)		
Surgery	2 (11)	–
Radiotherapy	1 (6)	–
Surgery + Radiotherapy	4 (22)	–
Surgery + Chemotherapy	3 (17)	–
Chemotherapy + Radiotherapy	2 (11)	–
Surgery, chemotherapy + radiotherapy	6 (33)	–
Time since final treatment		
<12 months, *n* (%)	10 (56%)	
Multidimensional Fatigue Inventory, mean (SD)		
General fatigue	12.9 (3.8)	–
Physical fatigue	11.8 (3.8)	–
Reduced activity	11.1 (3.7)	–
Reduced motivation	10.1 (3.5)	–
Mental fatigue	11.2 (3.8)	–

group × time interaction failed to reach significance ($p = .199$, Greenhouse-Geisser corrected).

Awareness daily activity levels

A low correlation of .193 ($p = .270$) was observed between self-rated VAS activity scores and mean daily PA as measured by the accelerometer, suggesting a low awareness of actual physical activity level in cancer survivors.

Patterns of fatigue

Of all VAS fatigue scores, 94% were available for analysis. Missing values occurred primarily for the evening hours, and were caused by technical failures (empty battery before the question was asked; question did not appear on the smartphone, or system was shut down before fatigue was scored due to connection failures with the activity sensor). Cancer survivors reported a significant increase in fatigue levels during the day ($p = .006$), with 89% of participants reporting a VAS fatigue score of >4 during the evening (Fig. 2).

Ambulatory fatigue rated with the VAS fatigue, did not correlate with fatigue measured with the MFI.

Relationship between PA behaviour and fatigue

Both PA in the morning and PA in the afternoon were moderately and positively correlated with fatigue in the evening (Table 3), meaning that the higher the physical activity in the morning and afternoon, the higher the level of fatigue in the evening. Furthermore, moderate negative correlations were found between levels of fatigue in the afternoon and evening and the magnitude of the decrease in PA from afternoon to evening. That is, the more the survivors felt fatigued, the higher the decrease in activity throughout the day.

No significant correlations were found between subscales of the MFI and ambulant measured PA behaviour, either accelerometry nor daily reported VAS activity.

Table 2
Day part activity (in counts per minute) in both cancer survivors and controls.

Day part activity (mean ± sd)	Morning	Afternoon	Evening
Cancer survivors ($n = 18$)	1364 ± 480	1034 ± 415	835 ± 353
Controls ($n = 18$)	1285 ± 517	1291 ± 402	1065 ± 453

Discussion

This study has explored the potential value of PA behaviour in CRF treatment, through investigation of daily activity behaviour and its relation to fatigue in cancer survivors by using ambulatory monitoring techniques. Furthermore, we investigated whether cancer survivors are aware of their own daily activity behaviour.

Our results show that, on average, daily activity levels of cancer survivors from this sample are comparable to those of age- and gender-matched controls. This finding is in line with the study of Servaes et al. (2002) who also found no difference in daily activity levels between post-treatment breast cancer survivors and healthy controls. However, distribution of physical activity throughout the day turned out to be less balanced in cancer survivors as compared to the healthy controls; with the cancer survivors displaying a significant decrease in physical activity from morning to evening. This is the first known study to show imbalances during the day in PA behaviour in cancer survivors. Imbalances in PA behaviour have also been reported for other chronic patient groups, such as COPD, chronic low back pain and chronic fatigued patients (Tabak et al., 2012; van Weering et al., 2009). In those studies, the existence of symptoms, e.g. fatigue, pain or dyspnea, was suggested as a possible cause of altered PA behaviour. That assumption is supported by the results of the present study: cancer survivors reported a significant increase in levels of fatigue from morning to evening. Furthermore, the more the survivors felt fatigued, the greater the decline in activity behaviour from afternoon to the evening displayed by the cancer survivors.

