Modifications of 24-h movement behaviors to prevent obesity in retirement: A natural experiment using compositional data analysis

Kristin Suorsa (kristin.suorsa@utu.fi)  
University of Turku  
https://orcid.org/0000-0002-3520-8069

nidhi gupta  
Tuija Leskinen  
University of Turku

Lars L. Andersen  
National Research Centre for the Working Environment

Jesse Pasanen  
University of Turku

Pasan Hettiarachchi  
Uppsala University, Uppsala University Hospital

Peter J. Johansson  
Uppsala University, Uppsala University Hospital

Jaana Pentti  
University of Turku

Jussi Vahtera  
University of Turku,  
https://orcid.org/0000-0002-6036-061X

Sari Stenholm  
University of Turku  
https://orcid.org/0000-0001-7560-0930

Article

Keywords: accelerometer, sleep, sedentary time, physical activity, compositional data analysis, body mass index, waist circumference

Posted Date: January 6th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-2439042/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.  
Read Full License
Abstract

Background

Retirement is associated with a more passive lifestyle, and may therefore lead to weight gain. This study aims to investigate longitudinal associations between changes in 24-h movement behaviors and obesity indicators in relation to the transition from work to retirement.

Methods

The study population included 213 retiring public sector workers (mean age 63.5 years, standard deviation 1.1) from the Finnish Retirement and Aging study. Before and after retirement with a 1-year lag, participants wore an Axivity accelerometer on their thigh and filled in a daily log for at least four days to measure daily time spent sleeping, in sedentary behavior (SED), light physical activity (LPA) and moderate-to-vigorous physical activity (MVPA). Also their body mass index (BMI) and waist circumference was measured twice. Compositional linear regression analysis and isotemporal substitution analysis were used to study associations between changes in 24-h movement behaviors and changes in obesity indicators.

Results

An increase in MVPA in relation to sleep, SED and LPA was associated with a decreasing BMI ($\beta=-0.60$, $p=0.04$) and waist circumference ($\beta=-2.14$, $p=0.05$) over one year from before retirement to after retirement. In contrast, increasing sleep in relation to SED, LPA and MVPA was associated with an increasing BMI ($\beta=1.34$, $p=0.02$). Reallocating 60 minutes from MVPA to SED or sleep was estimated to increase BMI by on average 0.8 – 0.9 kg/m$^2$ and waist circumference by 3.0 cm during one year.

Conclusions

In the transition from work to retirement, increase in MVPA and sleep in relation the remaining behaviors were associated with improvement and worsening, respectively, in obesity indicators. Common life-transitions, like retirement, should be taken into account, when giving recommendations and guidance for physically active life style and sleep.

Introduction

Obesity has grown to epidemic proportions worldwide as 39% of the world’s adult population was estimated to be overweight and 13% obese in 2016$^1$. In 2019 the prevalence of overweight among
European adults was estimated to be as high as 53\%\(^2\). Obesity is associated with several adverse health outcomes including higher risk of cardiovascular diseases, type 2 diabetes and mortality\(^1,3\).

One of key factors in obesity prevention is the amount of moderate-to-vigorous physical activity (MVPA)\(^4\). However, time spent in MVPA forms only a small proportion of a 24-h day, while the remaining time is spent in other activities, often referred as 24-h movement behaviors, i.e., sleeping, sedentary behavior (SED) and light physical activity (LPA), which all contribute to daily energy expenditure. Researchers have traditionally studied 24-h movement behaviors in isolation from each other and results suggest that not only MVPA, but also LPA is beneficially associated with obesity indicators\(^5\), while high SED is associated with higher risk of obesity\(^6\). Moreover, short sleep has been consistently associated with obesity\(^7\), and some indications on association between long sleep and obesity have also been reported\(^8\), thus, pointing out to U-shaped association that is often seen with respect to sleep and mortality\(^7,9\). The main limitation in these previous studies is that they have not taken into account the codependency between the behaviors. Movement behaviors are bound to a 24-h day, meaning that increasing time in one behavior inevitably decreases time used in at least one of the remaining behaviors. Recently there has been a shift towards the 24-h time use paradigm, that is, examining all behaviors as relative components of a 24-h day\(^10\)–\(^12\).

