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Brief Original Report

Engagement in muscular strengthening activities is associated with better sleep

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ABSTRACT

Few studies have examined whether engagement in muscular strengthening activities is associated with sleep duration, which was the purpose of this study. Data from the population-based 2005–2006 National Health and Nutrition Examination Survey were used, which included an analytic sample of 4386 adults (20–85 yrs). Sleep duration and engagement in muscle strengthening activities was self-reported. After adjustments (including aerobic-based physical activity), those engaging in muscular strength activities, compared to those not engaging in muscular strengthening activities, had an 19% increased odds of meeting sleep guidelines (7–8 h/night) (Odds Ratio = 1.19, 95% Confidence Interval: 1.01–1.38, $P = 0.04$). Promotion of muscular strengthening activities by clinicians should occur not only for improvements in other aspects of health (e.g., cardiovascular benefits), but also to help facilitate optimal sleep duration.

Introduction

Suboptimal (<7 or ≥9 h/night) sleep duration is associated with numerous negative health outcomes in adults, including cardiovascular disease, type-2 diabetes, obesity, and all-cause mortality (Sigurdson and Ayas, 2007). Among U.S. adults, approximately 35%–40% has problems with falling asleep or daytime sleepiness (Hossain and Shapiro, 2002).

Encouragingly, empirical evidence indicates that regular participation in aerobic-based physical activity is favorably associated with various sleep parameters in adults (e.g., reduced latency to fall asleep, increased likelihood of meeting sleep guidelines [7–8 hrs/night] and fewer nocturnal leg cramps) (Loprinzi and Cardinal, 2011; Yang et al., 2012). Clinicians are well suited to promote modifiable behaviors to help facilitate sleep among their patients (Taylor et al., 2007). Although beneficial effects of aerobic-based physical activity on various sleep-related parameters have been established, our understanding of the relationship between engagement in muscular strengthening activities (e.g., lifting weights) and sleep is relatively unknown. It is plausible to suggest a relationship between muscular strengthening activities and sleep as resistance training, for example, is a form of physical activity, with physical activity defined as any bodily movement produced by skeletal muscles that results in energy expenditure (Caspersen et al., 1985). Promotion of muscular strengthening activities (e.g., lifting light weights) by clinicians may be particularly important given that their patients may have limitations with ambulatory-based activities (e.g., fast walking, jogging).

As discussed elsewhere (Youngstedt and Kline, 2006), the mechanisms through which physical activity may favorably influence sleep is likely a result of temperature down-regulation following exercise. The temperature down-regulation theory posits that the onset of sleep is associated with a decline in body temperature, achieved by peripheral heat dissipation through vasodilation (Loprinzi and Cardinal, 2011). Physical activity is hypothesized to have sleep-promoting benefits by activating temperature down-regulation (in the hypothalamus-preoptic area) from the physical activity-induced body heating. Although it is plausible that such an effect may be more pronounced in high-intensity aerobic-based physical activity, it is conceivable that such an effect may also occur from engagement in muscular strengthening activities. Further, another plausible mechanism to explain the potential sleep-muscular strengthening activities relationship is from the body restoration and compensatory theory (Adam and Oswald, 1983), which posits that anabolic conditions during sleep will be favored following high anabolic activity (e.g., engagement in muscular strengthening activities) during waking hours.

Given that no epidemiological study, to our knowledge, has examined the relationship between engagement in muscular strengthening activities and sleep, the purpose of this brief report was to examine this relationship in a national sample of U.S. adults. Identification of such a potential association may provide individuals with a non-pharmacological, behavioral-based alternative to aerobic physical activity to help facilitate improved sleep.

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Methods

Design and participants

Data from the NHANES 2005–2006 were used in the analyses. NHANES uses a representative sample of non-institutionalized U.S. civilians, selected by a complex, multistage probability design. Briefly, participants were interviewed in their homes and subsequently examined in mobile examination centers (MEC) across numerous U.S. geographic locations. The study was approved by the National Center for Health Statistics ethics review board, with informed consent obtained from all participants prior to data collection.

Participants were excluded from the analysis if they were under 20 yrs and had missing data on any of the study variables. In the 2005–2006 NHANES cycle, 4979 adults (20+ yrs) were enrolled. After excluding those with missing sleep data ($n = 11$), 4968 remained. After excluding those with missing muscle strengthening data ($n = 1$), 4967 remained. Lastly, after excluding those with missing covariate data, 4386 remained, which constituted the analytic sample.

Measurement of muscle strengthening activities

Participants were asked two questions related to engagement in muscular strength activities: 1) "Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles such as lifting weights, push-ups or sit-ups?" (response option: *yes* or *no*), and 2) among those answering *yes* to this first question, they were asked, "Over the past 30 days, how many times did you do these activities designed to strengthen your muscles such as lifting weights, push-ups, or sit-ups?" These NHANES muscular strength activities items have provided evidence of convergent validity (e.g., shown to associate with cardiovascular-related parameters) (Loprinzi et al., 2015).

Measurement of sleeping variables

Using the Functional Outcomes of Sleep Questionnaire (Weaver et al., 1997), participants were asked, "*How much sleep do you usually get at night on weekdays or workdays?*", with hours slept per night categorized here as 7–8 (sleep recommendations) or other (i.e., <7 or ≥9). Notably, a modest ($r = 0.47$) correlation has been observed between self-report and objectively-determined sleep duration (Lauderdale et al., 2008).