Both the level and pattern of fatigue observed in our sample of cancer survivors are consistent with a previous study in which fatigue was assessed multiple times daily in breast cancer survivors (Curran et al., 2004), showing high levels of experienced fatigue from late morning to evening. Although increasing fatigue levels from late morning to evening are considered normal, and are also observed in healthy persons (Curran et al., 2004), cancer survivors seem more 'fatiguable' with overall higher levels of fatigue, except when getting up in the morning directly after a night's sleep (Curran et al., 2004).

In our study, the relation between PA behaviour and fatigue patterns suggests that cancer survivors might be performing too much activity in the morning, resulting in increased fatigue levels, which in turn results in a relapse in activity from the afternoon going into the evening. One possible explanation for this specific pattern of PA is that cancer survivors are not aware of their PA behaviour and the effect that certain activities have on their energy and fatigue levels. This phenomenon has been previously observed in other populations suffering from chronic disease (Evering et al., 2011a,b; Tabak et al., 2012; van Weering et al., 2011). For example, as described in the paragraph above, cancer survivors might feel 'good', i.e. not fatigued directly after waking up, and start with their 'normal' routine of daily activities. In healthy persons, this would not result in any significant increase in fatigue, whereas due to the high 'fatiguability' of cancer survivors (Curran et al., 2004), energy levels are quickly depleted in cancer survivors, resulting in increased levels of fatigue. This supports the assumption that

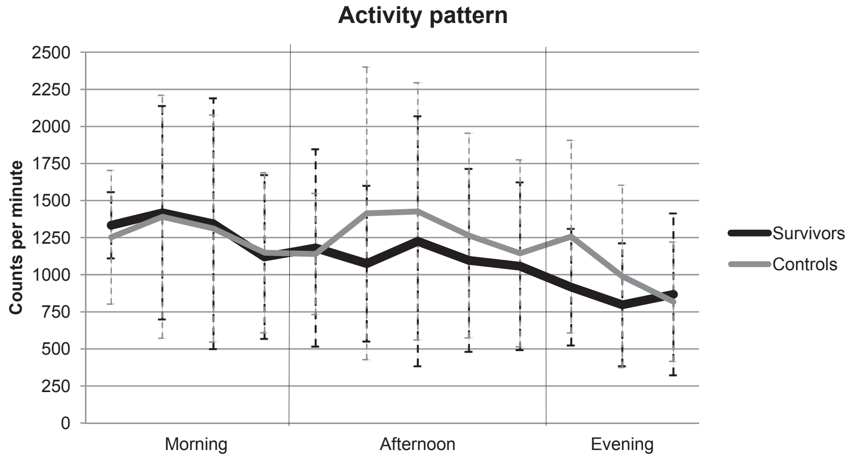

Fig. 1. Ambulatory activity. Activity patterns of cancer survivors ($n = 18$) and controls ($n = 18$).

balancing activity patterns, i.e. activity management, might reduce the experience of fatigue. Therefore, the role of PA as part of CRF treatment should not be limited to increasing the daily PA level, for example by exercise programs, but should also incorporate advice and tools for balancing activities over a day. In our study, we did not monitor fatigue levels directly following a night's sleep, and therefore cannot draw conclusions about whether or not this hypothesis holds for our sample of cancer survivors. Therefore, future research should further explore the interplay and cause-and-effect between changes in PA patterns and experienced fatigue.

The relationship between PA behaviour and fatigue in the present study is in contrast with previous studies that reported no causal relationship between ambulant measured PA level and fatigue (Gielissen et al., 2012; Goedendorp et al., 2010). As discussed in the Introduction, these contradicting findings might result from the use of different outcome measures to represent PA and fatigue between the present and previous studies. In the present study, ambulant monitoring techniques were used to assess both PA and fatigue, while previous studies correlated retrospective measures for fatigue with ambulant measured PA. Information gathered by means of ambulatory monitoring is likely to be different and result in other conclusions than when the outcomes are assessed by means of retrospective questionnaires, since ambulatory assessment is less subject to recall bias, but more importantly, provides more and more detailed outcome parameters, which allows for indepth analysis of actual PA patterns in relation to fatigue. Servaes et al. (2002) have already demonstrated that both retrospective measured PA and fatigue were correlated, as were ambulant measured PA and fatigue, while retrospective measures correlated poorly with ambulant outcome measures. This was supported by the findings of our study, as no significant correlations were found between retrospective measured fatigue (i.e. MFI) and ambulant measured fatigue, or between retrospective fatigue and ambulant measured PA behaviour. This emphasizes the importance of choosing suitable assessment methods when examining the relation between PA and fatigue.