Following the 24-h time use paradigm, increasing evidence suggests that from a health perspective, it is relevant to take into account how time is reallocated between 24-h movement behaviors\(^13\). For instance, reallocating time to MVPA may result in different changes in obesity indicators depending on whether time is allocated from sleep or SED. This is because sleep is known to be important for glucose metabolism and hormone levels regulating hunger and appetite\(^14\), while SED is considered as waking behavior characterized by low energy expenditure. While a plausible recommendation in obesity prevention would be to reallocate time from SED but not sleep to MVPA, evidence based on the 24-h time use paradigm is still lacking.

Compositional data analysis (CoDA) is a fairly new and feasible approach to examine relative changes in 24-h movement behaviors and to study health effects of time reallocations between the behaviors\(^11,12\). Previous studies applying CoDA show lower BMI, fat mass and waist circumference in adults who spend more time in MVPA in relation to the remaining behaviors\(^12,15–23\). Moreover, spending more time in LPA in relation to SED/sleep as well as in sleep in relation to SED have been suggested to be associated with lower BMI and waist circumference\(^12,19–21\). However, main limitation in these previous CoDA-based studies is that they are cross-sectional and thus unable to examine how within-individual changes in 24-h movement behaviors associate with concurrent changes in obesity indicators. Only one previous longitudinal study on this topic exists, indicating reallocation of time from SED to MVPA to be associated with decreases in BMI and adiposity (and vice versa) over seven years among older adults\(^23\). However, this study did not include sleep, an important component of a 24-h day. Thus, it is unknown how within-individual changes of all 24-h movement behaviors, including sleep associate with changes in obesity indicators.
The transition to retirement offers a natural experiment setting to examine how changes in 24-h movement behaviors are associated with changes in obesity indicators. Previous studies have shown that transition from work to retirement leads to changes in 24-h movement behaviors\textsuperscript{24–27}, as the proportion of sleep has been observed to increase in relation to physical activity at the population level\textsuperscript{27}. Also the proportion of SED changes, as both increases and decreases in relation to the remaining behaviors have been observed depending on occupation\textsuperscript{27}. Transition to retirement has also been linked to increased BMI\textsuperscript{28,29}, but it is unknown whether BMI changes are associated with changes in 24-h movement behaviors.

To fill the research gaps, we conducted repeated annual accelerometer and clinical measurements in aging employees over their transition from work to retirement. The aim of this study was to examine how within-individual changes in the composition of 24-h movement behaviors are associated with changes in obesity indicators over one year by applying CoDA methodology.

**Methods**

**Study design and participants**

The study population consisted of participants from the Finnish Retirement and Aging Study (FIREA), an ongoing longitudinal cohort study of older adults in Finland established in 2013. Details of the design and implementation of the FIREA study have been reported elsewhere\textsuperscript{30}. Shortly, participants were first contacted 18 months prior to their estimated retirement date by sending them a questionnaire. After responding to the questionnaire, Finnish-speaking participants with estimated retirement date between 2017 and 2019, who lived in Southwest Finland and were still working, were invited to participate in the clinical sub-study (n = 773). Of them, 290 agree to participate. Thereafter study participants have been followed annually with questionnaires, clinical and accelerometer measurements. To determine the timing of retirement, the actual retirement day was inquired during each phase of the data collection.

Flow chart for the selection of the analytical sample is presented in Supplement 1. Of the clinical sub-study participants, 240 participants took part in clinical measurements and successfully used accelerometer before and after the transition to full-time statutory retirement, with one year in between the measurements. We excluded participants who had less than three valid measurement days before and/or after retirement (n = 27), leaving 213 participants to the analytical sample.

