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# Reallocating time to sleep, sedentary time or physical activity: associations with waist circumference and body mass index in breast cancer survivors

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## Abstract

**Background—**Moderate-to-vigorous intensity physical activity (MVPA) has been inversely associated with waist circumference and body mass index among breast cancer survivors. Limited research has focused on behaviours that account for larger portions of the day [sleep, sedentary time, and light-intensity physical activity (LPA)]. In this study we investigated the interdependent associations of self-reported sleep, objectively-assessed prolonged and short bouts of sedentary time, total LPA and total MVPA with waist circumference and BMI in breast cancer survivors.

**Methods—**A cross-sectional sample of breast cancer survivors (N=256, mean age=60 years; mean time since diagnosis=3 years) wore an Actigraph® GT3X+ accelerometer during waking hours for seven days. Participants also completed the Pittsburgh Sleep Quality Index, and self-reported their waist circumference, height and weight. An isotemporal substitution approach was used in linear regression models to explore the associations of reallocating time to sleep, sedentary and active behaviours on waist circumference and BMI, after adjusting for potential confounders.

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**Results—**Reallocating 30 minutes to total MVPA was associated with lower waist circumference when allocated from sleep (−2.50cm, 95% CI = −4.45cm, −0.56cm), prolonged sedentary time (−2.51cm, 95% CI = −4.38cm, −0.64cm) or LPA (−2.71cm, 95% CI = −4.72cm, −0.69cm). Reallocating 30 minutes of prolonged sedentary time to non-prolonged sedentary time was associated with lower waist circumference (−0.94cm, 95% CI = −1.79cm, −0.10cm). Similar results were observed for BMI.

**Conclusion/Impact—**Increasing MVPA levels and decreasing time spent in prolonged, unbroken sedentary bouts may be avenues for improving body composition in this population.

### Keywords

breast cancer; survivors; physical activity; sedentary behaviour; waist circumference; body mass index

## INTRODUCTION

Obesity is associated with poorer prognosis in females diagnosed with breast cancer (1). Weight gain after diagnosis, in particular, has been associated with greater comorbidity and poorer quality of life (1). The majority of breast cancer survivors gain weight during and after treatment (2), so it is important to identify strategies that can prevent this from occurring.

Research indicates that higher levels of moderate-to-vigorous intensity physical activity (MVPA) are associated with improved weight control and body composition in breast cancer survivors (3, 4). However, MVPA comprises a small fraction of each day; studies using objective measures have found MVPA accounts for 1% to 3.5% of waking hours in breast cancer survivors (5–8). Few studies have examined behaviours that account for much larger portions of the day, such as sleep, sedentary behaviour and light-intensity physical activity (LPA) (9). Recent research in breast cancer survivors has found sedentary time accounts for between 57% and 79% of waking hours, LPA accounts for between 20% and 40%,(5–8) and daily sleep duration is approximately 7 hours (10). One previous study has examined how sedentary behaviour and LPA are associated with body composition. This study suggested higher levels of sedentary time and lower levels of LPA were significantly associated with higher body mass index (BMI) and greater waist circumference, however these associations were largely attenuated after adjustment for MVPA (8).

Sleep, sedentary, and physically active behaviours are interdependent, because the finite number of hours in a day means that increasing time in one of these behaviours decreases time spent in others. The way sedentary time is accumulated throughout the day may also impact its influence on health outcomes. Previous research indicates that prolonged, unbroken bouts of sedentary time have a greater detrimental effect on cardiometabolic outcomes than shorter bouts (11, 12). No previous studies in breast cancer survivors have examined sedentary time accumulation patterns or taken into account the interdependent nature of sleep, sedentary and active behaviours.

In this study we used isotemporal substitution modelling to account for the full 24-hour day to investigate the interdependent associations of self-reported sleep and objectively-assessed sedentary time, LPA and MVPA with waist circumference and BMI in breast cancer survivors.

## MATERIALS AND METHODS

### Participants

The ACCEL-Breast study was a cross-sectional study that was conducted in Western Australia (WA) in 2013. The full methods have been described previously.(6) Briefly, participants were between two and four years post-diagnosis, between 18 and 80 years of age and residing in WA at the time of diagnosis, and had previously taken part in a case-control study (13). Breast cancer survivors who were currently receiving chemotherapy or radiotherapy, had experienced a recurrence of their breast cancer, or had been diagnosed with another cancer were ineligible.

