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24-Hour Movement and Nonmovement Behaviors in Older Adults. The IMPACT65+ Study

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24-Hour Movement and Nonmovement Behaviors in Older Adults. The IMPACT65+ Study

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Abstract

Introduction. The aims of this study were: (i) to provide a detailed description of movement and non-movement behaviors objectively-assessed over the complete 24-hour period in a sample of older adults, and (ii) to analyze differences in these behaviors by sex, age, educational level, body mass index, self-rated health, and chronic conditions.

Methods. The sample comprised 607 high-functioning community-dwelling older adults (383 women), aged 65 to 92 years, who participated in the IMPACT65+ study. Movement and non-movement behaviors were assessed by the Intelligent Device for Energy Expenditure and Activity, which provide estimates on both temporal and spatial gait parameters, and identify specific functional activities on the basis of acceleration and position information.

Results. The final sample with valid data was 432 older adults (284 women). Around 30.7% of daily time was engaged in sedentary behavior (SB), while 33.5% and 35.8% was represented by physical activity (PA) and sleep, respectively. Sitting passive was the most prevalent SB (vs. lying and reclining), while most of light PA was by standing (vs. active sitting and walking at <2.5 mph). Time spent walking at ≥ 2.5 mph was the major contributor to moderate-to-vigorous PA. No differences were found in sleep time by socio-demographic or health-related characteristics, but there were relevant differences in sedentary and PA behaviors.

Conclusion. This study offers a detailed description of the distribution of SB, PA and sleep in elderly across the 24-hour spectrum. The results could be used to focus the strategies aimed to improve health in the old age.

Keywords: sitting; lying; standing; walking; sleep; IDEEA.

Introduction

Increasing life expectancy has resulted in a demographic shift in which older adults account for a significantly large portion of the overall population. The risk of morbidity and disability increases with age, which provides a challenge for health and social care resources (1). Thus, the need to monitor and promote the lifestyle behaviors that can prolong independence and reduce the harmful impact of aging on health systems and older people's quality of life has been encouraged (2). Sedentary behavior (SB), physical activity (PA) and sleep duration seems to be key behaviors for these purposes, since they have demonstrated strong relevance for the primary and secondary prevention of chronic diseases in the old age (3–5).

The SB Research Network (SBRN) orchestrated an exhaustive effort to provide a conceptual model of movement and non-movement behaviors arranged around a 24-hour period (6). This model represents the main behavior categories (i.e., SB, PA and sleep) organized based on body posture (i.e., sitting, reclining, lying, standing and others). However, no study has provided real data based on the conceptualization suggested by the SBRN, since it is difficult to assess body postures and movements over a 24-hour period. Technological advances in the last decades have provided objective methods to assess movement behaviors in free-living conditions (7). Activity monitors offer non-invasive, cost-effective, and reliable measures of movement patterns, and it overcomes many of the limitations of self-reported measurements (8). Nevertheless, most of activity monitor-based studies have limitations by quantifying the main behaviors without postural allocation considerations, and by including only the measurement to waking periods since, until recently, monitors were usually removed during sleep (9, 10).

In contrast to standard monitors, the Intelligent Device for Energy Expenditure and Activity (IDEEA) multi-sensor activity monitor provides estimates on both temporal and spatial gait parameters and identifies specific functional activities on the basis of acceleration and position information (11). These characteristics turn the IDEEA into a unique tool to objectively describe daily movement and non-movement behaviors, and to provide a real representation to the conceptual model proposed by the SBNR. Therefore, the aim of this study was to provide a description of movement and non-movement behaviors objectively assessed by the IDEEA over the complete 24-hour period in a sample of older adults. In addition, we aimed to analyze differences in these behaviors by sex, age, educational level, body mass index (BMI) status, self-rated health, and chronic conditions.

Methods

Participants

The study sample consists of 607 high-functioning community-dwelling older adults (383 women), aged 65 to 92 years, participating in the IMPACT65+ (Objectively assessed physical activity and its impact on frailty, quality of life and health in population aged 65 and older) study. The IMPACT65+ study aims to examine the association of objectively-measured PA with frailty, health-related quality of life and other health indicators in Spanish people aged 65 and older. Data from this study were collected from April 2015 to June 2017. The study has been approved by the Ethics Committee of the Autonomous University of Madrid (Madrid, Spain). Prior to data collection, all participants were informed of the nature of the study, and participants provided written informed consents.

The IDEEA pattern-recognition activity monitor

24-hour movement and non-movement behaviors were assessed by the IDEEA® (version 3, Minisun, Fresno, CA). This is a microcomputer-based measurement system formed by a small data recorder device (dimensions: $70 \times 44 \times 18$ mm; weight: 59 g; capacity: 200 MB) connected with five sensors (dimensions: $16 \times 14 \times 4$ mm; weight: 2 g) which are biaxial accelerometers detecting angular acceleration and displacement in two orthogonal planes. Acceleration and position information obtained from the five sensors is integrated in the microprocessor within the recorder device. The IDEEA has shown high levels of accuracy for estimating temporal and spatial gait parameters, energy expenditure, and functional activities in different populations, including older adults (11, 12).

Procedures

Participants were asked to wear the IDEEA for two consecutive days, without removing it at any time. Since the device is not waterproof, participants were instructed to not perform water activities nor take showers while carrying the monitor. The equipment was positioned by trained researchers locating the main-recorder device on waist; the five sensors were adhered with a medical tape to specific body locations. Three sensors, connected to the main-recorder device by wires, were attached to the anterior sternum (i.e., just below the sternal angle), and the anterior side of each thigh (i.e., midpoint between anterior superior iliac spine and knee joint). Moreover, two sensors were placed on the plantar surface under each foot (i.e., under the foot arch); these sensors are connected by wires to two sub-recorders located on the lateral side of the each ankle which, in turn, are wirelessly connected to the main-recorder device. Chest and thigh sensors were vertically oriented (i.e., z-axis) while foot sensors were oriented in an anteroposterior direction (i.e., y-axis). Finally, a baseline calibration was performed following

the manufacturer's instructions. In brief, each participant was asked to sit in a chair in an upright position with the feet flat on the floor, the thighs parallel to the ground, and the upper body in a vertical position. The calibration process was repeated until the correct position for calibration was confirmed by the IDEEA software allowing a maximal deviation of 15 degrees in each direction. After monitoring for a maximum of 2 days (owing to battery life restrictions), data were downloaded at 32 Hz using the IDEEA software.

Data processing

The IDEEA is able to accurately evaluate more than 40 activity types (11). For this study, all activities were merged into the following categories: lying, reclining, passive sitting, active sitting, standing, walking, and other activities (see Table, Supplemental Digital Content 1, Classification of IDEEA activity types into categories, <http://links.lww.com/MSS/B439>). Moreover, walking was divided into two categories according to the 2.5 mph cut-point, which identifies light (<2.5 mph) and moderate-to-vigorous (≥ 2.5 mph) intensities (13).