**Assessment of 24-h movement behaviors**

A triaxial accelerometer Axivity AX3 (Axivity Ltd Newcastle, UK) accompanied with a daily log was used to estimate 24-h movement behaviors, that is, sleep, SED, LPA and MVPA before and after retirement. Detailed description of the measurement protocol is reported elsewhere\textsuperscript{31}. Shortly, a study nurse fastened the accelerometer with adhesive waterproof film dressing to the skin on the right thigh, into a standardized position\textsuperscript{32}. Before retirement participants were asked to wear the accelerometer at least four
days and nights, including at least two workdays and two days off and after retirement at least four days and nights. Moreover, participants were instructed to wear the devices at all times 24 h/day, including water-based activities such as swimming, but to remove them for sauna bathing. Participants were also asked record date, waking time, bedtime, reference measurement times and information about workday on a daily log for each day that they wore the devices.

Data from the accelerometers were downloaded through Open Movement software (version 1.0.0.37; Open Movement, Newcastle University, UK). The raw data were further processed and analyzed using a customized MATLAB program, ActiPASS (version 0.80)\textsuperscript{33}, an automatized version of Acti4\textsuperscript{32,34}, which determines the type and duration of different activities and body postures with a high sensitivity and specificity\textsuperscript{32,34}. The detailed data analysis procedures in the ActiPASS software are described elsewhere\textsuperscript{32,33}. We restricted the measurement period to days between the first and last date and time recorded in the daily log. Non-wear time was detected using algorithm in the ActiPASS software (\(\geq 60\) min periods without movement)\textsuperscript{32}. The measurement day was determined from midnight to midnight and a valid measurement day was defined as a day with at least 10 hours of wear time during waking hours and daily log-determined waking and bed times. Sleep was estimated based on the bedtimes and waking times recorded in the daily log. Sitting and lying time were merged into SED. Standing, moving and slow walking, with a cadence less than 100 steps/min were merged into LPA. Finally, walking fast with a cadence 100 steps/min or more\textsuperscript{35}, stair walking, running, cycling and other physical activity were merged into MVPA. All 24-h movement behavior components were averaged across all valid days.

**Assessment of obesity indicators**

During the two clinical visits, a study nurse measured participants’ height and weight with a wall-mounted stadiometer and a bioimpedance scale (Inbody 720, Biospace Co., Seoul, Korea) with the participants wearing only light clothing. BMI was calculated as weight in kg / (height in m)\(^2\). Waist circumference was measured to the nearest 0.1 cm directly on the participant’s skin, in the midpoint of the lowest rib and the iliac crest, during light exhalation in upright position. The measurement was repeated twice, and the mean value was used in the analysis.

**Assessment of pre-retirement characteristics**

Sex, date of birth, and pre-retirement occupational title were obtained from the Keva Public Sector Pensions register. Participants were divided into two occupational status groups according to the occupational titles of the last known occupation preceding retirement by using the International Standard Classification of Occupations (ISCO)\textsuperscript{36}: manual workers (e.g. cleaners, maintenance workers; ISCO classes 5 – 9) and non-manual workers (e.g. teachers, physicians, registered nurses, technicians; ISCO classes 1 – 4).

Other health-related characteristics were obtained from the questionnaire preceding the transition to retirement: smoking (no/yes), self-reported doctor-diagnosed chronic diseases (angina pectoris, myocardial infarction, cerebrovascular disease, claudication, osteoarthritis, osteoporosis, sciatica,
fibromyalgia, rheumatoid arthritis, and diabetes) (no/yes, one or more), mobility limitations as difficulties in walking 2.0 kilometers (no/yes)\textsuperscript{37,38}, sleep duration (hours per night)\textsuperscript{39}, sitting time (sum of daily hours spent sitting at work, watching television, using computer at home, sitting in a vehicle and other sitting)\textsuperscript{30} and non-occupational physical activity as metabolic equivalents (MET) hours per week\textsuperscript{4}.