Participants were asked to wear an Actigraph GT3X+ accelerometer (ActiGraph Corporation, Pensacola FL) on their right hip during waking hours for seven consecutive days, and to complete a written questionnaire assessing demographic information and patient-reported outcomes. A total of 552 eligible breast cancer survivors were invited to take part in the study, 340 of whom agreed to participate in the study and were sent the study questionnaire and an accelerometer. Of those 340 participants, 274 (50% of the 552 eligible breast cancer survivors invited) completed the study. The participants and non-participants did not differ in terms of age, socioeconomic status, breast cancer grade or time since diagnosis (6). Eighteen participants were missing data on one or more of the variables used in this analysis, leaving 256 participants in the current study. A further 18 participants did not report their current height and/or weight, so the BMI analysis contains only 238 participants. Written informed consent was obtained from all participants, and the study was approved by Human Research Ethics Committees at the WA Department of Health and The University of WA.

### Measures

**Exposures—**The accelerometer data were summarised using 60 second epochs. Commonly applied cutpoints were used to derive daily time spent sedentary [<100 counts per minute (CPM)], in LPA (100–1,951 CPM) and in MVPA ((≥1952 CPM).(14, 15) Time spent sedentary was split into prolonged sedentary time (≥20 minutes, with no allowance for an interruption) and non-prolonged sedentary time, as sedentary bouts of ≥20 minutes have been shown to adversely affect cardio-metabolic biomarkers (16). Non-wear time was defined as intervals of at least 60 consecutive minutes of zero counts (with allowance for ≤2 minutes of observations of <50 CPM). To be considered valid, days of data collection required at least ten hours of wear time and no excessive counts (>20,000 CPM).

Average sleep duration in the last month was assessed using the following question from the Pittsburgh Sleep Questionnaire Index (PSQI): "During the past month, how many hours of actual sleep did you get at night (this may be different than the number of hours you spent in bed)?" (17). The PSQI has acceptable validity and reliability when assessing sleep quality and duration in the general population and in people with cancer (17, 18).

**Outcomes—**Waist circumference was measured (by each participant) using an elastic tape measure. Participants were asked to stretch out the tape measure, wrap it around their (exposed) waist at navel-level, then breathe out and measure (to the nearest 0.1 cm). They were asked to repeat this three times. The average of the three measurements was used in these analyses. Participants were also asked to self-report their current height and weight.

**Covariates—**Breast cancer stage and time since diagnosis were determined from data obtained from the WA Cancer Registry. Information about various demographic, behavioural and medical factors, including highest level of education, current working status, smoking status, comorbidities, breast cancer treatment and hormone therapy use, was obtained via self-report from the participants (6). Area-level socioeconomic status was assessed using the Index of Relative Socio-Economic Disadvantage at the postcode level (19).

## Analysis

All exposure variables in isotemporal models must be in the same metric, so daily time spent sleeping and in prolonged sedentary, non-prolonged sedentary, LPA and MVPA were all converted to units of 30 minutes (e.g., 15 minutes=0.5, 30 minutes=1). We also created a 'total time' variable, which was the sum of these five activities, and converted this to the same 30-minute metric. We chose to use 30-minute units to aid interpretation of the results; as it is assumed the relationship between the exposure variables and the outcomes is linear, the choice of metric does not impact the results. The 30-minute unit variables were used in all analyses.

Three linear regression models were used to estimate the associations of the activity exposures (sleep duration, prolonged sedentary time, non-prolonged sedentary time, LPA and MVPA) with waist circumference and BMI: a single effects model, a partition model, and an isotemporal substitution model. Age, socioeconomic status, comorbidity and smoking status were included as confounders in all models. Education, working status, breast cancer stage at diagnosis, time since diagnosis, breast cancer treatment type, and current hormone therapy use were also considered as potential confounders, but were not included in the final models as their inclusion had minimal effect on the results.

A full description of, and rationale behind, the single effects, partition and isotemporal substitution models have been described by others (20, 21). In brief, the single effects model estimates the association between an individual activity and the outcome, without taking into account the other activities (i.e., they are not included in the model), while in the partition model all the activities are mutually adjusted. The variance inflation factors for each of the exposure variables in the partition models for waist circumference and BMI were less than four, suggesting absence of problematic multicollinearity.