Prior to analyses, the sleep period for each participant and day was identified by a validated automated algorithm developed by the research team using Visual Basic for Applications (14). This algorithm (algorithm #7) has demonstrated a high accuracy to detect sleep period time compared with self-report (95.3%) and expert visual analysis of raw data (97.7%) (14). An additional visual inspection of files was carried out when the sleep time was lower than 6 hours or higher than 12 hours. Once the sleep period was identified, sleep time was determined as the time while lying, reclining or sitting during the sleep period, whereas the active time after sleep onset (i.e., standing, walking, and other activities) was added to the waking period.

We considered a participant as valid for analyses when having ≥ 1 days with, at least, 10 hours of waking time, and with the sleep period detected. The time spent in each movement and non-movement behavior was calculated as the mean of time during the valid periods.

Socio-demographic and health-related characteristics

Information on sex and age was collected. Two age groups were created according to the median of the sample (≤ 70 years and > 70 years). Participants reported their educational level which was classified into low (i.e. illiterate or primary studies [basic school education]) and high (i.e. secondary studies [high school education], medium university studies or vocational training, or higher university studies). Height and weight were measured following standardized procedures (15). BMI was calculated as weight (kg) divided by squared height (m^2), and obesity was defined as $\text{BMI} \geq 30 \text{ kg/m}^2$ (15). Self-rated health was assessed with the following standardized question: “In general, would you say your health is?” (16). Responses were grouped into optimal (i.e., excellent, very good, or good) and suboptimal (i.e., fair or poor). Finally, information on the following chronic conditions diagnosed by a physician and reported by the participants was also recorded: coronary heart disease, stroke, rheumatism, hip fracture, cancer at any site, Parkinson disease, and dementia/Alzheimer. Responses were categorized into two groups: having or not having chronic conditions.

Statistical analyses

All analyses were performed using SPSS Statistics 21.0 for Windows (IBM, Armonk, New York), with level of significance defined as $p < 0.05$. Descriptive characteristics of the study sample are presented as means or percentages. Differences in movement and non-movement behaviors between groups of sex, age, educational level, BMI, self-rated health, and chronic conditions were examined by analysis of covariance controlling for wearing time. Benjamini-

Hochberg method based on false discovery rate was applied for multiple testing correction (17). As well, differences of percentage of participants meeting PA (i.e. ≥ 30 minutes of moderate-to-vigorous PA [MVPA] considering the mean of the valid days) (18) and sleep recommendations (i.e. 7.00-8.99 hours considering the mean of the valid days) (19) were assessed using logistic regression controlling for wearing time. Since no specific guidelines delimiting the amount of sedentary time in elderly have been provided, we were not able to analyze this issue.

Results

Figure 1 shows the flow chart of the final sample selection process. From the 607 older adults who participated in the IMPACT65+ study wearing the IDEEA, 65 files were excluded during the download process: 36 files were not available for download and 29 downloaded files were corrupt. Next, 96 files were removed based on the preliminary analyses of data: we identified 72 files in which one or more sensors recorded incomplete data, 16 files in which steps difference between right and left foot was $>20\%$, 4 files which contained one or more bouts longer than 12 hours, and 4 files with artificial data. Of the remaining 446 files, 14 did not meet the inclusion criteria for the wake ($n=7$) or sleep period ($n=7$), and hence, the final sample of study was established in 432 participants. Participants in the final sample were more likely to be women than participants in the initial sample ($p=0.034$), but no differences were found in terms of age, educational level, BMI, self-rated health or chronic conditions (all $p>0.3$).

Descriptive characteristics of the study sample are shown in Table 1. Figure 2 shows the percentage of time spent on average in each movement and non-movement behavior in the 24-hour period in the final sample. Around 30.7% (7.1 h) of daily time was engaged in SB, while 33.5% (7.8 h) and 35.8% (8.3 h) was represented by PA and sleep, respectively. Passive sitting was the most prevalent SB representing the 22.1% (5.1 h) of daily time. SB at lie and recline

position symbolized 3.5% (0.8 h) and 5.1% (1.2 h) of daily time, respectively. Most of PA was performed at light PA that accounted for 31.5% (7.3 h) of daily time, so that 2.6% (0.6 h), 21.9% (5.1 h) and 7.1% (1.6 h) of daily time was spent in active sitting, standing and walking at <2.5 mph, respectively. Around 2.0% (0.5 h) of the daily time was invested in MVPA, with 1.6% (0.4 h) spent in walking at ≥ 2.5 mph and 0.4% (0.1 h) spent in other activities. Most of sleep time was performed at lie position (24.5%, 5.7 h), whereas sleeping at recline and sit positions was 0.8% (0.2 h) and 10.4% (2.4 h), respectively.

Differences in movement and non-movement behaviors by sex, age, educational level, BMI, self-rated health and chronic conditions are presented in Table 2. No differences for awake or sleep time were found among groups (all $p > 0.05$). Mainly, men showed more total SB and MVPA than women, while women accumulated more total light PA than men (all $p < 0.001$). Participants aged > 70 years accumulated more total SB ($p = 0.030$) but less time in MVPA ($p < 0.001$) than younger participants. Participants with low educational level engaged in more total light PA ($p = 0.033$) but less total MVPA ($p < 0.001$) than participants with high educational level. Total time in SB ($p < 0.001$) was higher within obese participants, but MVPA duration ($p < 0.001$) was longer within non-obese participants. Participants who rated an optimal health showed more total time in MVPA ($p < 0.001$) than participants who rated a sub-optimal health. Finally, subjects with none chronic conditions accumulated more total time in MVPA ($p = 0.002$) than subjects with one or more chronic conditions. Several differences in individual behaviors were also found among groups (Table 2).

Overall, 31.2% of the participants accomplished PA recommendations. PA recommendations were met by a greater proportion of men (vs. women), participants aged ≤ 70 years (vs. > 70 years), subjects with a high educational level (vs. low educational level), non-

obese participants (vs. obese participants), subjects with optimal self-rated health (vs. suboptimal self-rated health), and participants with none chronic conditions (vs. one or more chronic conditions) (all $p < 0.05$) (Figure 3). Moreover, 54.3% of the participants fulfilled the current sleep time recommendations for older adults; no differences were detected in compliance with sleep recommendations by socio-demographic or health-related characteristics (all $p > 0.05$).