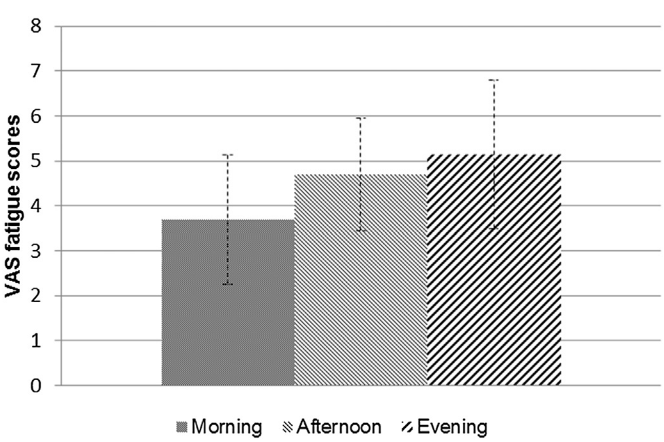

Fig. 2. Daily fatigue pattern measured with the VAS fatigue in cancer survivors ($n = 18$).

As indicated by behaviour change theories (e.g. Cognitive Behavioural Theory), awareness of a subject's own PA behaviour is very important, otherwise PA behaviour change programs are unlikely to be successful (Pinto and Ciccolo, 2011). In the present study, awareness was operationalized by the relationship between the daily PA level measured using an accelerometer, and the PA level rated by the cancer survivor at the end of each measurement day on an 11-point scale. By using this approach, the recalled period of PA behaviour matches the period of objectively assessed PA. Also, both the score on self-rated PA and the resulting correlation will be less biased by recall problems than when measured using a questionnaire. Therefore, this approach is considered more advantageous than comparing objective PA with retrospective questionnaires, and a better indicator for the mismatch between perception of and the actual PA behaviour. The results demonstrate low awareness in cancer survivors, suggesting that the survivors' perception of the PA performed on a particular day deviates from the actual level of PA. Therefore, for activity management to be successful, treatment should also focus on increasing awareness of actual activity behaviour.

Table 3
Correlations between ambulatory PA behaviour (accelerometry) and fatigue (VAS fatigue) in cancer survivors ($n = 18$).

	VAS fatigue		
	Morning	Afternoon	Evening
Day part activity			
Morning	−.007	.076	.326†
Afternoon	−.146	.149	.454**
Evening	−.292	−.092	.133
PA pattern			
Afternoon–Morning	−.232	−.107	−.074
Evening–Afternoon	−.097	−.428*	−.430*
Evening–Morning	−.213	−.226	−.336†

$^{*}p$ value < .05; $^{**}p$ value < .01; †p value < .10.

This study provides evidence of the value of ambulatory monitoring in the management of both PA and fatigue. As reported previously by Hermens et al., the use of ambulatory monitoring and feedback applications is a promising approach to monitoring, increasing awareness of, and thereby positively influencing daily activity behaviour (Hermens and Vollenbroek-Hutten, 2008). By using these applications, activity behaviour is measured using ambulatory monitoring techniques, e.g. an accelerometer. By receiving personalized feedback messages on a smartphone, patients can be informed about their activity behaviour, and are provided with advice about how to optimize activity behaviour. Previous research demonstrated that giving real-time feedback on actual activity behaviour can positively influence the activity behaviour in patients suffering from chronic fatigue and chronic pain (Evering, 2013; van Weering, 2011). The use of ambulatory monitoring and feedback applications might also be a promising approach to providing activity management efficiently in the treatment of CRF.