The isotemporal model includes 'total time' and all of the activities, except the activity of interest. The coefficient from the regression analysis in the isotemporal models for each of the included activities is an estimate of the mean effect on the outcome of reallocating 30 minutes of the omitted activity with 30 minutes of each included activity, while holding time spent in the other activities constant. It is important to note that these activity reallocations generate the predicted change in outcome at the population level rather than at the individual level, and that these are cross-sectional associations rather than causal associations of individuals reallocating time between activities.

We also conducted two sensitivity analyses to investigate the issues of non-wear time and the integration of self-reported sleep duration with objectively-measured sedentary and active time. In the first, we limited the isotemporal substitution analyses to only those participants with fewer than 21 hours of 'total time' (i.e., sleep, sedentary and active values that summed to less than 21 hours). Just over one-third of the participants had fewer than 21 hours of 'total time'. In the second sensitivity analysis, we re-ran the original isotemporal substitution analyses with only the accelerometer variables (i.e., dropping the sleep variable).

A two-sided *P*-value of <0.05 was considered statically significant. Stata 14.1 (StataCorp, College Station TX) was used for all analyses.

# RESULTS

## Participants

The participants were between 36 and 84 years of age and were 2.3 to 3.7 years post-diagnosis (Table 1). Three-quarters of the participants had been diagnosed with a Stage I or II breast cancer. Mean waist circumference was 92.2cm, and mean BMI was 26.7 kg/m$^2$. Most participants (86%) had a waist circumference greater than 80cm, indicating an increased risk of metabolic complications (22), and most participants (57.5%) were classified as being overweight or obese based on their BMI.

Prolonged sedentary time was significantly correlated with LPA (Pearson's r= −0.75), non-prolonged sedentary time (−0.29) and MVPA (−0.27), while LPA and MVPA were also significantly correlated (0.24). All other correlations between the different activities were low (between −0.10 and 0.07) and not statistically significant.

## Associations between activity and waist circumference and BMI

MVPA was the only activity significantly associated with waist circumference in the single effects model, with an increase of 30 minutes of MVPA associated with lower waist circumference (2.22cm, 95% CI −4.04cm, −0.40cm) (Table 2). When all activities were mutually adjusted (i.e., the partition model), increasing amounts of sleep, non-prolonged sedentary time and MVPA were significantly associated with lower waist circumference and lower BMI. Removing prolonged sedentary time (which was significantly correlated with LPA, non-prolonged sedentary time and MVPA) from the partition models had minimal effect on the results (data not shown).

In the isotemporal substitution models (Table 3; Figures 1 and 2), reallocating 30 minutes to MVPA was associated with lower waist circumference when allocated from sleep (−2.50cm, 95% CI=−4.45cm, −0.56cm), prolonged sedentary time (−2.51cm, 95% CI=−4.38cm, 0.64cm) or LPA (−2.71cm, 95% CI=−4.72cm, −0.69cm). A similar pattern was observed for BMI, although the only statistically significant difference was for replacing prolonged sedentary time with MVPA (−0.93kg/m$^2$, 95% CI = −1.75kg/m$^2$, −0.10kg/m$^2$). Reallocating 30 minutes of prolonged sedentary time to non-prolonged sedentary time was significantly associated with lower waist circumference (−0.94cm, 95% CI = −1.79cm, −0.10cm) and lower BMI (−0.41kg/m$^2$, 95% CI = −0.79kg/m$^2$, −0.03kg/m$^2$). Interchanging 30 minutes of sleep, prolonged sedentary time or LPA with each other were not significantly associated with waist circumference or BMI differences.

The results observed in both of the sensitivity analyses were similar to those from the original analyses (Supplementary Tables 1 and 2).

## DISCUSSION

In this study we found that reallocating 30 minutes of sleep, prolonged sedentary time or LPA to 30 minutes of MVPA was associated with significantly lower waist circumference and/or body mass index in breast cancer survivors. Reallocating 30 minutes of prolonged sedentary time to 30 minutes of non-prolonged sedentary time was also associated with significantly lower waist circumference and body mass index.