Discussion

The aim of this study was to provide a detailed description of movement and non-movement behaviors objectively-measured by the IDEEA over the complete 24-hour period in a sample of older adults, as well as, to identify the differences by age, sex, educational level, BMI status, self-rated health and chronic conditions. Overall, SB occupied 30.7% of daily time, while 33.5% and 35.8% was engaged in PA and sleep, respectively. No differences in sleep time were found, but time spent in SB, light PA and MVPA varied by socio-demographic and health-related characteristics. To our knowledge, this is first study to examine objectively-measured movement and non-movement behaviors classified by combining body posture and activity type over a 24-hour period in older adults.

The mean daily sedentary time in our sample is lower than has been found previously in older adults using activity monitors (7, 20, 21). On average, our participants spent 7.1 hours/day in SB, being passive sitting the most prevalent SB (5.1 hours/day). A recent review by Harvey et al. (21) found that objectively-measured SB in older adults (mean=72 years) ranged from 8.5 to 10.7 hours per waking day in studies using ActiGraph ($n=10$) or Actical ($n=1$) accelerometers. This difference may be because the quantification of SB varies between devices. While the IDEEA has demonstrated a high accuracy detecting sedentary (i.e., sit, lie and recline) and stand positions (11), SB could be misclassified by devices based on energy expenditure in combination

with specific cut-off points (e.g. hip- or wrist-worn accelerometers) since standing is difficult to distinguish from sitting when performed below the sedentary cut-off point (7). Koster et al. (22) evaluated the accuracy of ActiGraph accelerometers to define SB considering as the reference criteria the sum of the minutes where the participant was classified as sitting or lying by a device able to assess body posture (i.e. ActivPAL); they concluded that using the standard cut-off point to identify SB in ActiGraph devices (i.e., <100 cpm) results in an overestimation of sedentary time by almost two hours compared to activPAL (22).

Light PA is the most common intensity category for the physical activities in which older adults engage (7, 23, 24). Evidence suggest that older adults may prefer low intensity rather than high-intensity physical activities (24). This is supported by our results, since light PA (i.e., active sitting, standing, and walking at <2.5 mph) accounted for more than 90% of total PA. These findings are comparable to those found among older adults in Norway (25), Iceland (23) and China (26) where most of PA was accumulated at light intensities. Specifically, standing was the most prevalent light PA in our study occupying around five hours per day. This finding is in close agreement with the study from Fitzsimons et al. (27) showing a high prevalence of standing assessed by activPAL (i.e., more than four hours per day) among community-dwelling older adults in Scotland. In contrast, a review by Chan et al. (20) found lower mean hours spent in a standing position by older people using activPAL (ranged from 0.8 to 3.4 hours). However, direct comparison could be somewhat problematic, due to most of studies included in this review enrolled older adults with diseases or activity limitations while our sample is characterized by high-functioning community-dwelling older adults.

On average, the time spent in MVPA in our sample was 27.5 min/day. Prevalence of MVPA among older people varies considerably between studies. In a similar population study (≥ 65 years) in Norway (28) and China (26), accelerometer-derived MVPA was 34.1 (using ActiGraph) and 37.8 min/day (using Active style Pro), respectively. However, lower values (ranged 5 to 29 min/day) were found in studies using ActiGraph in samples of older people from Iceland (73-98 years) (23), United Kingdom (≥ 70 years) (29), Sweden and USA (60-75 years) (30). The use of different devices and processing criteria obviously result in severe differences in MVPA estimates. Evenson et al. (31) analyzed ActiGraph-derived data from 2630 adults aged 60 or older using different cut-points to define MVPA, and observed that MVPA ranged from 10.8 to 106.8 min/day depending on the different cut-points used. In another way, comparisons are hampered by the different study population characteristics of studies (e.g., age). Davis and Fox (32) found lower mean values of ActiGraph-derived MVPA in a sample of older people (≥ 70 years) from UK, France and Italy than ours; however, our finding also found practically identical estimation of MVPA in participants 70 years or older (i.e. 19.9 vs. 19.7 min/day).

A relevant aspect of daily time use among older adults is sleep, since it is also one of the most important determinants of health (5, 33). The overall average of sleep time in our study was 8.3 h/day. Former studies using actigraphy in older adults aged ≥ 62 years have reported means of sleep time lower than 7 h/day (34, 35). Nonetheless, a recent research utilizing Actiwatch for sleep measurements in older adults (73-91 years) from Iceland, found a sleep time closer to ours (7.9 h/day) (36). Varying methods across studies could explain discrepancies between studies (5). Moreover, the higher sleep time detected in our study might be connected to cultural differences. Adjei and Brand (33) analyzed pooled data from the Multinational Time Use Study on more than 35,000 elderly men and women from Germany, Italy, Spain, UK, France,

Netherlands and USA, and observed that older people in Spain and France self-reported the highest time of sleep hours (around 10 h/day), while the average sleep time in the other countries was one hour less.

In the present study, no differences were detected in sleep time or in the compliance of sleep recommendations based on socio-demographic or health-related characteristics, suggesting that these factors could be more strongly associated to sleep efficacy rather to sleep time (35). However, time spent in SB, light PA and MVPA significantly varied between groups. In concordance with former research using activity monitors (23, 31), women accumulated less time in SB but more time in light PA compared with men. Inequalities in the distribution of housework activities may explain the sex differences; although time dedicated to house tasks among men has increased over last years, elderly women devote more time on housework activities such as washing clothes, cooking, cleaning house or gardening than men (33). By contrast, a higher percentage of men (45.3%) than women (23.9%) met the PA recommendations. Most research in older adults showed higher levels of objectively-measured MVPA among men than women (29, 31, 37, 38), but two studies found that women were more active than men in terms of time spent in MVPA (26, 39). Moreover, older participants (>70 years) accumulated more time in SB and were less likely to meet the PA recommendations compared to their younger counterparts (≤ 70 years) which is in accordance with literature indicating that PA declines while increasing age (23, 25, 29, 39). A review by Notthoff et al. (40) pointed out that the association between educational level and PA could depend on the specific PA domain. Our results support this hypothesis since participants with a high educational level were more likely to accomplish PA guidelines, but they enrolled in less light PA than participants with low educational level.

Similar to previous research (23, 26, 29, 39), we found that non-obese participants accumulated less MVPA and engaged in more SB than non-obese participants. The descriptive design of our study does not allow us to discern the direction of these potential relationships. However, Van der Berget et al. (41) observed a temporal relationship between obesity during midlife and objectively-measured SB in old age. Similarly, Ekelund et al. (42) reported that BMI in middle age healthy adults predicted sedentary time at a five year follow up. This suggests that obesity could be a determinant rather a consequence of increased sedentary time in adults and older people (43). Lastly, suffering chronic conditions and rating suboptimal health have been previously related with lower PA levels (38, 40), which concurs with the present study. Collectively, our results suggest opportunities for focused intervention, targeting specifically in those with higher age and BMI, as well as those suffering from deteriorate health.

