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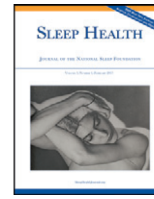

Bidirectional associations of accelerometer-determined sedentary behavior and physical activity with reported time in bed: Women's Health Study☆,☆☆

Kelley Pettee Gabriel, MS, PhD [a,*], Barbara Sternfeld, PhD [b], Eric J. Shiroma, PhD [c,d,e], Adriana Pérez, MS, PhD [f], Joseph Cheung, MD, MS [g], I-Min Lee, MBBS, MPH, ScD [c,d]

[a] Department of Epidemiology, Human Genetics and Environmental Sciences, University of Texas Health Science Center in Houston, School of Public Health—Austin Campus, Austin, TX 78701
[b] Division of Research, Kaiser Permanente Northern California, Oakland, CA 94612
[c] Division of Preventive Medicine, Brigham & Women's Hospital, Harvard Medical School, Boston, MA
[d] Department of Epidemiology, Harvard TH Chan School of Public Health, Boston, MA
[e] National Institute on Aging, National Institutes of Health, Bethesda, MD
[f] Department of Biostatistics, University of Texas Health Science Center in Houston, School of Public Health—Austin Campus, Austin, TX 78701
[g] Stanford Center for Sleep Sciences and Medicine, Stanford University; Palo Alto, CA 94304

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ABSTRACT

Objective: To examine the day-to-day, bidirectional associations of accelerometer-derived sedentary behavior and physical activity (PA) with reported time in bed in a large cohort of older women.
Methods: Data are from 10 086 Women's Health Study participants (aged 71.6 years; SD, 5.7) who agreed to wear an accelerometer and complete a diary for 7 consecutive days. Generalized linear (multilevel) models with repeated measures were used to examine the adjusted associations of the following: (1) reported time in bed with next-day accelerometer-determined counts and time spent sedentary and in light- and moderate-to-vigorous–intensity PA (MVPA) and (2) accelerometer estimates with reported time in bed that night, expressed as short (<7 hours), optimal (7-9 hours), and long (>9 hours) sleep.
Results: Across days, short sleep was associated with an average of 5500 (SE, 1352) higher accelerometer counts the following day but was also related to higher average sedentary (46.5 [SE, 1.5] minutes) and light-intensity PA (11.9 [SE, 1.2] minutes) than optimal sleep (all $P < .001$). Long sleep was associated with lower accelerometer counts, time spent sedentary and in light-intensity PA, and a reduced likelihood of engaging in ≥20 minutes of MVPA (all $P < .001$) than optimal sleep. Higher PA during the day (higher accelerometer counts and ≥20 minutes of accumulated MVPA) was associated with a reduced likelihood of reporting short or long sleep that night (all $P < .001$).
Conclusions: Findings support the bidirectional associations of accelerometer-determined sedentary behavior and PA with reported time in bed in older women. Future studies are needed to confirm findings with sleep actigraphy in older women.

Introduction

Changes in sleep patterns are thought to be part of the normal aging process.[1] Although sleep needs remain relatively constant across the adulthood, older adults have more difficulty initiating and maintaining sleep.[2] Research has also shown that reduced sleep efficiency in older adults is associated with existing chronic diseases[3] and the medications that are used to treat these conditions.[4] There is growing evidence to suggest that both short (<6 hours) and long (>9 hours) sleep duration are associated with adverse health outcomes, including total mortality, cardiovascular disease (CVD), type 2 diabetes, obesity, and psychiatric illness.[5,6]

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* Corresponding author at: Division of Epidemiology, Human Genetics, and Environmental Sciences, University of Texas Health Science Center at Houston, School of Public Health—Austin Campus, 1616 Guadalupe St, Suite 6.300, Austin, TX 78701, USA. Tel.: +1 512 391 2525; fax: +1 512 482 6185.
E-mail address: Kelley.P.Gabriel@uth.tmc.edu (K. Pettee Gabriel).

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Regular physical activity (PA) has numerous health benefits including a reduced risk of premature death, coronary heart disease, stroke, hypertension, hyperlipidemia, type 2 diabetes, metabolic syndrome, depression, and maintenance of cognitive function in older adults.[7] Yet, older adult women are one of the least active subgroups in the United States.[8] A reciprocal association of PA with sleep has also been hypothesized and evaluated.[9–12] Once an association is established, prevention strategies targeting older adult women to improve sleep hygiene may lead to improvements in PA levels and vice versa. However, there is a lack of consensus in the literature regarding the day-to-night associations of waking and nonwaking behaviors. More specifically, *does sleep duration at night impact sedentary behavior and PA the next day* and/or *do sedentary behavior and PA during the day influence sleep duration that night?*

Historically, to examine these associations in population-based research, daily records or accounts of sedentary behavior, PA, and sleep duration were required. However, with recent advancements in technology, examining these associations with accelerometers is now possible. Accelerometers provide direct estimates of waking behaviors, including sedentary behavior and PA. Several strategies have been used to concurrently assess sedentary behavior, PA, and sleep duration using accelerometers to describe 24-hour periods. The first strategy is to use accelerometers that are capable of complete 24-hour monitoring. However, this technology is relatively new and can be challenging, given that the optimal monitor placement varies by behavior (waist during waking hours; wrist during sleep). The second option is to request participants to wear 2 monitors during data collection, which increases participant burden and study costs. The third option is to ask participants to wear the monitor only during waking hours and complete a wear time diary where times in and out of bed are recorded. Yet, this option requires participants to record times in and out of bed (rather than simply reporting nonwear time), representing an abbreviated sleep diary for subjective quantification of time in bed.