Increasing MVPA was most strongly associated with body composition in this study, which is consistent with randomized controlled trials of physical activity interventions conducted in breast cancer survivors (3, 4) and reinforces the important role that MVPA plays in breast cancer survivorship. Higher levels of MVPA have also been associated with improved prognosis, higher quality of life and lower fatigue (23). We did not observe any evidence that allocating time to sleep from sedentary or active time was associated with lower waist circumference or body mass index in this study. However, we did find that longer sleep duration was associated with lower waist circumference and lower BMI in the partition models. This is consistent with previous research in the general population, which indicates short sleep duration (i.e., fewer than six hours) is associated with higher BMI (24). While previous studies have found that sleep duration and/or sleep quality are associated with health-related quality of life, fatigue, depression and anxiety in breast cancer survivors (10, 25, 26), we are not aware of any previous studies that have investigated the association between sleep duration and body composition in this population.

Longitudinal studies conducted among females in the general population have found that higher levels of sedentary behaviour were associated with higher BMI and/or waist circumference (27, 28), and the only previous (cross-sectional) study to be conducted among breast cancer survivors reported a similar finding, although the association attenuated when adjusted for MVPA (8). Our study provides more context to these findings; in keeping with previous studies conducted in the general population (11, 12, 29–31), we found that the way sedentary time is accumulated may impact its association with body composition. Previous studies in blue collar workers (32, 33), older adults (34) and the general population (35) have all found that spending greater time in shorter bouts of sedentary time is associated with either lower or no change in waist circumference and/or BMI, while also finding that greater time in longer bouts of sedentary time is associated with higher waist circumference and/or

BMI (32–35). Our results are also similar to those observed in a recent study of overweight and obese people with type two diabetes, which found that replacing prolonged sedentary time with an equivalent amount of non-prolonged sedentary time was associated with lower waist circumference and body mass index (36). These results lend some support to the notion that decreasing time spent in prolonged, unbroken sedentary bouts (by taking breaks from prolonged periods of sitting) may be an avenue for improving body composition in clinical populations.

Strengths of this study include objective measurement of sedentary time and physical activity, assessment of the full 24-hour day (i.e., sleep, sedentary and active time), and use of a statistical technique that allowed these activities to be investigated simultaneously. While allocating time to MVPA is likely to be the most potent behaviour for improving a wide range of health outcomes (20), there is clearly a limit to how much time can realistically be spent doing MVPA. It is therefore important to examine the associations between other activities that take up larger portions of the day. The isotemporal methods used in this study allow us to examine these associations, as well as how they may change depending on the activity they replace. However, it has recently been argued that a compositional data analysis approach may be a better than isotemporal methods for understanding the effects of reallocating time between sleep, sedentary and active behaviours (37).

A limitation of this study is the sample size, which may have resulted in low power to detect modest associations. As such, although we did not observe any significant associations for longer sleep duration or higher levels of LPA in the isotemporal models, it is not possible to rule out a beneficial effect for these behaviours. It is also important to note that body composition is just one outcome, and that reallocating time from sitting to sleep and/or LPA has been associated with obesity and metabolic outcomes in the general population (20, 37, 38). Examining the interdependent associations between sleep, sedentary and active behaviours with other metabolic outcomes in breast cancer survivors may be an avenue for future research. Other limitations include the use of self-reported sleep duration, BMI and waist circumference, which may have resulted in some measurement error. Finally, the use of a waist-worn accelerometer means the sedentary time estimates are likely to have included periods of stationary standing, and, as the cut-points used to differentiate MVPA from LPA in this study were calibrated to measure ambulatory activities such as walking and running (14), it is also possible that some less ambulatory moderate-to-vigorous activities were misclassified as LPA.

In conclusion, we found that replacing 30 minutes of prolonged, unbroken sedentary time with 30 minutes of non-prolonged sedentary time or 30 minutes of MVPA was associated with significantly lower waist circumference and body mass index in breast cancer survivors. These results reinforce the important role that MVPA plays in breast cancer survivorship, and provide some evidence that decreasing time spent in prolonged, unbroken sedentary bouts may be an avenue for improving body composition in this population.

## Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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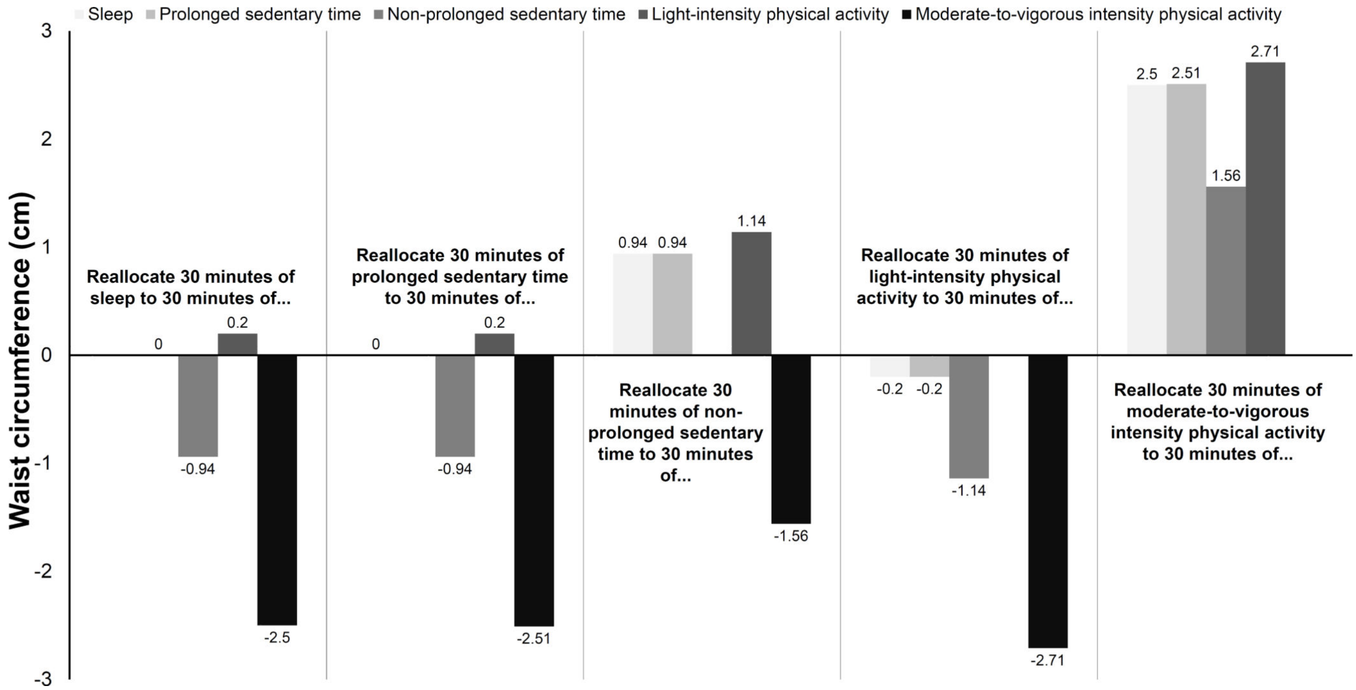


**Figure 1.**

Associations between sleep, prolonged sedentary bouts, non-prolonged sedentary bouts, light-intensity physical activity and moderate-to-vigorous physical activity with waist circumference when reallocating 30 minutes of one activity to 30 minutes of another activity in a sample of breast cancer survivors