This study has several strengths. It is the first study providing a detailed description of daily activities in older adults over the 24-hour period, considering body posture and activity type. Thus, the conceptual model proposed by the SBNR (6) is represented with real data for the first time. Moreover, the use of the IDEEA allowed us to accurately classify standing as non-SB, and to distinguish between different activity types (e.g. active sitting and passive sitting). However, this study is not exempt of limitations. The IDEEA was worn only during 48 hours, so it is possible that variability in behaviors was not completely assessed. The analysis of gait and activities parameters produces hundreds millions of data points (i.e., 21 data points/row * 32 rows/second * 86,400 seconds/day * 2 days = 116,121,600 data points), so that storage (around 1000MB) and battery life restrictions does not allow using the IDEEA for longer periods. In any case, a study analyzing how many days are enough to reliably assess activity patterns in older people through hip accelerometers showed that 2 day averages were highly correlated with 7

days averages for all accelerometry measures ($r=0.90-0.93$) (44). Similarly, it has been estimated that 1.2 to 2.6 days of measurement are sufficient to achieve $ICC \geq 0.70$ for most of behaviors assessed by the IDEEA device (45). Otherwise, we used an algorithm to define sleep time based of variations on activity type, speed, intensity and gait curves throughout the day. This algorithm has been previously validated in contrast to self-reported measures and expert visual analysis of raw data (14), but the accuracy of sleep detection of the algorithm was not contrasted to polysomnography. It is possible that the algorithm overestimated sleep time in participants who have difficulty falling asleep after going to bed. Moreover, walking was classified into light PA or MVPA according to the compendium of PA; but walking at less than 2.5 mph may involve a moderate or vigorous effort for some older people. Finally, the sample used in this study was not representative which limits the generalizability of results across the population.

This study provided a detailed description of movement and non-movement behaviors in older people assessed by the IDEEA, which is able to distinguish several body postures and activity types. Several differences were found in SB, light PA and MVPA by socio-demographic and health-related characteristics. This better understanding of the distribution of activity across the 24-hour time spectrum might guide more effective public health recommendations or interventions in the old age. Specifically, high-functioning community-dwelling older adults should be encouraged to maintain a high level of light PA, in order to reduce the time spent in SB as suggested recently (46, 47); but, at the same time, advices should be provided for older people to perform MVPA which could produce more significant improvements in their health and quality of life. In addition, health-improvement interventions should consider all movement and non-movement behaviors in the 24-hour period, since changes in one specific behavior, by definition, would displace other behaviors.

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Conflict of interest

Each author declared no competing interest. The results of the present study do not constitute endorsement by ACSM. The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

References

1. Bähler C, Huber CA, Brüngger B, Reich O. Multimorbidity, health care utilization and costs in an elderly community-dwelling population: A claims data based observational study. *BMC Health Services Research*. 2015;15:23.
2. Dogra S, Ashe MC, Biddle SJH, et al. Sedentary time in older men and women: an international consensus statement and research priorities. *British Journal of Sports Medicine*. 2017;51(21):1526–32.
3. Wirth K, Klenk J, Brefka S, et al. Biomarkers associated with sedentary behaviour in older adults: A systematic review. *Ageing Research Reviews*. 2017;35:87–111.
4. Bauman A, Merom D, Bull FC, Buchner DM, Fiatarone Singh MA. Updating the Evidence for Physical Activity: Summative Reviews of the Epidemiological Evidence, Prevalence, and Interventions to Promote “active Aging.” *Gerontologist*. 2016;56:S268–80.
5. Devore EE, Grodstein F, Schernhammer ES. Sleep duration in relation to cognitive function among older adults: A systematic review of observational studies. *Neuroepidemiology*. 2016;46(1):57–78.
6. Tremblay MS, Aubert S, Barnes JD, et al. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. *The International Journal of Behavioral Nutrition and Physical Activity*. 2017;14(1):75.
7. Wullems JA, Verschueren SMP, Degens H, Morse CI, Onambélé GL. A review of the assessment and prevalence of sedentarism in older adults, its physiology/health impact and non-exercise mobility counter-measures. *Biogerontology*. 2016;17(3):547–65.
8. Taraldsen K, Chastin SFMM, Riphagen II, Vereijken B, Helbostad JL. Physical activity

- monitoring by use of accelerometer-based body-worn sensors in older adults: A systematic literature review of current knowledge and applications. *Maturitas*. 2012;71(1):13–9.
9. Lee I-M, Shiroma EJ. Using accelerometers to measure physical activity in large-scale epidemiological studies: issues and challenges. *British Journal of Sports Medicine*. 2014;48(3):197–201.
 10. Schrack JA, Cooper R, Koster A, et al. Assessing Daily Physical Activity in Older Adults: Unraveling the Complexity of Monitors, Measures, and Methods. *The journals of gerontology Series A, Biological sciences and medical sciences*. 2016;71(8):1039–48.
 11. Zhang K, Werner P, Sun M, Pi-Sunyer FX, Boozer CNCN, Pi-Sunyer FX. Measurement of human daily physical activity. *Obesity research*. 2003;11(1):33–40.
 12. Marsh AP, Vance RM, Frederick TL, Hesselmann SA, Rejeski WJ. Objective assessment of activity in older adults at risk for mobility disability. *Medicine and Science in Sports and Exercise*. 2007;39(6):1020–6.
 13. Ainsworth BE, Haskell WL, Herrmann SD, et al. 2011 compendium of physical activities: A second update of codes and MET values. *Medicine and Science in Sports and Exercise*. 2011;43(8):1575–81.
 14. Cabanas-Sanchez V, Higuera-Fresnillo S, De La Camara MÁ, Veiga OL, Martinez-Gomez D. Automated algorithms for detecting sleep period time using a multi-sensor pattern-recognition activity monitor from 24-h free-living data in older adults. *Physiological measurement*. 2018;39(5):055002.
 15. Gutiérrez-Fisac JL, López E, Banegas JR, Graciani A, Rodríguez-Artalejo F. Prevalence of overweight and obesity in elderly people in Spain. *Obesity Research*. 2004;12(4):710–