**Statistical analyses**

Descriptive information on participant characteristics is presented using means and standard deviations for continuous variables and frequencies and percentages for categorical variables. To examine selection to the current study, the pre-retirement participant characteristics were compared between the current study population (n = 213) and survey-only study population (n = 3698) using Chi squared test for categorical variables and ANOVA for continuous variables.

In the statistical analysis the proportion of time spent in each behavior was treated as compositional data. The analyses were conducted in the statistical software RStudio (version 4.0.5). The data set did not include zero values for MVPA, thus no imputation was needed.

**Compositional data analysis**

The compositional means were calculated to describe the average 24-h movement behaviors. To illustrate the heterogeneity in changes in 24-h movement behavior composition over one year, the compositional differences between pre- and post-retirement compositions were calculated for each participant following the principles reported elsewhere\textsuperscript{27,40}. The resulting composition of the compositional differences was visualized as ternary plots.

An isometric logratio (ilr) transformation was used to map the compositional data into real-valued coordinates, which reduces the dimensionality of the data and allows standard statistical methods to be used\textsuperscript{41}. We used pivot coordinates, the specific type of ilr coordinates, that are a set of ilrs where the first coordinate enables one part of the composition (for instance sleep) to be considered relative to the remaining parts of the composition (that is, SED, LPA and MVPA). We created four sets of pivot coordinates to enable each behavior to be considered relative to the remaining behaviors.

We used linear regression model to examine associations between changes in 24-h movement behaviors and changes in obesity indicators during the transition to retirement. The model included change in obesity indicator as the outcome variable, and changes in 24-h movement behaviors (expressed as ilrs) as the explanatory variables. Covariates included before retirement 24-h movement behavior composition (expressed as ilrs), BMI/waist circumference before retirement, age, sex and occupational status. The model was repeated for each set of pivot coordinates. The associations were presented as beta coefficients and their standard errors.

To illustrate the effect of observed reallocations between 24-h movement behaviors on obesity indicators the compositional isotemporal substitution model was used\textsuperscript{42}. The previously described linear regression
model was used for this purpose. The compositional mean of 24-h movement behaviors before retirement and after retirement was used as the baseline and follow-up measurements respectively. From baseline to follow-up compositional means, systematic reallocations between movement behaviors were estimated to reflect the “measured changes” in the composition. The sizes of one-to-one reallocations were 10, 30 and 60 minutes for reallocation between MVPA and one of the remaining behaviors (sleep/SED/LPA) while for reallocations between sleep, SED and LPA the size of one-to-one reallocations was up to 120 minutes. We chose these sizes of reallocations based on the actual measured range of change from baseline to follow-up in 24-h movement behaviors. Thereafter, each reallocated composition was transformed to ilrs and a difference between ilrs for each reallocated composition and baseline composition was calculated. After that, the regression based coefficients were applied on the calculated difference in ilrs to predict changes in obesity indicator corresponding to changes in composition of movement behaviors during transition from work to retirement. The model-estimated standard error of the change in obesity indicators was used to derive 95% confidence intervals (CI) for the estimated change in obesity indicators.

Furthermore, given that associations between changes in 24-h movement behaviors and obesity indicators may differ depending on whether sleep is increased from insufficient level or sufficient level\cite{7,8}, we conducted sensitivity analysis by excluding those reporting sleeping more than 9 hours per night before retirement (n = 26, 12%).