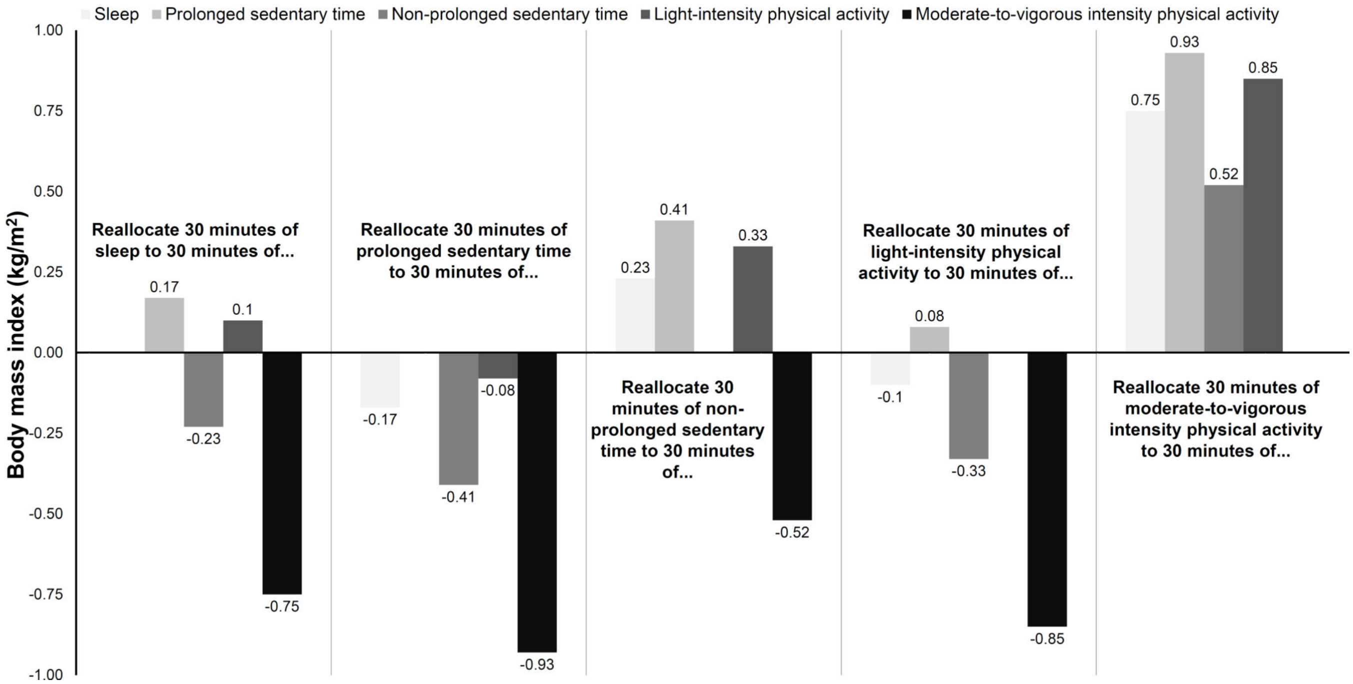


**Figure 2.**

Associations between sleep, prolonged sedentary bouts, non-prolonged sedentary bouts, light-intensity physical activity and moderate-to-vigorous physical activity with body mass index when reallocating 30 minutes of one activity to 30 minutes of another activity in a sample of breast cancer survivors

### Table 1

Demographic, medical and behavioural characteristics of the participants in a study conducted among breast cancer survivors in Western Australia, 2013

| | Participants (n=256) |
|---|---|
| | % |
| Age (mean, SD) | 60.1 years (10.7) |
| Highest level of education | |
| Did not complete high school | 16.4 |
| Completed high school | 22.3 |
| Trade/technical qualification | 34.0 |
| University degree | 27.3 |
| Current working status | |
| Not working | 48.0 |
| Part-time work | 28.5 |
| Full-tine work | 23.4 |
| Socioeconomic status | |
| Group 1 (Lowest socioeconomic status) | 19.9 |
| Group 2 | 27.0 |
| Group 3 | 28.1 |
| Group 4 (Highest socioeconomic status) | 25.0 |
| Time between diagnosis & study participation (mean, SD) | 2.9 years (0.4) |
| Stage of breast cancer at diagnosis | |
| I | 45.7 |
| II | 30.5 |
| III | 6.6 |
| IV | 5.9 |
| Unknown | 11.3 |
| Breast cancer treatment | |
| Surgery only | 19.9 |
| Chemotherapy, no radiotherapy | 14.1 |
| Radiotherapy, no chemotherapy | 30.5 |
| Chemotherapy and radiotherapy | 35.6 |
| Currently receiving hormone therapy | |
| No | 28.5 |
| Yes | 71.5 |
| Comorbidity | |
| None | 54.7 |
| Only high blood pressure &/or high cholesterol | 30.5 |
| Angina, heart attack, stroke &/or diabetes | 14.8 |
| Smoking status at diagnosis | |
| Never | 56.2 |
| Former | 38.7 |

| | Participants (n=256) |
|---|---|
| | % |
| Current | 5.1 |
| Waist circumference (mean, SD) | 92.2 cm (11.6) |
| Waist circumference category (based on WHO cutpoints) | |
| <80cm | 14.1 |
| 80–87.9cm (increased risk of metabolic complications) | 24.2 |
| >88cm (substantially increased risk of metabolic complications) | 61.7 |
| Body mass index (mean, SD)[a] | 26.7 (5.0) |
| Body mass index category (based on WHO cutpoints) | |
| <24.9 kg/m$^2$ (Normal weight) | 42.4 |
| 25–29.9 kg/m$^2$ (Overweight) | 34.0 |
| >30 kg/m$^2$ (Obese) | 23.5 |
| Sleep (daily mean, SD) | 7.0 hours (1.3) |
| Accelerometer wear time (daily mean, SD) | 14.5 hours (1.1) |
| Prolonged sedentary time (daily mean, SD) | 3.1 hours (1.5) |
| Non-prolonged sedentary time (daily mean, SD) | 5.1 hours (1.0) |
| Light-intensity physical activity (daily mean, SD) | 5.8 hours (1.3) |
| Moderate-to-vigorous intensity physical activity (daily mean, SD) | 0.5 hours (0.4) |
| Moderate-to-vigorous intensity physical activity (daily median, IQR) | 0.4 hours (0.2, 0.7) |