- 5.
16. Ware JJ, Sherbourne C. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. *Medical Care*. 1992;30(6):473–83.
 17. Benjamini Y, Hochberg Y. Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing. *Journal of the Royal Statistical Society Series B (Methodological)*. 1995;57:289–300.
 18. Nelson ME, Rejeski WJ, Blair SN, et al. Physical activity and public health in older adults: Recommendation from the American College of Sports Medicine and the American Heart Association. *Medicine and Science in Sports and Exercise*. 2007;39(8):1435–45.
 19. Hirshkowitz M, Whiton K, Albert SM, et al. National Sleep Foundation’s updated sleep duration recommendations: Final report. *Sleep Health*. 2015;1(4):233–43.
 20. Chan CS, Slaughter SE, Jones CA, Ickert C, Wagg AS. Measuring Activity Performance of Older Adults Using the activPAL: A Rapid Review. *Healthcare*. 2017;5(4):E94.
 21. Harvey JA, Chastin SFM, Skelton DA. How sedentary are older people? A systematic review of the amount of sedentary behavior. *Journal of Aging and Physical Activity*. 2015;23(3):471–87.
 22. Koster A, Shiroma EJ, Caserotti P, et al. Comparison of Sedentary Estimates between activPAL and Hip- and Wrist-Worn ActiGraph. *Medicine and Science in Sports and Exercise*. 2016;48(8):1514–22.
 23. Arnardottir NY, Koster A, Domelen D Van, et al. Objective measurements of daily physical activity patterns and sedentary behaviour in older adults: Age, Gene/Environment Susceptibility-Reykjavik Study. *Age and Ageing*. 2013;42(2):222–9.

24. Amireault S, Baier JM, Spencer JR. Physical Activity Preferences among Older Adults: A Systematic Review. *Journal of Aging and Physical Activity*. 2017;1–38.
25. Lohne-Seiler H, Hansen BH, Kolle E, Anderssen SA. Accelerometer-determined physical activity and self-reported health in a population of older adults (65-85 years): A cross-sectional study. *BMC Public Health*. 2014;14:284.
26. Chen T, Narazaki K, Honda T, et al. Tri-axial accelerometer-determined daily physical activity and sedentary behavior of suburban community-dwelling older Japanese adults. *Journal of Sports Science and Medicine*. 2015;14(3):507–14.
27. Fitzsimons CF, Kirk A, Baker G, Michie F, Kane C, Mutrie N. Using an individualised consultation and activPALTM feedback to reduce sedentary time in older Scottish adults: Results of a feasibility and pilot study. *Preventive Medicine*. 2013;57(5):718–20.
28. Hansen BH, Kolle E, Dyrstad SM, Holme I, Anderssen SA. Accelerometer-determined physical activity in adults and older people. *Medicine and science in sports and exercise*. 2012;44(2):266–72.
29. Davis MG, Fox KR, Hillsdon M, Sharp DJ, Coulson JC, Thompson JL. Objectively measured physical activity in a diverse sample of older urban UK adults. *Medicine and Science in Sports and Exercise*. 2011;43(4):647–54.
30. Hagströmer M, Troiano RP, Sjöström M, Berrigan D. Levels and patterns of objectively assessed physical activity-a comparison between Sweden and the United States. *American Journal of Epidemiology*. 2010;171(10):1055–64.
31. Evenson K, Buchner D, Morland K. Objective Measurement of Physical Activity and Sedentary Behavior Among US Adults Aged 60 Years or Older. *Preventing Chronic Disease*. 2012;9:E26.

32. Davis MG, Fox KR. Physical activity patterns assessed by accelerometry in older people. *European Journal of Applied Physiology*. 2007;100(5):581–9.
33. Adjei NK, Brand T. Investigating the associations between productive housework activities, sleep hours and self-reported health among elderly men and women in western industrialised countries. *BMC Public Health*. 2018;18:110.
34. Lambiase MJ, Gabriel KP, Kuller LH, Matthews K a. Sleep and Executive Function in Older Women: The Moderating Effect of Physical Activity. *The journals of gerontology Series A, Biological sciences and medical sciences*. 2014;69(9):1170–6.
35. Blackwell T, Yaffe K, Laffan A, et al. Associations of Objectively and Subjectively Measured Sleep Quality with Subsequent Cognitive Decline in Older Community-Dwelling Men: The MrOS Sleep Study. *Sleep*. 2014;37(4):655–63.
36. Brychta RJ, Arnardottir NY, Johannsson E, et al. Influence of day length and physical activity on sleep patterns in older icelandic men and women. *Journal of Clinical Sleep Medicine*. 2016;12(2):203–13.
37. Doherty A, Jackson D, Hammerla N, et al. Large scale population assessment of physical activity using wrist worn accelerometers: The UK biobank study. *PLoS ONE*. 2017;12(2):e0169649.
38. Ramires VV, Wehrmeister FC, Böhm AW, et al. Physical activity levels objectively measured among older adults: a population-based study in a Southern city of Brazil. *The international journal of behavioral nutrition and physical activity*. 2017;14(1):13.
39. Koolhaas CM, van Rooij FJA, Schoufour JD, et al. Objective Measures of Activity in the Elderly: Distribution and Associations With Demographic and Health Factors. *Journal of the American Medical Directors Association*. 2017;18(10):838–47.

40. Notthoff N, Reisch P, Gerstorf D. Individual Characteristics and Physical Activity in Older Adults: A Systematic Review. *Gerontology*. 2017;63(5):443–59.
41. Van Der Berg JD, Bosma H, Caserotti P, et al. Midlife determinants associated with sedentary behavior in old age. *Medicine and Science in Sports and Exercise*. 2014;46(7):1359–65.
42. Ekelund U, Brage S, Besson H, Sharp S, Wareham NJ. Time spent being sedentary and weight gain in healthy adults: Reverse or bidirectional causality? *American Journal of Clinical Nutrition*. 2008;88(3):612–7.
43. Chastin SFM, Buck C, Freiburger E, et al. Systematic literature review of determinants of sedentary behaviour in older adults: A DEDIPAC study. *International Journal of Behavioral Nutrition and Physical Activity*. 2015;12:127.
44. Kocherginsky M, Huisinigh-Scheetz M, Dale W, Lauderdale DS, Waite L. Measuring Physical Activity with Hip Accelerometry among U.S. Older Adults: How Many Days Are Enough? *PloS one*. 2017;12(1):e0170082.
45. de la Cámara MÁ, Higuera-Fresnillo S, Martinez-Gomez D, Veiga OL. Inter-day Reliability of the IDEEA Activity Monitor for Measuring Movement and Non-Movement Behaviors in Older Adults. *Journal of Aging and Physical Activity*. 2018;29:1–33.
46. Sparling PB, Howard BJ, Dunstan DW, Owen N. Recommendations for physical activity in older adults. *BMJ (Clinical research ed)*. 2015;350:h100.
47. Gardner B, Smith L, Lorencatto F, Hamer M, Biddle SJ. How to reduce sitting time? A review of behaviour change strategies used in sedentary behaviour reduction interventions among adults. *Health Psychology Review*. 2016;10(1):89–112.

FIGURE LEGENDS

Figure 1. Flow chart of the final sample selection process in the IMPACT65+ study.

Abbreviations: IDEEA, Intelligent Device for Energy Expenditure and Activity.

