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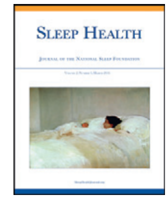

An intensive longitudinal examination of daily physical activity and sleep in midlife women

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ABSTRACT

Objectives: Previous research examining physical activity (PA) and sleep link has largely ignored the day-to-day variability that is present in these 2 health behaviors, and few studies have addressed this relation using objective assessments of PA and sleep. Through an intensive longitudinal design, the present study aimed: (1) to elucidate the reciprocal associations between PA and sleep; and (2) to better understand the role of body mass index (BMI) in these 2 health behaviors.
Methods: Community-dwelling midlife women (N = 103; M = 53, age range = 40-60 years) wore an accelerometer for the objective assessment of PA and sleep for 21 days. A series of multilevel models were estimated to test concurrent and lagged associations between PA (activity counts, moderate-to-vigorous PA) and sleep (total sleep time [TST], sleep efficiency, sleep fragmentation indices).
Results and conclusions: In concurrent, same-day analyses, a positive association emerged between PA and sleep such that as activity counts increased during the day, TST at night also increased ($P < .05$). In lagged analyses examining next-day effect of sleep on PA, a negative association was found such that greater TST on a given night was associated with less moderate-to-vigorous PA the subsequent day ($P < .05$). A moderation effect by BMI was also observed such that women with a high BMI engaging in overall lower levels of PA demonstrated poorer-quality sleep. The data suggest that leading a physically active lifestyle may have protective effects on sleep, particularly for overweight and obese women.

Introduction

Maintaining adequate and quality sleep is paramount because habitual poor sleep leads to adverse health consequences such as depression, obesity, and all-cause mortality.[1,2] Unfortunately, the aging process leads to shorter (reduced total sleep time [TST]) and more disrupted sleep (prolonged awakenings, decreased sleep efficiency), and prevalence rates for sleep disturbances are more common as women reach midlife,[3,4] with the menopausal transition often identified to be a time window that negatively affects sleep. In fact, an estimated 45%-48% of peri- and postmenopausal women report sleep complaints, raising concerns for the daily functioning and well-being of women during this time.[5]

Engaging in regular physical activity (PA) has been identified to be one behavioral strategy to promote sleep,[6–8] with benefits such as longer TST and improved sleep continuity (eg, reduced wake after sleep onset [WASO]) demonstrated in habitually active women in comparison to their sedentary counterparts.[9,10] Unfortunately, results from experimental studies in midlife women have not been as encouraging, with some studies demonstrating enhanced sleep[11,12] and others reporting no such improvements.[13,14] The inconsistency in the literature can partially be attributed to methodological limitations, such as different assessment methods (eg, objective vs subjective) between studies.

Moreover, one critical characteristic that has often been overlooked in the literature is the natural, day-to-day fluctuations that are present in both PA and sleep. Indeed, despite the substantial within-person variability that has been demonstrated for both self-reported and objective PA and sleep,[15–17] a dearth of studies exists examining potential within-person associations. Although the emphasis of previous research has been in identifying the stable, slow-changing, interindividual factors that impact these behaviors, it appears reasonable to assume the presence of time-changing, intraindividual factors that influence this association. For instance, on a day a woman obtains a restful night of sleep in comparison to her usual, she may be more likely to be physically active the subsequent day and vice versa.

One promising approach that can overcome some of the aforementioned limitations of previous research is through the use of intensive longitudinal designs that provide multivariate, multi-subject data with repeated assessments over time.[18] A notable strength of this approach is the potential to examine the natural variation of

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both PA and sleep over time, which one-time measures are unable to capture. Furthermore, although observational in nature, obtaining intensive longitudinal data can provide key insights into the temporal ordering of these behaviors and mutual associations through testing both concurrent and lagged relations. Previous research has highlighted the ability of PA to improve sleep[6–8]; yet, the majority of the work has been cross-sectional, obscuring the causal nature of the PA and sleep link. Nonetheless, emerging evidence shows that poor sleep leads to less PA,[19] and experimentally-induced short sleep duration (<6 hours) has resulted in lower daytime PA.[20] Only a handful of studies have examined the presence of a reciprocal association, with a few studies demonstrating night-to-night fluctuations in sleep parameters to predict PA the following day[21–23] and one study reporting lack of associations.[24] Clearly, more research is warranted to better disentangle the reciprocity of the association, especially because both PA and sleep are important and modifiable health behaviors.