Our study provides new insights into daily activity behaviour and its relation with self-reported fatigue in cancer survivors. However, potential limitations should be considered to help interpret the results. First, selection bias might be present due to the sampling method chosen for this study. We included cancer survivors who voluntarily applied for a cancer rehabilitation program to improve their physical and mental recovery following cancer treatment. It is likely that people who start a rehabilitation program, will experience a higher burden of symptoms and functional limitations in daily life compared to survivors who do not apply for supervised rehabilitation. It remains unknown how representative the findings of this study are regarding daily activity and fatigue for cancer survivors in general. Therefore, caution should be taken in generalizing the findings. Second, the small sample resulted in low statistical power, which might result in spurious effects or correlations. However, by using the mean value of a minimum of three days in the analysis, the probability of the disproportionate influence of a single extreme measurement on the end result was reduced. Future research should further test the observed relationship between PA behaviour and patterns of fatigue in a larger, adequately powered study. Last, although the present study suggests that daily physical activity patterns are associated with self-reported levels of fatigue in cancer survivors, no causal relationship between physical activity and fatigue could be established due to the cross-sectional nature of the study design. One further step would be to investigate whether activity coaching in daily life decreases self-reported fatigue in cancer survivors.

Conclusion

This is one of the first studies reporting on daily PA patterns in cancer survivors. Cancer survivors demonstrated imbalanced PA patterns as compared to those shown by the controls, while the overall level of PA was comparable between groups. Also, in cancer survivors PA behaviour was associated with the experience of fatigue during the day; the more the survivors felt fatigued, the greater the decline in activity behaviour from afternoon to the evening. This implies that providing survivors with advice and tools for balancing activities efficiently over a day might be of importance in the treatment of CRF. Furthermore, the observed low awareness in cancer survivors regarding the daily PA performed suggests that during treatment attention should be paid to making patients aware of their activity behaviour. The use of ambulatory monitoring techniques is a promising method to employ activity management more efficiently in cancer survivors. These methods enable daily monitoring of PA and fatigue, and can provide survivors with real-time feedback on their behaviour, improving both awareness and the ability to change PA behaviour. Future research should determine if balancing activity through the use of ambulatory techniques indeed reduces the experience of fatigue in cancer survivors.

Conflict of interest

I can confirm that there are no financial relationships between the authors and the organization which funded this research. The corresponding author has full control of all primary data, which can be reviewed should this be required.

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References

Alt, C.A., Gore, E.M., Montagnini, M.L., Ng, A.V., 2011. Muscle endurance, cancer-related fatigue, and radiotherapy in prostate cancer survivors. Muscle & Nerve 43, 415–424.

Barsevick, A.M., Dudley, W., Beck, S., Sweeney, C., Whitmer, K., Nail, L., 2004. A randomized clinical trial of energy conservation for patients with cancer-related fatigue. Cancer 100, 1302–1310.

Blaauwbroek, R., Bouma, M.J., Tuinier, W., Groenier, K.H., de Greef, M.H., Meyboom-de Jong, B., et al., 2009. The effect of exercise counselling with feedback from a pedometer on fatigue in adult survivors of childhood cancer: a pilot study. Supportive Care in Cancer: Official Journal of the Multinational Association of Supportive Care in Cancer 17, 1041–1048.

Bouten, C., Westerterp, K., Verduin, M., Janssen, J., 1994. Assessment of energy expenditure for physical activity using a triaxial accelerometer. Medicine and Science in Sports and Exercise 23, 21–27.

Broderick, J., Ryan, J., O'Donnell, D., Hussey, J., 2014. A guide to assessing physical activity using accelerometry in cancer patients. Supportive Care in Cancer 1–10.