**Results**

Characteristics of the study population are presented in Table 1. Majority of the study population were women (82%) and non-manual workers (69%). Before retirement, the mean BMI was 26.3 kg/m$^2$ (SD 4.8) and the mean waist circumference was 91.4 cm (SD 13.0) (women 89.5 cm (SD 12.8); men 100.0 cm (SD 10.7)). Participants spent on average 8.3 hours sleeping, 9.7 h sedentary, 4.7 h in LPA and 77 min in MVPA per day before retirement.
Table 1
Characteristics of the study population (n = 213) before and after retirement.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Before retirement</th>
<th>After retirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD)</td>
<td>63.5 (1.1)</td>
<td>64.6 (1.2)</td>
</tr>
<tr>
<td>Women, n (%)</td>
<td>175 (82)</td>
<td></td>
</tr>
<tr>
<td>Occupational group, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manual</td>
<td>67 (31)</td>
<td></td>
</tr>
<tr>
<td>Non-manual</td>
<td>146 (69)</td>
<td></td>
</tr>
<tr>
<td>Body Mass Index, mean (SD), kg/m²</td>
<td>26.3 (4.8)</td>
<td>26.2 (4.8)</td>
</tr>
<tr>
<td>BMI = Body mass index, IQR = interquartile range</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal weight (&lt; 25 kg/m²)a</td>
<td>85 (40)</td>
<td>87 (41)</td>
</tr>
<tr>
<td>Overweight (25 – 29.9 kg/m²)</td>
<td>92 (43)</td>
<td>93 (44)</td>
</tr>
<tr>
<td>Obese (≥ 30 kg/m²)</td>
<td>36 (17)</td>
<td>33 (15)</td>
</tr>
<tr>
<td>Waist circumference, mean (SD), cm</td>
<td>91.4 (13.0)</td>
<td>90.5 (13.3)</td>
</tr>
<tr>
<td>Number of valid measurement days (range)</td>
<td>4.6 (3 – 10)</td>
<td>4.6 (3 – 7)</td>
</tr>
<tr>
<td>Number of daily log-determined nights (range)</td>
<td>3.1 (1 – 8)</td>
<td>3.2 (2 – 6)</td>
</tr>
<tr>
<td>Wear time during waking hours, h (IQR)</td>
<td>15.5 (15.0 – 16.1)</td>
<td>15.2 (14.6 – 15.7)</td>
</tr>
<tr>
<td>Compositional mean of sleep, SED, LPA and MVPA, min</td>
<td>497, 584, 282, 77</td>
<td>520, 572, 272, 76</td>
</tr>
</tbody>
</table>

Among the current study population smoking was less common (4% vs. 9%), and mobility limitations were rarer (8% vs. 14%) compared to the survey-only study population. Moreover, the current study population had lower self-reported BMI (26.0 vs. 26.8 kg/m²) and higher self-reported non-occupational physical activity (26.9 vs. 23.4 MET-hours/week) (Supplement 2).

Changes in the 24-h movement behavior composition after the retirement transition are illustrated in Fig. 1. As seen in ternary plots B and C, the proportion of sleep increased for the majority of the participants in relation to LPA and MVPA. However, overall there was relatively high variation in the observed proportional changes. Especially proportional changes in MVPA differed; some participants increased the proportion of MVPA markedly in relation to SED and sleep, whereas others reduced the proportion of MVPA markedly in relation SED and sleep (Fig. 1, plot D).
Table 2 presents the longitudinal associations between the one-year changes in 24-h movement behaviors and the changes in obesity indicators from work to retirement. Increasing MVPA in relation to the remaining behaviors was associated with decreasing BMI ($\beta_{ilr} = -0.60$, $p = 0.04$) and waist circumference ($\beta_{ilr} = -2.14$, $p = 0.05$). Increasing LPA in relation to the remaining behaviors also tended to decrease BMI ($\beta_{ilr} = -0.66$, $p = 0.06$) and waist circumference ($\beta_{ilr} = -1.76$, $p = 0.17$). Increasing sleep was associated with increase in BMI ($\beta_{ilr} = 1.34$, $p = 0.02$), but no statistically significant association with waist circumference was observed ($\beta_{ilr} = 1.51$, $p = 0.48$). Increasing SED in relation to the remaining behaviors was not associated with changes in BMI ($\beta_{ilr} = -0.09$, $p = 0.85$), but a tendency towards increasing waist circumference was observed ($\beta_{ilr} = 2.39$, $p = 0.15$). When long sleepers (over 9 hours) were excluded, associations between increasing sleep and obesity indicators attenuated, whereas association between increasing SED and increasing waist circumference became statistically significant (Supplement 3).