Evidently, PA and sleep influence one another via complex mechanisms, with potential moderators and mediators which may also influence these pathways.[25] Body mass index (BMI) is one such factor that is often highlighted to be interrelated to the PA and sleep link, although the specific role it plays in these 2 health behaviors has yet to be elucidated. It has been well-established that both PA and sleep are associated with obesity[26–29]; hence, the relation between PA, sleep, and BMI may be reciprocal. Alternatively, it can be posited that regular PA leads to a lower BMI,[30] which then may lead to better quality sleep. High BMI could also lead to both poor sleep and lack of PA.[16,31] For instance, as a consequence of being obese or overweight, individuals may engage in less PA because the discomfort associated with PA (eg, greater musculoskeletal complaints and sweating, decreased affect) may be worse when one is overweight.[32] Despite these plausible mechanisms, how BMI may (or may not) function in the PA and sleep association remains unclear, as the majority of these studies have examined PA and sleep independent from one another. Exploring the role of BMI with intensive longitudinal data may, therefore, provide insight into how being overweight or obese may impact one's overall (between-person, time-invariant) and daily (within-person, time-variant) PA and sleep.

The majority of previous research on PA and sleep has relied on self-report assessments of both behaviors, with a lack of studies addressing this link using objective assessments. The measurement error (eg, recall bias, social desirability effects) associated with these self-reported behaviors has been well-recognized.[33,34] Furthermore, despite the high prevalence rates of sleep complaints reported by menopausal women,[3–5] research using objective measures of sleep have indicated no such differences.[35] It may be particularly meaningful, therefore, to obtain direct measures of these health behaviors in this specific population. Accelerometry provides one means to objectively assess PA and sleep through a single monitor in an individual's natural living environment.

As illustrated, despite the substantial attention that has been directed to better understand the PA and sleep association, inherent limitations exist, including: (1) the lack of objective data; (2) failure to assess the day-to-day variability in the 2 health behaviors; and (3) uncertainty in respect to the directionality as well as moderators and mediators of the association. The first aim of the present study was to elucidate the reciprocal associations between PA and sleep among middle-aged women with intensive longitudinal data and the use of accelerometry. It was hypothesized that: (1) greater daily PA would be associated with enhanced sleep parameters; and (2) better sleep at night would be associated with greater PA the subsequent day. Second, this work also sought to understand the extent to which BMI had an influence on the PA and sleep relation. It was hypothesized that having a high BMI would have unfavorable consequences on the PA and sleep association.

Methods

Participants

As part of a prospective study on PA and symptom management,[36] community-dwelling midlife women (N = 103; 40-60 years) wore an accelerometer for the objective assessment of PA and sleep consecutively for 21 days and 20 nights. Participants were recruited through recruitment letters, handouts, and flyers placed in community locations, and word-of-mouth. An online ad was also posted on the research studies website for volunteers at the local institution. Participants were excluded if they: had a history of hysterectomy with bilateral oophorectomy, had used hormone therapy in the previous 6 months, or regularly used alternative therapies specifically targeted toward menopausal symptom management. Participants were all capable of performing normal PA (ie, without physical disabilities). Data collection took place from May 2013 to September 2013.

All procedures were approved by the Institutional Review Board at the local institution, and all participants provided informed consent. At the introductory laboratory visit, participants were fitted with an accelerometer and were instructed to wear the device at all times throughout the study period, except when engaging in water-related activities. Further instructions included positioning the accelerometer over one's nondominant hip during all waking hours and switching the accelerometer to the wrist at night, as close as possible to one's time to bed. Participants were provided a log in which they were told to record the times for when the monitor was: (1) switched to the hip in the morning upon waking; and (2) switched to the wrist at night before bed. Participants were also instructed to report any other times when the monitor was taken off and to indicate the activities they were engaging in during these times (eg, swimming, forgot). Before analyses, nights of reported monitor removal (eg, when the participant forgot to switch the monitor to the wrist) were treated as missing data.

Study procedures

A triaxial accelerometer (Actigraph model GT3X, Pensacola, FL) was used to objectively assess daily PA and sleep. The GT3X monitor is a validated instrument[37] that has demonstrated substantial reliability worn on the wrist for the assessment of sleep.[38] Each participant wore an accelerometer that was initialized to collect data in 60-second epochs, which was processed and analyzed processed, and analyzed using the ActiLife data analysis software (version 6.8.0). Data screening determined *valid days*, which were defined as days with more than 10 hours of valid wear time. *Non-wear time* was defined as a period of 90 minutes or more when the accelerometer recorded consecutive zeros.[39] PA data were examined and adjusted for *wear time* using the: (1) daily activity counts (counts per minute per day; $ct{\cdot}min^{-1}{\cdot}d^{-1}$), which is the raw PA data representing average volume of PA without imposing any cut point decisions; and (2) time spent per day in moderate to vigorous PA (MVPA; $min{\cdot}d^{-1}$) defined by the intensity threshold of 2020 counts (equivalent to 3 METS, defined by activities such as light effort biking and walking at 3.0 mph).[40] This cut-point value was determined across 4 calibration studies in adults (≥18 years old), which linked raw activity counts data from the accelerometer to measured PA energy expenditure.[41–43]

The Cole-Kripke algorithm developed in middle-aged adults (with the wrist as the attachment site) was used to determine minute-by-minute sleep-wake states.[44] Sleep parameters derived from the algorithm and considered in the present study were TST (total number of minutes scored as sleep), WASO (the total number