Cramp, F., Byron-Daniel, J., 2012. Exercise for the management of cancer-related fatigue in adults. Cochrane Database of Systematic Reviews (Online) 11. CD006145.

Curran, S.L., Beacham, A.O., Andrykowski, M.A., 2004. Ecological momentary assessment of fatigue following breast cancer treatment. Journal of Behavioral Medicine 27, 425–444.

Curt, G.A., Breitbart, W., Cella, D., Groopman, J.E., Horning, S.J., Itri, L.M., et al., 2000. Impact of cancer-related fatigue on the lives of patients: new findings from the Fatigue Coalition. Oncologist 5, 353–360.

Donnelly, C.M., Lowe-Strong, A., Rankin, J.P., Campbell, A., Allen, J.M., Gracey, J.H., 2010. Physiotherapy management of cancer-related fatigue: a survey of UK current practice. Supportive care in cancer 18, 817–825.

Evering, R.M., 2013. Ambulatory Feedback at Daily Physical Activity Patterns. University of Twente, Enschede, The Netherlands.

Evering, R.M., Tonis, T.M., Vollenbroek-Hutten, M.M., 2011a. Deviations in daily physical activity patterns in patients with the chronic fatigue syndrome: a case control study. Journal of Psychosomatic Research 71, 129–135.

Evering, R.M., van Weering, M.G.H., Groothuis-Oudshoorn, K.C., Vollenbroek-Hutten, M.M., 2011b. Daily physical activity of patients with the chronic fatigue syndrome: a systematic review. Clinical Rehabilitation 25, 112–133.

Ferriolli, E., Skipworth, R.J., Hendry, P., Scott, A., Stensteth, J., Dahele, M., et al., 2012. Physical activity monitoring: a responsive and meaningful patient-centered outcome for surgery, chemotherapy, or radiotherapy? Journal of Pain and Symptom Management 43, 1025–1035.

Flechner, H., Bottomley, A., 2002. Fatigue assessment in cancer clinical trials. Expert Review of Pharmacoeconomics & Outcomes Research 2, 67–76.

Gielissen, M.F., Wiborg, J.F., Verhagen, C.A., Knoop, H., Bleijenberg, G., 2012. Examining the role of physical activity in reducing postcancer fatigue. Supportive care in Cancer: Official Journal of the Multinational Association of Supportive Care in Cancer 20, 1441–1447.

Goedendorp, M.M., Peters, M.E., Gielissen, M.F., Witjes, J.A., Leer, J.W., Verhagen, C.A., et al., 2010. Is increasing physical activity necessary to diminish fatigue during cancer treatment? Comparing cognitive behavior therapy and a brief nursing intervention with usual care in a multicenter randomized controlled trial. Oncologist 15, 1122–1132.

Grossman, P., Deuring, G., Garland, S.N., Campbell, T.S., Carlson, L.E., 2008. Patterns of objective physical functioning and perception of mood and fatigue in post-treatment breast cancer patients and healthy controls: an ambulatory psychophysiological investigation. Psychosomatic Medicine 70, 819–828.

Hermens, H.J., Vollenbroek-Hutten, M.M.R., 2008. Towards remote monitoring and remotely supervised training. Journal of Electromyography and Kinesiology 18, 908–919.

Knols, R.H., de Bruin, E.D., Aufdemkampe, G., Uebelhart, D., Aaronson, N.K., 2009. Reliability of ambulatory walking activity in patients with hematologic malignancies. Archives of Physical Medicine and Rehabilitation 90, 58–65.

Mitchell, S.A., Beck, S.L., Hood, L.E., Moore, K., Tanner, E.R., 2007. Putting evidence into practice: evidence-based interventions for fatigue during and following cancer and its treatment. Clinical Journal of Oncology Nursing 11, 99–113.

Morrow, G.R., Andrews, P.L., Hickok, J.T., Roscoe, J.A., Matteson, S., 2002. Fatigue associated with cancer and its treatment. Supportive care in cancer. Official Journal of the Multinational Association of Supportive Care in Cancer 10, 389–398.