<table>
<thead>
<tr>
<th>Body Mass Index (kg/m$^2$)</th>
<th>Waist circumference (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\beta_{ilr}$ (SE)</td>
</tr>
<tr>
<td>Sleep vs remaining, difference</td>
<td>1.34 (0.57)</td>
</tr>
<tr>
<td>SED vs remaining, difference</td>
<td>-0.09 (0.44)</td>
</tr>
<tr>
<td>LPA vs remaining, difference</td>
<td>-0.66 (0.34)</td>
</tr>
<tr>
<td>MVPA vs remaining, difference</td>
<td>-0.60 (0.28)</td>
</tr>
</tbody>
</table>

Adjusted for baseline body mass index (BMI)/waist circumference, baseline 24-h movement behavior composition, age, sex and occupation.

Figure 2 and Supplement 4 show how the one-to-one reallocations between MVPA and sleep, MVPA and SED, MVPA and LPA associated with the changes in BMI and waist circumference. Reallocation of time from MVPA to sleep and from MVPA to SED increased obesity indicators in a relatively similar manner: BMI by $+0.78 - 0.91$ kg/m$^2$ and waist circumference by $+3.0$ cm with a 60-min reallocation, by $+0.25 - 0.32$ kg/m$^2$ and $+1.0$ cm with a 30-min reallocation, and by $+0.07 - 0.09$ kg/m$^2$ and $+0.3$ cm with a 10-min reallocation. Reallocation of time from MVPA to LPA was also associated with increased obesity indicators, but to a smaller extent (Supplement 4). Overall, the effects of increasing MVPA were smaller compared with the effects of decreasing MVPA (Fig. 2). Also, reallocating time between sleep, SED and LPA were associated with markedly smaller changes in obesity indicators than those between MVPA and sleep, SED and LPA (Supplement 5). For instance, a 90-min increase in LPA at the cost of SED was needed to observe similar changes in obesity indicators when compared to increasing 30 min of MVPA at the cost of SED.
Discussion

This natural experiment study, over the one year when transitioning from work to retirement, showed that increasing MVPA in relation to the remaining 24-h movement behaviors was associated with decreasing BMI and waist circumference, while increasing sleep was associated with increasing BMI. Thus, changes in MVPA and sleep had contrasting effects on obesity indicators, which is important and novel knowledge in relation to public health recommendations for people transitioning into retirement.

Our findings support the well-known health benefits of MVPA in preventing obesity\textsuperscript{4}. However, the novelty of our study is that we were able to show how the change in obesity indicators depended on by which of the 24-h movement behaviors MVPA replaced or was replaced with. We observed that the beneficial effect of increasing MVPA did not markedly differ when MVPA replaced sleep or SED, but slightly smaller benefits were observed when MVPA replaced LPA. Given that MVPA is located at the high end of the energy expenditure continuum\textsuperscript{43}, replacing behaviors located at the low end of the continuum (sleep, SED) with MVPA increases the overall energy expenditure. This may lead to weight loss and decrease in body fat if the energy intake remains constant. In line with previous studies\textsuperscript{23,44,45}, the effect of decreasing MVPA was larger compared with the effect of increasing MVPA, highlighting the importance of maintaining MVPA levels when retiring to prevent weight gain and central obesity.