Abbreviations: IQR, interquartile range; SD, standard deviation; WHO, World Health Organization

[a]n=238 (18 participants were missing height and/or weight data)

### Table 2

Associations between sleep, prolonged sedentary bouts, non-prolonged sedentary bouts, light-intensity physical activity (LPA) and moderate-to-vigorous intensity (MVPA) and waist circumference and body mass index in a sample of breast cancer survivors

| | Waist Circumference, cm (n=256) | | Body Mass Index, kg/m$^2$ (n=238) | |
|---|---|---|---|---|
| | Model | | Model | |
| | Single-effects | Partition | Single-effects | Partition |
| Behaviour (per 30 minutes/day) | β (95% CI)[a] | β (95% CI)[b] | β (95% CI)[a] | β (95% CI)[b] |
| Sleep | −0.52 (−1.05, 0.01) | −0.60 (−1.12, −0.08) | −0.22 (−0.45, 0.01) | −0.24 (−0.48, −0.01) |
| Prolonged sedentary | 0.19 (−0.29, 0.66) | −0.59 (−1.38, 0.19) | 0.21 (0.00, 0.41) | −0.07 (−0.42, 0.29) |
| Non-prolonged sedentary | −1.12 (−1.80, 0.44) | −1.54 (−2.27, −0.80) | −0.39 (−0.70, −0.09) | −0.47 (−0.80, −0.14) |
| LPA | −0.09 (−0.62, 0.43) | −0.39 (−1.22, 0.43) | −0.17 (−0.40, 0.06) | −0.14 (−0.51, 0.23) |
| MVPA | −2.22 (−4.04, −0.40) | −3.10 (−4.97, −1.23) | −0.85 (−1.65, −0.05) | −0.99 (−1.83, −0.16) |

Abbreviations: CI, confidence interval; LPA, light-intensity physical activity; MVPA, moderate-to-vigorous intensity physical activity

[a]Adjusted for age, socioeconomic status, comorbidity, and smoking status

[b]Adjusted for all variables in Model A and all the other behaviours

**Table 3**

Associations between sleep, prolonged sedentary bouts, non-prolonged sedentary bouts, light-intensity physical activity (LPA) and moderate-to-vigorous physical activity (MVPA) with waist circumference and body mass index when reallocating 30 minutes of one activity to 30 minutes of another activity in a sample of breast cancer survivors

| | | Waist circumference, cm (n=256) | Body mass index, kg/m$^2$ (n=238) |
|---|---|---|---|
| **Reallocate 30 minutes of …** | **to 30 minutes of …** | **β (95% CI)[a]** | **β (95% CI)[a]** |
| Sleep | Prolonged sedentary | 0.00 (−0.85, 0.85) | 0.17 (−0.20, 0.55) |
| | Non-prolonged sedentary | −0.94 (−1.80, −0.08) | −0.23 (−0.62, 0.15) |
| | LPA | 0.20 (−0.68, 1.09) | 0.10 (−0.30, 0.49) |
| | MVPA | −2.50 (−4.45, −0.56) | −0.75 (−1.61, 0.11) |
| Prolonged Sedentary | Non-prolonged sedentary | −0.94 (−1.79, −0.10) | −0.41 (−0.79, −0.03) |
| | LPA | 0.20 (−0.34, 0.74) | −0.08 (−0.32, 0.16) |
| | MVPA | −2.51 (−4.38, −0.64) | −0.93 (−1.75, −0.10) |
| Non-prolonged sedentary | LPA | 1.14 (0.18, 2.10) | 0.33 (−0.10, 0.77) |
| | MVPA | −1.56 (−3.40, 0.27) | −0.52 (−1.34, 0.30) |
| LPA | MVPA | −2.71 (−4.72, −0.69) | −0.85 (−1.75, 0.05) |

Abbreviations: CI, confidence interval; LPA, light-intensity physical activity; MVPA, moderate-to-vigorous intensity physical activity

[a]Adjusted for age, socioeconomic status, comorbidity, and smoking status