Pinto, B.M., Ciccolo, J.T., 2011. Physical activity motivation and cancer survivorship. Recent results in cancer research. Fortschritte der Krebsforschung. Progres dans les recherches sur le cancer 186, 367–387.

Plasqui, G., Westerterp, K.R., 2007. Physical activity assessment with accelerometers: an evaluation against doubly labeled water. Obesity 15, 2371–2379.

Ream, E., Richardson, A., Alexander-Dann, C., 2006. Supportive intervention for fatigue in patients undergoing chemotherapy: a randomized controlled trial. Journal of Pain and Symptom Management 31, 148–161.

Rogers, L.Q., Hopkins-Price, P., Vicari, S., Pamenter, R., Courneya, K.S., Markwell, S., et al., 2009. A randomized trial to increase physical activity in breast cancer survivors. Medicine and Science in Sports and Exercise 41, 935–946.

Schwarz, R., Krauss, O., Hinz, A., 2003. Fatigue in the general population. Onkologie 26, 140–144.

Servaes, P., Verhagen, C.A., Bleijenberg, G., 2002. Relations between fatigue, neuropsychological functioning, and physical activity after treatment for breast carcinoma: daily self-report and objective behavior. Cancer 95, 2017–2026.

Seyidova-Khoshknabi, D., Davis, M.P., Walsh, D., 2011. Review article: a systematic review of cancer-related fatigue measurement questionnaires. The American Journal of Hospice & Palliative Care 28, 119–129.

Shiffman, S., Stone, A.A., Hufford, M.R., 2008. Ecological momentary assessment. Annual Review of Clinical Psychology 4, 1–32.

Smets, E.M., Garssen, B., Bonke, B., De Haes, J.C., 1995. The Multidimensional Fatigue Inventory (MFI) psychometric qualities of an instrument to assess fatigue. Journal of Psychosomatic Research 39, 315–325.

Smith, G.F., Toonen, T.R., 2007. Primary care of the patient with cancer. American Family Physician 75, 1207–1214.

Tabak, M., Vollenbroek-Hutten, M.M., van der Valk, P.D., van der Palen, J., Tonis, T.M., Hermens, H.J., 2012. Telemonitoring of daily activity and symptom behavior in patients with COPD. International Journal of Telemedicine and Applications 2012, 438736.

Temel, J.S., Pirl, W.F., Recklitis, C.J., Cashavelly, B., Lynch, T.J., 2006. Feasibility and validity of a one-item fatigue screen in a thoracic oncology clinic. Journal of Thoracic Oncology 1, 454–459.

van Poppel, M.N., Chinapaw, M.J., Mokkink, L.B., van Mechelen, W., Terwee, C.B., 2010. Physical Activity Questionnaires for Adults: a Systematic Review of Measurement Properties, 40. Sports Medicine, Auckland, N.Z, pp. 565–600.

van Weering, M.G., Vollenbroek-Hutten, M.M., Hermens, H.J., 2011. The relationship between objectively and subjectively measured activity levels in people with chronic low back pain. Clinical Rehabilitation 25, 256–263.

van Weering, M.G.H., 2011. Towards a New Treatment for Chronic Low Back Pain Patients: Using Activity Monitoring and Personalized Feedback. University of Twente, Enschede, The Netherlands.

van Weering, M.G.H., Vollenbroek-Hutten, M.M., Tonis, T.M., Hermens, H.J., 2009. Daily physical activities in chronic lower back pain patients assessed with accelerometry. European Journal of Pain 13, 649–654.

Yates, P., Aranda, S., Hargraves, M., Mirolo, B., Clavarino, A., McLachlan, S., et al., 2005. Randomized controlled trial of an educational intervention for managing fatigue in women receiving adjuvant chemotherapy for early-stage breast cancer. Journal of Clinical Oncology 23, 6027–6036.