Recent studies examining the bidirectional associations of sedentary behavior and PA with sleep duration reflect these different measurement strategies. Using a single monitor worn on the waist during waking hours and wrist during sleep, Kishida et al (2016)[13] found that an increase in daily PA was related to increases in total sleep time that night; however, there was a null association between moderate- to-vigorous intensity PA (MVPA) and total sleep time among a sample of 103 midlife women. Higher total sleep time was also significantly related to lower MVPA the next day. Studies by Lambiase et al[9] and Mitchell et al[10] used 2 monitors, worn concurrently, to assess these behaviors. Lambiase et al[9] examined these associations using data collected from the ActiGraph GT1M accelerometer and Actiwatch-64m in older women ($n = 143$; aged 73.3 (1.7) years) and found that a 10% increase in daily accelerometer counts and accumulated MVPA was associated with a 0.04% and 0.02% reduction in sleep duration that night. Although statistically significant, the impact of PA on sleep duration was negligible. Mitchell et al[10] used 2 ActiGraph GT3X+ monitors in 353 women, aged 21-75 years, and found no significant associations of sedentary behavior and MVPA with total sleep time that night or total sleep time with sedentary behavior or MVPA the following day. In a study by Baron et al,[14] 11 women (61.3 ± 4.1 years) with insomnia wore an Actiwatch-64 during sleep and completed an exercise log where they reported start time, duration, perceived exertion, and exercise type. Results showed that reported exercise was not significantly associated with sleep time that night. In addition, there was no association between total sleep time and reported exercise duration the following day. Given this conflicting research, additional studies are needed to confirm these findings in larger study samples while using clinically meaningful cut-points that reflect the (1) well-established U-shaped distribution[15,16] between sleep and mortality and chronic disease and (2) current PA guidelines for general health benefit to determine the impact of both short and long sleep on waking behaviors. Furthermore, no previous studies have examined the bidirectional associations of light-intensity PA and sleep, and only the study by Mitchell and colleagues[10] explored potential day-to-day relations with sedentary behavior.

The primary objective of this study is to examine the bidirectional, day-to-day associations between accelerometer-derived PA, sedentary behavior, and participant-recorded time in bed in the Women's Health Study (WHS), a large, population-based sample of older women. Similar to the assessment strategy used by Baron et al,[14] and because sleep actigraphy data were not collected in the WHS, reported accounts of time in bed were used in the current study to estimate sleep duration. Subjective report of time in bed from sleep diaries has been shown to be comparable to objective sleep duration measurements.[17–20] In addition, in the current study, the longitudinal structure of the data collected for 7 consecutive days was retained, and reported time in bed was used as an estimate of sleep duration,[18] which was further classified as short (<7 hours per night), optimal (7-9 hours per night), and long (>9 hours per night) sleep to reflect National Sleep Foundation recommendations.[21] Furthermore, because of the well-established benefits of a PA dose reflecting 150 minutes of MVPA per week on health and well-being[22], MVPA was further classified as <20 and ≥20 minutes per day to reflect 2008 Physical Activity Guidelines for Americans.[22] These categorical estimates were used specifically to enhance the interpretation of study findings.

Participants and methods

Design overview and study participants

Participants are from the WHS, a completed randomized trial (1994-2004) testing the benefits and risks of low-dose aspirin and vitamin E for primary prevention of cancer and CVD in 39 876 US women aged ≥45 years.[23,24] When the trial ended, women were invited to continue in an observational follow-up study, and 89% of those alive consented. In 2011, an ancillary study was initiated with the primary goal to examine the associations of accelerometer-determined PA and sedentary behavior on health outcomes.

As of January 1, 2014, 26,978 women had been invited to participate in the accelerometer ancillary study, and 23,934 (88.7%) responded. Of the 23,934, 1204 (5.0%) were ineligible because they were unable to walk independently outside the home (eligibility criterion). Among the remaining 22 730 women, 16,689 (73.4%) agreed to participate. Participants provided written informed consent, and the study was approved by the Brigham and Women's Hospital's institutional review board committee.

Participants included in the ancillary study were mailed an accelerometer and asked to wear it on the hip for 7 days during waking hours. They also completed a wear time diary, indicating which days the monitor was worn, and returned both the accelerometer and diary by mail. Women were then mailed a brief PA questionnaire, inquiring about leisure time PA during the time the monitor was worn. As of May 2014, 14,796 women had returned their accelerometers, who represent those potentially eligible for these analyses.

Data collection

Participant characteristics

Women's Health Study participants complete annual questionnaires that ask about sociodemographic characteristics, health behaviors, and medical history. Date of birth, race, and education were obtained from the baseline questionnaire at the start of the WHS trial, whereas information on weight, height, self-rated health, and