Figure 2. Graphic representation of 24-hour movement and non-movement behaviors of the sample (n=432). The figure shows for each behavior the percentage of day time (%) and the average time (h/day). Active sitting only includes movements with lower body extremities. Other activities include up and down stairs, running, and jumping. Abbreviations: MVPA, Moderate-to-Vigorous Physical Activity; h, hours; mph, miles per hour. *MVPA: 2.0% (0.5 h).

Figure 3. Percentage of participants meeting physical activity recommendations according to sex, age, educational level, body mass index status, self-rated health, and chronic conditions. Differences between groups were adjusted for wearing time.

Supplemental Digital Content

Table—Classification of IDEEA activity types into categories

Figure 1

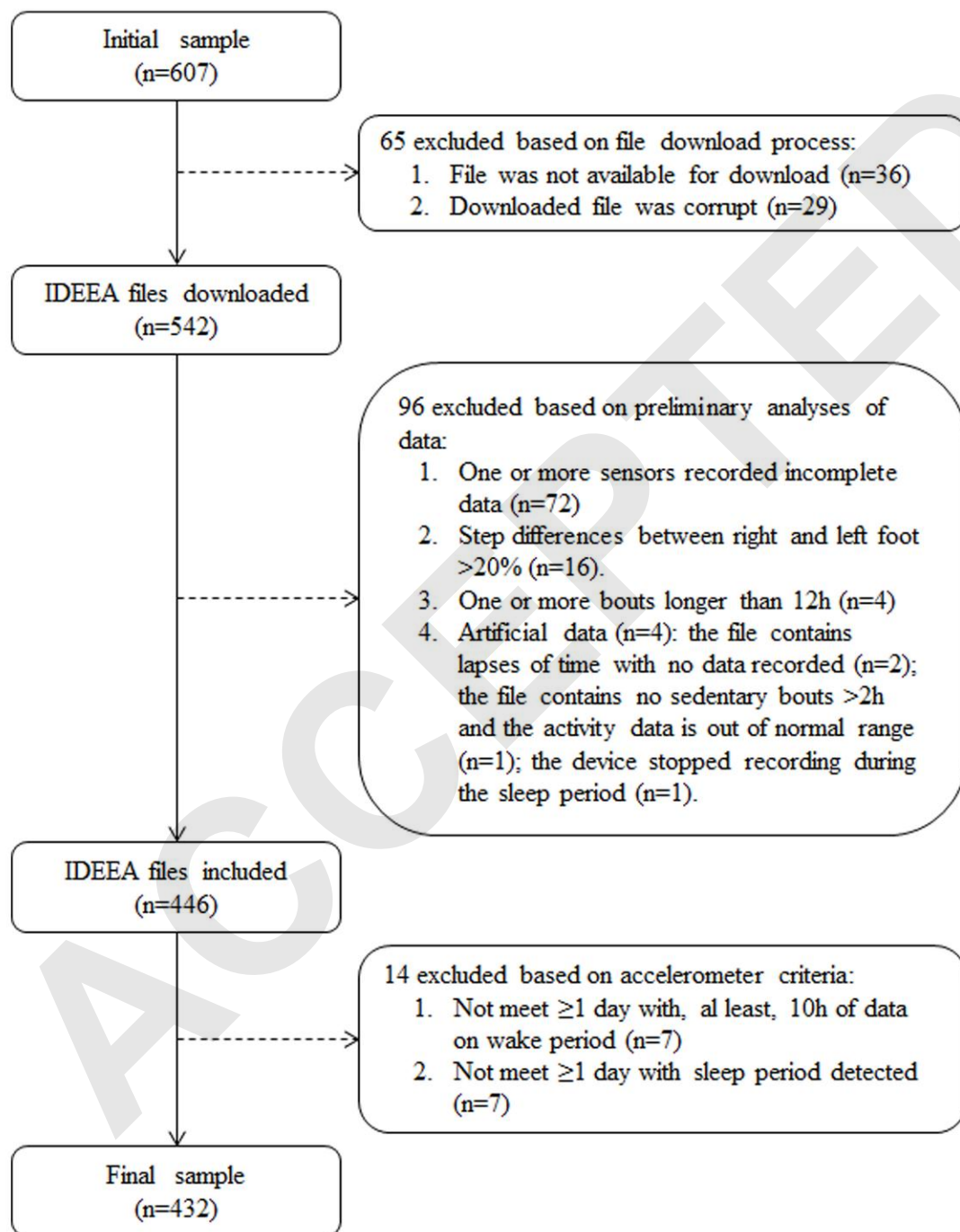


Figure 2

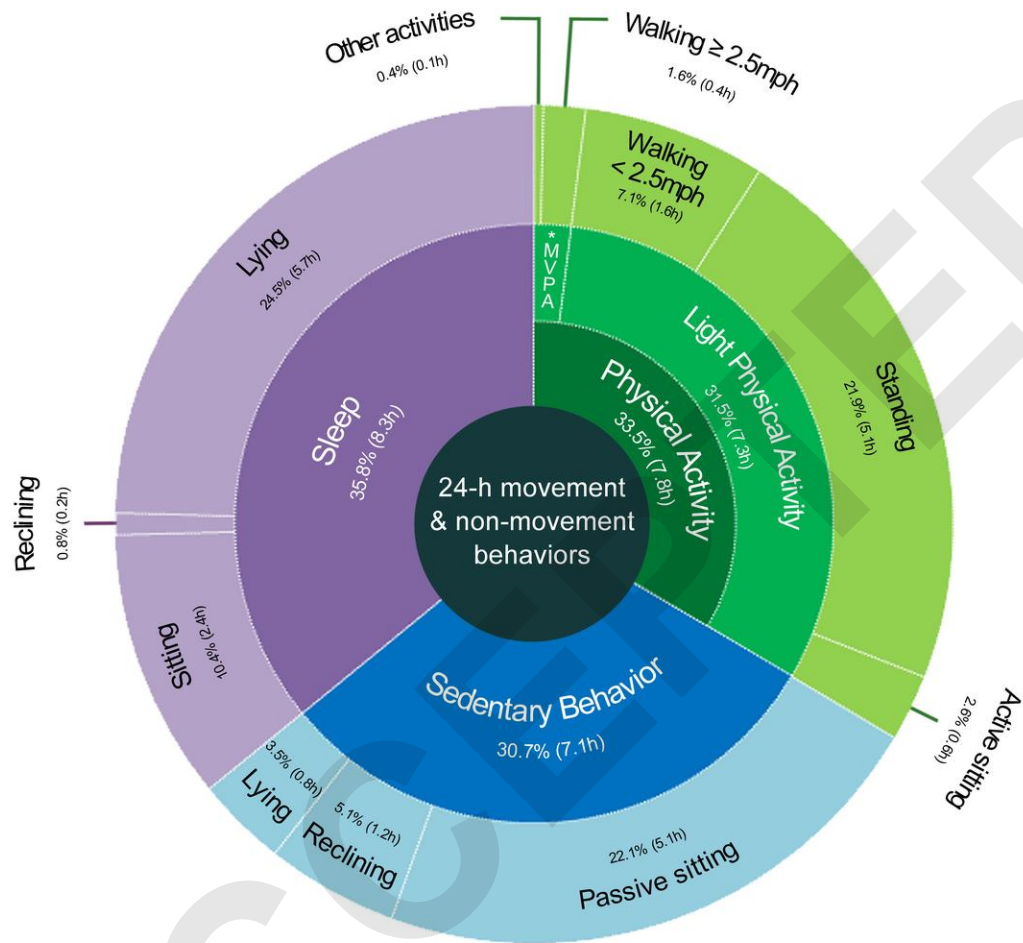


Figure 3

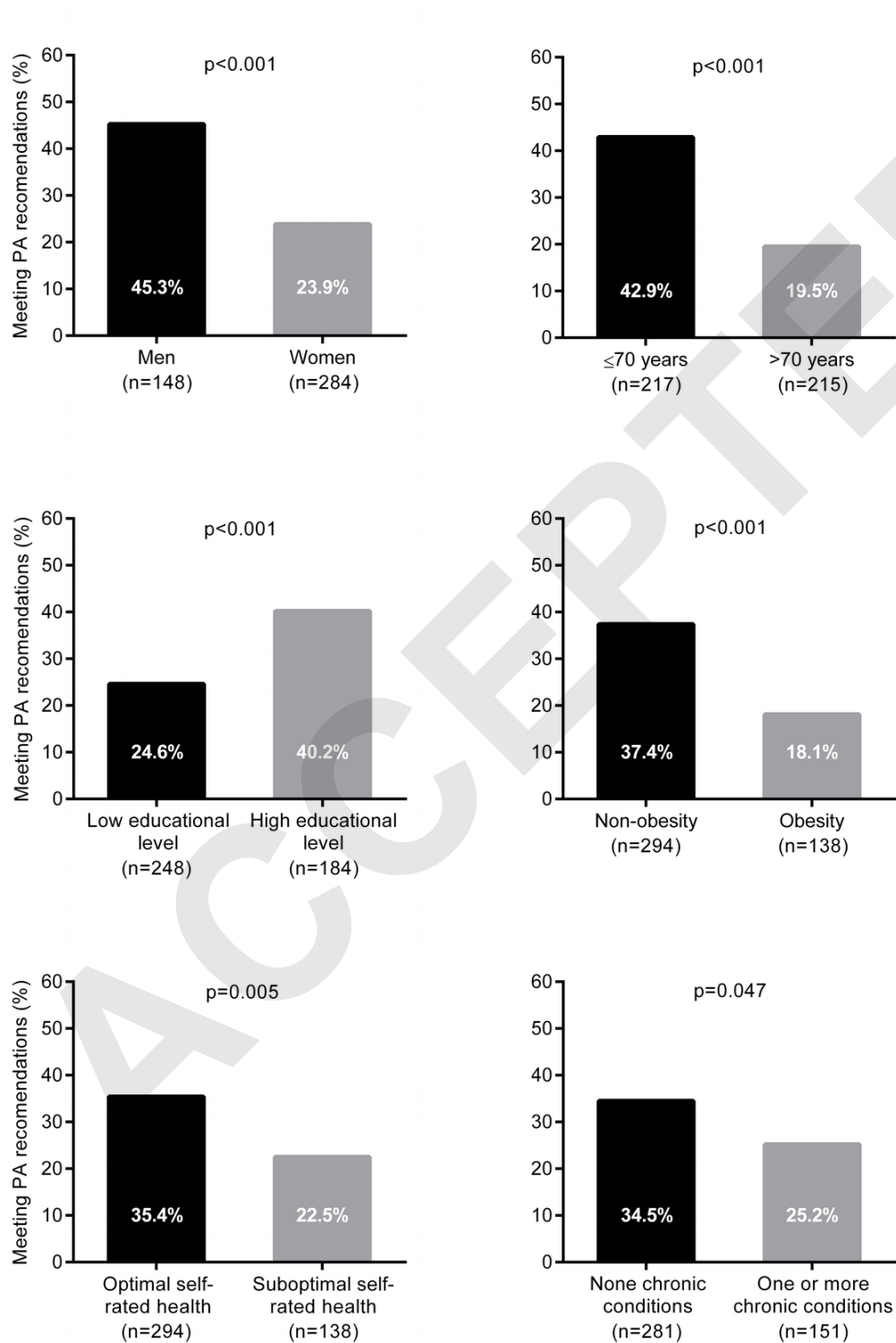


Table 1. Descriptive characteristics of study sample

Participants, n	432
Men, n (%)	148 (34.3)
Age, years (SD)	71.69 (5.28)
Educational level, n (%)	
Illiterate	17 (3.9)
Primary studies	231 (53.5)
Secondary studies	61 (14.1)
Medium university studies/ vocational training	54 (12.5)
Higher university studies	69 (16.0)
Weight, kg (SD)	71.27 (12.88)
Height, cm (SD)	157.29 (8.87)
Body mass index, kg*m ⁻² (SD)	28.78 (4.54)
Self-rated health, n (%)	
Bad	23 (5.3)
Regular	115 (26.6)
Good	241 (55.8)
Very good	45 (10.4)
Excellent	8 (1.9)
Chronic conditions, n (%)	
Coronary heart disease	19 (4.4)
Stroke	18 (4.2)
Rheumatism	77 (17.8)
Cancer	47 (10.9)
Hip fracture	12 (2.8)
Parkinson	6 (1.4)
Dementia/Alzheimer	8 (1.9)

Values are mean (SD) or number of participants (percentage).

Table 2. Differences in movement and non-movement behaviors by sex, age, educational level, body mass index, self-rated health and chronic conditions.

