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Experimentally increasing sedentary behavior results in decreased sleep quality among young adults

Meghan K. Edwards [b],
Paul D. Loprinzi, PhD Director, Exercise Psychology Laboratory, Director, Physical Activity Epidemiology Laboratory, Director of Research Engagement – Jackson Heart Study Vanguard Center of Oxford [a, *]

[a] *Department of Health, Exercise Science and Recreation Management, Exercise Psychology Laboratory, Physical Activity Epidemiology Laboratory, The University of Mississippi, University, MS, USA*
[b] *Exercise Psychology Laboratory, Physical Activity Epidemiology Laboratory, University of Mississippi, USA*

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Objective: Sleep has been shown to influence cardiometabolic function, and physical activity and sedentary behavior have both been shown to epidemiologically influence sleep. However, no study has experimentally evaluated the effects of sedentary behavior on sleep quality, which was this study's purpose.
Methods: This study employed a 2-group parallel randomized controlled intervention protocol; young adult (18–35 years old) participants confirmed to be active were randomly assigned into a sedentary behavior intervention group (n = 26) or a control group (n = 13). The intervention group was asked to minimize steps to ≤5000 steps/day for one week whereas the control group was asked to continue normal physical activity levels for one week. Both groups completed the Pittsburgh Quality Sleep Index (PSQI) pre- and post-intervention. The intervention group resumed normal physical activity levels for one week post-intervention.
Results: A significant group × time interaction effect was observed ($F = 4.49$, $P = 0.04$), with contrast tests indicating significant PSQI change score in the intervention group. Specifically, PSQI scores significantly decreased by 3.16 points (representing improved sleep quality) from Visit 2 to Visit 3 ($P < 0.001$) in the intervention group.
Conclusion: Active young adults who removed structured exercise and significantly decreased their step counts (e.g., increased their amount of time spent being sedentary) for one week experienced significant decreases in sleep quality. The present findings underscore the importance of maintaining regular physical activity for optimal sleep quality.

1. Introduction

Sleep deprivation (failure to obtain adequate amounts of sleep, with adult recommendations being a minimum of 7 h per night) (Watson et al., 2015) and sleep deficiency (the presence of sleep deprivation, disrupted sleep cycles, or a sleeping disorder) ("What are sleep deprivation and deficiency, 2012") have been associated with a number of modifiable negative health outcomes, such as obesity, depression, diabetes, cardiovascular disease, and cardiovascular mortality and all-cause mortality (Shankar, Syamala, & Kalidindi, 2010). Prescription medications utilized to treat sleep disorders can be costly, do not cure the underlying condition, and may induce maladaptive side effects, central nervous system toxicities, dependency, or potential rebound sleep impairment after discontinuation (Khalsa, 2004). Certain sleep-related disorders may be due in part to an individual's regular behavior and lifestyle habits. For example, weight status is a significant risk factor for sleep apnea, with approximately 50 percent of sleep apnea patients being classified as overweight or obese ("How is sleep apnea

* Corresponding author. Department of Health, Exercise Science, and Recreation Management, The University of Mississippi, 229 Turner Center, University, MS 38677, USA.
E-mail address: pdloprin@olemiss.edu (P.D. Loprinzi).

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treated?, 2012"). Poor sleep quality can also extend to individuals with sub-clinical poor sleep symptomology (lacking a diagnosed sleep disorder). For instance, troubles with falling asleep or daytime sleepiness affect approximately 35–40% of the U.S. adult population (Hossain & Shapiro, 2002). While excessive daytime sleepiness is a common side effect of numerous sleep disorders, it is also associated with sleep deprivation and is often observed in patients with psychiatric disorders (e.g., depression, seasonal affective disorder) (Tsuno, Besset, & Ritchie, 2005). It is evident that sleep quality may be impeded by both intrinsic factors (i.e., an existing sleep disorder) and extrinsic factors (e.g., chronic alcohol or drug use, excessive caffeine consumption, poor sleep hygiene) (Sleep Disorders and Sleep Deprivation: An Unmet Public Health Problem, 2006). Regardless of the cause, failure to obtain optimal sleep quality can negatively impact individuals in a myriad of ways, including cognitive impairment (e.g., decreased attention, working memory, long-term memory, and decision-making abilities) (Alhola & Polo-Kantola, 2007). Additionally, as previously mentioned, inadequate sleep may also have a negative influence on one's mental health (Tsuno et al., 2005) and also puts an individual at an increased risk for a number of physical, chronic diseases (Shankar et al., 2010).