Epidemiological evidence suggests the U-shaped curve between sleep duration and health, i.e., that it is detrimental to sleep too little but also too much\textsuperscript{7–9}. Our study complements the knowledge by showing that with respect to BMI and waist circumference, increasing sleep at the cost of physical activity was harmful. This may be explained by decreased energy expenditure. Unfortunately, these findings concern a majority of the retirees, as sleep is shown to increase after retirement\textsuperscript{25,27,39}, e.g., in our study population by 23 minutes and the increase in sleep mainly contributes to decreasing LPA and MVPA among retirees\textsuperscript{27}. However, associations between changes in sleep in relation to the remaining 24-h movement behaviors and obesity indicators may depend on the baseline sleep duration levels. For example, increasing sleep duration from insufficient level generally improves cardiometabolic health and reduces adiposity\textsuperscript{46–48}. In the current study, majority of the study participants had recommended level (7 – 9 h per nigh)\textsuperscript{49} of sleep already before the retirement transition and it is therefore possible that an increase of sleep time from already sufficient level only decreased overall energy expenditure without adding any benefits for metabolism that are reported for sufficient sleep\textsuperscript{14,50}. Given that our study sample included very few individuals with short (14%) or long (12%) sleep, future studies with larger proportion of short and long sleepers are needed to elucidate how the baseline sleep duration affects these associations.

Previous cross-sectional studies have shown beneficial associations when more time is spent in sleep in relation SED\textsuperscript{19–21}. In our study, we did not observe notable benefits in terms of obesity indicators when SED was replaced with sleep. Both sleep and SED have very low energy expenditure, which may explain why reallocations between them did not change obesity indicators notably. Moreover, it should be noted that given that sleep time was based on self-reported waking and bedtimes, we cannot be sure of how
much of the increased sleep time is actual sleep and how much of it is consisted of lying in bed awake i.e., sedentary time. Thus, the possible beneficial effects of sleep may be slightly underestimated when using self-reported sleep time.

Our findings give indications of how retirees should spend their time in 24-h movement behaviors to prevent weight gain and central obesity. Given that the detrimental effect of decreasing MVPA was larger compared with beneficial effect of increasing MVPA, we conclude that maintaining MVPA levels after retirement is important. This may also be a more feasible goal than aiming to increase MVPA levels, because the pre-retirement MVPA levels may be relatively high (in this study ≈ 80 min/day). Moreover, a large proportion of pre-retirement daily physical activity comes from worktime physical activity and active commuting which may be difficult to compensate after retirement. We observed some benefits of replacing SED with LPA, but compared to that of MVPA a threefold increase in LPA was needed to gain approximately same amount of reduction in obesity indicators. Our findings also suggest that increasing sleep when retiring may not be as detrimental for health in terms of obesity, if it does not decrease daily total physical activity. However, because studies are showing the opposite, compensation of the removed physical activities due to retirement can be achieved by engaging in regular leisure time MVPA such as organized activities, brisk walking and cycling, but also in active lifestyle throughout the day for instance by breaking up sedentary time at home, doing heavy household chores and walking short distances instead of driving by car.

We observed associations between changes in 24-h movement behaviors and obesity indicators over one-year follow-up, but larger effects could be expected with longer follow-up periods. For instance, in our study reallocating 30 min from MVPA to SED was estimated to increase BMI by 0.25 kg/m², whereas in the 7-year follow-up study among Central European older women (mean baseline age 63.9) the effect on BMI was estimated to be 0.75 kg/m². However, it should be noted that sleep was not included in the estimations of that study, and thus the effect of MVPA may be overestimated. Therefore, future studies covering changes in all 24-h movement behaviors over longer follow-up periods are needed.

The most important strengths of this study are a longitudinal study design, which decreases the risk of self-selection and the effect of time-invariant confounders. Using repeated accelerometer-based measurements of 24-h movement behaviors instead of self-reports, the risk of recall and information bias is removed. We used posture-based identification of SED, LPA and MVPA with ActiPASS (Acti4) which has shown to identify postures and physical activities with high sensitivity (80%) and specificity (> 90%) during semi-standardized and free-living conditions. In addition, we used appropriate statistical methods to examine changes and reallocations between codependent components of a 24-h day.