	Sex		Age		Educational level		Body mass index		Self-rated health		Chronic conditions	
	Men	Women	≤70 years	>70 years	Low	High	Non-obesity	Obesity	Optimal	Sub-optimal	None	One or more
n	148	284	217	215	248	184	294	138	294	138	281	151
AWAKE TIME	911.61 (99.87)	888.18 (109.19)	892.85 (105.17)	899.60 (108.07)	898.87 (102.21)	892.62 (112.33)	897.52 (106.76)	893.41 (106.46)	892.99 (106.51)	903.08 (106.72)	894.61 (100.69)	899.19 (116.97)
SB	468.1 (102.32)	408.08 (97.26)***	419.04 (103.72)	438.33 (101.45)*	423.08 (101.44)	436.14 (104.72)	418.32 (100.22)	450.63 (105.51)***	426.03 (99.61)	434.21 (109.84)	426.07 (106.40)	433.43 (96.30)
Lying	49.07 (58.98)	49.00 (53.53)	52.68 (55.59)	45.33 (55.07)	51.52 (53.91)	45.67 (57.30)	42.54 (53.10)	62.84 (57.78)***	46.33 (51.77)	54.77 (62.22)	47.25 (55.21)	52.32 (55.76)
Reclining	54.98 (59.42)	80.11 (79.19)**	60.42 (60.34)	82.68 (84.14)	78.11 (81.23)	62.59 (61.84)	55.93 (62.47)	104.68 (84.95)***	65.86 (66.94)	83.51 (85.99)	67.29 (69.34)	79.34 (81.44)
Passive sitting	364.05 (112.01)	278.97 (107.44)***	305.93 (112.84)	310.32 (119.63)	293.45 (119.00)	327.88 (109.46)***	319.85 (110.16)	283.12 (124.78)***	313.83 (113.19)	295.93 (121.77)*	311.53 (117.24)	301.77 (114.23)
Light PA	404.59 (105.62)	458.50 (122.82)***	438.47 (118.82)	441.60 (121.15)	452.42 (120.03)	423.32 (117.90)*	447.17 (120.47)	424.82 (117.53)	435.42 (115.74)	449.85 (128.08)	438.65 (120.51)	442.60 (119.00)
Active sitting [†]	42.76 (26.91)	32.14 (20.87)***	35.71 (23.29)	35.85 (24.02)	33.51 (22.17)	38.83 (25.20)**	37.05 (23.08)	33.07 (24.62)*	37.34 (24.58)	32.45 (21.16)	36.14 (23.29)	35.10 (24.31)
Standing	265.74 (84.66)	326.37 (101.15)***	304.83 (98.44)	306.37 (101.71)	318.53 (100.91)	288.17 (96.23)**	310.34 (98.90)	295.49 (101.82)	299.68 (95.49)	318.20 (108.18)	302.19 (97.92)	311.94 (103.70)
<2.5 mph walking	96.09 (36.61)	99.99 (36.31)*	97.93 (34.32)	99.38 (38.49)	100.38 (37.05)	96.33 (35.53)	99.78 (36.51)	96.26 (36.23)	98.40 (35.35)	99.20 (38.72)	100.32 (37.08)	95.56 (35.08)
MVPA	38.92 (36.53)	21.61 (23.51)***	35.34 (33.69)	19.67 (22.68)***	23.37 (28.12)	33.16 (31.05)***	32.04 (31.59)	17.96 (22.75)***	31.54 (31.74)	19.02 (22.92)***	29.89 (30.84)	23.16 (27.22)**
≥2.5 mph walking	31.31 (33.68)	17.90 (22.12)***	30.04 (31.41)	14.88 (19.90)***	18.26 (25.36)	28.20 (28.94)***	26.19 (28.75)	14.61 (22.26)***	26.37 (29.22)	14.22 (20.69)***	25.03 (28.94)	17.78 (23.52)**
Other activities	7.62 (11.74)	3.71 (4.72)***	5.30 (7.30)	4.79 (8.78)**	5.11 (8.62)	4.96 (7.27)	5.85 (9.18)	3.35 (4.47)**	5.17 (8.32)	4.80 (7.52)	4.86 (7.52)	5.39 (9.01)
SLEEP TIME	500.69 (80.28)	499.58 (89.00)	504.20 (86.74)	495.68 (85.28)	503.46 (88.90)	495.25 (81.98)	501.34 (87.60)	497.01 (82.79)	500.85 (85.18)	498.07 (88.06)	502.17 (78.51)	495.85 (98.63)
Lying	336.57 (114.15)	345.40 (129.75)	347.61 (124.36)	337.09 (124.83)	331.8 (126.02)	356.63 (121.45)	351.64 (124.47)	322.65 (122.89)	345.04 (124.75)	336.7 (124.42)	347.13 (123.15)	333.53 (127.10)
Reclining	13.64 (27.88)	10.78 (18.33)	10.79 (17.98)	12.73 (25.57)	14.34 (24.57)	8.28 (17.68)***	10.88 (21.35)	13.62 (23.55)*	11.44 (23.18)	12.44 (19.60)*	11.26 (21.85)	12.68 (22.56)
Sitting	150.48 (101.67)	143.40 (107.08)	145.80 (103.37)	145.85 (107.25)	157.32 (108.98)	130.34 (98.05)**	138.83 (105.98)	160.74 (102.29)*	144.37 (106.35)	148.93 (103.02)	143.78 (103.99)	149.64 (107.65)

Values are mean (SD) in minutes per day. IDEEA-derived variables were log transformed but untransformed values are presented in the table. Differences between groups were computed by analysis of covariance controlling for wearing time. Abbreviations: SB, Sedentary Behaviors; PA, Physical Activity; MVPA, Moderate-to-Vigorous Physical Activity; mph, miles per hour. Other activities include: up and down stairs, running, and jumping. [†]Only including movements with lower body extremities. * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. All tests in the table were subjected to the Benjamini & Hochberg correction for multiple comparisons. Statistically significant values after alpha correction are in bold.

Supplementary table 1. Classification of IDEEA activity types into categories

Category	Activity type
Lying	Lie face up Lie face down Lie on right shoulder Lie on left shoulder Sit to lie Stand to lie
Reclining	Recline normal Recline left leg over right Recline right leg over left Changes within recline Sit to recline Stand to recline
Passive sitting	Sit feet elevated Sit upright Sit left leg over right Sit right leg over left Sit elbows on legs Sit right foot under seat Sit left foot under seat Sit both feet under seat
Active sitting	Sit left foot move Sit right foot move Sit both feet move Changes within sit Stand to sit Lie to sit
Standing	Stand normal Stand elbows on a counter Stand right foot up Stand left foot up Stand right shoulder on wall Stand left shoulder on wall Stand right foot move Stand left foot move Stand pick up object Changes within stand Lie to stand Recline to stand Sit to stand
<2.5 mph walking [†]	Walk right leg at <2.5 mph Walk left leg at <2.5 mph
≥2.5 mph walking [†]	Walk right leg at ≥2.5 mph Walk left leg at ≥2.5 mph
Other activities	Up stairs right leg Up stairs left leg Down stairs right leg Down stairs left leg Jump up both leg Jump down (landing) Run right leg Run left leg

Abbreviations: mph, miles per hour. [†] Walking at ≥ 2.5 mph was classified as moderate-to-vigorous intensity according to the compendium of physical activities (<https://sites.google.com/site/compendiumofphysicalactivities/>)

ACCEPTED