As a result of the comorbidities (Foley, Ancoli-Israel, Britz, & Walsh, 2004) often associated with poor sleep quality or sleep disorders, recent research has examined alternative methods of promoting better quality sleep. Physical activity, which has many well-established global health benefits (decreased risk for cardiovascular disease, heart attack, stroke, certain cancers, Type II diabetes and obesity as well as an increased overall quality of life) (Bernstein, Henderson, Hanisch, Sullivan-Halley, & Ross, 1994; Diabetes Prevention Program Research, 2002; Haennel & Lemire, 2002; Otto et al., 2007; Wannamethee & Shaper, 1992; Young-McCaughan & Sexton, 1991), has been evaluated as a possible method for improving various sleep-related parameters. Epidemiological work has demonstrated a positive relationship between physical activity and sleep (P. Loprinzi, 2016; P. Loprinzi, Loprinzi & Cardinal, 2012; P. L. Loprinzi and JP, 2015; Sherrill, Kotchou, & Quan, 1998). Research utilizing objective measurements of physical activity to evaluate its effects on sleep quality is sparse, however a recent study using accelerometry to measure physical activity found that physical activity significantly negatively influenced perceived daytime sleepiness as well as the ability to focus when tired (P. Loprinzi, Nalley & Selk, 2014). One proposed mechanism to explain physical activity's positive influences on sleep is the temperature down-regulation theory, which postulates that sleep onset is associated with a decline in body temperature experienced post-exercise (via peripheral heat dissipation through vasodilatation) (Driver & Taylor, 2000).

In addition to the demonstrated positive effects of physical activity on sleep, most health scientists would likely agree that physical activity is imperative for good overall health and well-being. Emerging research suggests that regardless of time spent being physically active, sedentary behavior is linked with a number of negative health outcomes (P. D. Loprinzi, 2016; Proper, Singh, van Mechelen, & Chinapaw, 2011). For instance, recent epidemiological work has demonstrated a negative association between sedentary behavior and daytime sleepiness, independent of physical activity levels (P. Loprinzi, et al., 2014). However, few studies have utilized experimentally designed interventions and an objective measurement of sedentary behavior to draw conclusions upon (Thyfault, Du, Kraus, Levine, & Booth, 2015). Notably, sedentary behavior should be distinguished from failing to adhere to recommended physical activity guidelines; sedentary behavior has been defined as any waking activity characterized by an energy expenditure of 1.5 METS or less while in the sitting or lying body position (Sedentary Behavior Research Network, 2012).

The purpose of this study was to build upon current understandings of the sedentary behavior-sleep relationship via a randomized, controlled sedentary behavior intervention. Among an "active" college sample, we assessed several sleep-related parameters (detailed later herein) to determine if a sedentary behavior intervention (i.e., minimizing physical activity and increasing sedentary behavior) had a significant effect on any of these parameters. We hypothesized active individuals whose sedentary behavior was increased for one week would have worse post-intervention sleep. In addition, we hypothesized that sleep would again improve after normal activity was resumed (i.e. returned to baseline levels). This hypothesis is plausible because, as mentioned previously, research has demonstrated a positive relationship between physical activity and sleep quality (Driver & Taylor, 2000). Thus, it is reasonable to suggest that sleep quality may worsen if sedentary behavior is increased. This approach may provide the strongest evidence of a potential cause-and-effect relationship between sedentary behavior and sleep quality.

2. Methods

2.1. Recruitment

Participants (college students) were eligible for the study if they were between 18 and 35 years old, were confirmed to be active, spoke English, and provided informed consent. Participants were excluded from the study if they failed to obtain adequate levels of physical activity (described below) in the week of accelerometer data collection prior to the intervention. All participants provided informed consent and the study procedures were approved by the authors' institutional review board.

The recruitment goal was 30–40 participants with at least $n = 22$ in the intervention group; this was based of our pilot data (P. D. Loprinzi & Sng, 2016) showing that changes in sedentary behavior were significantly associated with changes in various psychological-related parameters. A student researcher at the authors' institution recruited participants using a non-probability convenience sampling approach (specifically, word of mouth was used to recruit co-workers as well as students from undergraduate classes within the authors' department). The final recruited sample size was $N = 39$, and using a 2:1 sample size ratio for intervention and control participants (Dumville, Hahn, Miles, & Torgerson, 2006), 26 participants were randomly assigned into the sedentary behavior intervention group and 13 participants were randomly assigned into the control group.

2.2. Visit details

Each participant completed either two (control group) or three (intervention group) visits, in addition to a pre-visit meeting. Hereafter, these visits are referred to as Baseline Visit (both groups), Visit 1 (both groups), Visit 2 (both groups), and Visit 3 (intervention group only), respectively. The visits were scheduled approximately one week apart and at roughly the same time of day. Fig. 1 contains a visual overview of the experimental design, with details explained in the narrative that follows.

At the Baseline Visit, the participant came in to our laboratory to confirm they met inclusion criteria for the study and, if deemed eligible to participate, to pick up their accelerometer. At this visit, the participant provided written informed consent of all of the study procedures. Next, they completed the International Physical Activity Questionnaire short form (IPAQ-SF) as a screening method to ensure that they were meeting the United States Department of Health and Human Services (USDHHS) guideline for American