Our study naturally has some limitations. We examined concurrent short-term changes in 24-h movement behaviors and obesity indicators, thus we were unable to show the direction of causation. Our study sample was relatively small, which increases the risk of type II errors (failure to identify significant effect that actually exists). We did not have information on changes in body composition, which could also
have changed due to reallocation of the movement behaviors. Moreover, we were unable to separate contexts of physical activity (for instance physically strenuous work tasks, strength training). These aspects may be relevant, because removal of physically strenuous work tasks may reduce muscle mass and body weight, whereas opposite changes may occur if strength training increases after retirement. In addition to changes in movement behaviors, there may also be other factors affecting changes in obesity indicators that we did not measure, such as energy intake. Previous studies have reported for example decreasing consumption of vegetables and increasing consumption of fruits after retirement. Aging is associated with loss of muscle mass and increase in total body fat, but age-related changes unlikely affected our results notably due to the short follow-up period. Sleep estimates were based on self-reported measures which reflect time in bed rather than actual sleep time. However, there were no marked differences in sleep estimates between participant log used in the current study and accelerometer-based sleep detection methods, which are considered as more reliable methods to estimate sleep in field-based studies. Finally, given that the current study population was generally leaner, healthier and more active compared with the survey-only study participants, the generalizability of the findings may be limited.

In conclusion, increasing MVPA in relation to sleep, SED and LPA over one year during transition from work to retirement was associated with beneficial changes in BMI and waist circumference, whereas increasing sleep was associated with detrimental changes in these obesity indicators. Future studies are needed to elucidate the long-term effects of changes in 24-h movement behaviors on BMI, waist circumference and body composition.

Declarations

Acknowledgements

The authors want to thank the FIREA participants for their willingness to participate in the study and the FIREA study staff members for their contribution in the data collection.

Author Contributions

SS designed this study and the data collection. PH guided the accelerometer data processing. KS conducted the statistical analyses with the help of NG, JP and JP. KS drafted the manuscript. All authors contributed to data interpretation, revised article critically, and approved the final version of manuscript.

Competing Interests

Authors declare no competing financial interests in relation to the current work.

Funding

This study was supported by funding granted by the Academy of Finland (286294, 319246, 294154, 332030 to SS), Finnish Ministry of Education and Culture (to SS); Juho Vainio Foundation (to SS and KS), and Hospital District of Southwest Finland (to SS and KS). The development of the data processing tool
for this study was partly funded by FORTE, Swedish Research Council for Health, Working Life and Welfare (2021–01561) to Magnus Svartengren, Occupational and Environmental Medicine Uppsala University, Uppsala, Sweden, and the Swedish state under the agreement between the Swedish government and the county councils, the ALF-agreement (1040232).

Data Availability

Anonymised partial datasets of the FIREA study are available by application with bona fide researchers with an established scientific record and bona fide organisations. In case of data requests, please contact the principal investigator Sari Stenholm, sari.stenholm@utu.fi.

Ethical statement

Informed consent was obtained from all participants. The FIREA was conducted in line with the Declaration of Helsinki and was approved by the Ethics Committee of Hospital District of Southwest Finland.

References


**Figures**
Figure 1

Ternary plots illustrating the changes in the compositions of 24-h movement behaviors between before and after retirement in the three-dimensional sub-compositions (A, B, C, and D). Observations (colored areas) indicate the change in the proportions between 24-h movement behaviors after the transition to retirement. Black dot indicates the center of the ternary plot that is, no change in the proportions between 24-h movement behaviors. The light-dark turquoise contour plot indicates the occurrence of
compositional differences in the study population, with the density of the light to dark turquoise color representing the number of individuals; lighter turquoise indicating low density and darker turquoise higher density. MVPA=moderate-to-vigorous physical activity, LPA=light physical activity, SED=sedentary time.

Figure 2
One-to-one reallocations between MVPA and sleep, MVPA and SED, MVPA and LPA and changes in BMI and waist circumference over one-year from work to retirement.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplement1.docx
- Supplement2.docx
- Supplement3.docx
- Supplement4.docx
- Supplement5.docx