Assessment of covariates

Based on previous research demonstrating an association between sleep and physical activity (Loprinzi and Cardinal, 2011; Youngstedt and Kline, 2006), the following covariates were assessed: age (continuous), gender, race-ethnicity, weight status (normal weight [measured BMI 18.5–24.9 kg/m^2) or overweight/obese (measured BMI 25+ kg/m^2), engagement in moderate-to-vigorous physical activity in the past 30 days (yes/no), smoking status (smoker/non-smoker based on cotinine of ≥10 ng/mL), physician-diagnosed diabetes status (yes/no) and physician-diagnosed hypertension status (yes/no). Further details of the methodological procedures and psychometric aspects of these measures are published elsewhere (Loprinzi et al., 2015).

Analysis

Data were analyzed using survey data procedures in Stata (v. 12), while accounting for the complex, probability design employed in NHANES. Multivariable logistic regression was used to examine the association between engagements in muscular strength activities and self-report of optimal levels (7–8 h/night) of sleep (outcome variable). Statistical significance was set at the customary alpha level of 0.05.

Results

The weighted characteristics of the study variables are shown in Table 1. Those who engaged in muscle strengthening activities in the past 30 days, compared to those who did not, were younger, more likely to be male and white, engaged in more aerobic-based physical activity, and were less likely to be overweight, smoke, have diabetes, or have hypertension; all these parameters were thus included as covariates in the multivariable model. Among those engaging in muscular strength activities in the past 30 days, the mean number of times they did these activities in the past 30 days was 13.5 (0.4).

The main findings are displayed in Table 2. In an unadjusted model, those engaging in muscle strengthening activities had a 33% increased odds of meeting sleep guidelines (OR = 1.33; 95% CI: 1.13–1.55; $P = 0.001$). After adjustments (including aerobic-based physical activity), those engaging in muscular strengthening activities, compared to those not engaging in muscular strengthening activities, had an 18% increased odds of meeting sleep guidelines (OR = 1.19, 95% CI: 1.01–1.38, $P = 0.04$); when adding in other covariates (e.g., alcohol; # drinks/day) in the model, results were unchanged (OR = 1.19; $P = 0.03$). Among those engaging in muscular strengthening activities, there was no dose–response relationship between the frequency of engaging in muscular strengthening activities and sleep (OR = 1.01, 95% CI: 0.99–1.01, $P = 0.36$). Notably, the association between muscle strengthening activities and sleep (OR = 1.18) was similar to that of aerobic-based physical activity and sleep guidelines (OR = 1.21). In a multiplicative interaction model, there was no evidence of an interaction effect of muscle strengthening activities and aerobic-based physical activity with meeting sleep guidelines (OR = 1.44; 95% CI: 0.89–2.34; $P = 0.12$).

Discussion

Here, we examined the association between engaging in muscular strengthening activities and sleep duration among a national sample of U.S. adults, which, to our knowledge, is the first study specifically on this topic. Our main finding was that adults engaging in muscular strengthening activities were more likely to adhere to sleep guidelines. This finding is in accordance to the growing body of experimental and epidemiological literature supporting beneficial effects of aerobic-based physical activity and sleep.

Not only is aerobic-based physical activity associated with better sleep in the general adult population, but also evidence indicates that aerobic-based physical activity may also help improve sleep quality among various subpopulations, such as those with sleep disorders (Reid et al., 2010), pregnant women (Loprinzi et al., 2012a), and adolescents (Loprinzi et al., 2012b). Although our findings, along with those of others looking at aerobic-based physical activity, suggest that muscular strengthening activities are associated with optimal levels of sleep, it has been suggested that the potential beneficial effect of physical activity on sleep may be moderated by the time of day in which physical activity occurs, as well as the intensity of the said physical activity.

Table 1
Weighted characteristics of the study variables stratified by engagement in muscle strengthening activities within the past 30 days.

	Engaged in MSA ($n = 1168$)	Did not engage in MSA ($n = 3218$)
Age, yrs	43.1 (0.7)	48.1 (0.8)
Male, %	51.4	46.7
Non-Hispanic white, %	74.4	71.7
Overweight/Obese, %	60.1	70.6
MVPA, %	91.2	57.2
Smoke, %	21.8	30.6
Diabetes, %	4.7	8.9
Hypertension, %	22.7	32.8
Meets sleep guidelines, %	62.3	55.3

MSA, muscle strengthening activities; MVPA, moderate-to-vigorous physical activity.

Table 2
Weighted multivariable logistic regression examining the association between muscle strengthening activities and meeting sleep guidelines.

	Odds ratio for meeting sleep guidelines	95% CI	*P*-value
Engaging in MSA in past 30 days vs. not	1.19	1.01–1.38	0.04
Covariates			
Age, 1 yr increase	1.00	0.99–1.01	0.24
Female vs. male	1.03	0.84–1.27	0.69
Race–ethnicity			
Mexican American vs. white	0.84	0.65–1.07	0.14
Black vs. white	0.43	0.34–0.53	<0.001
Other vs. white	0.81	0.59–1.11	0.18
Overweight/Obese vs. not	0.96	0.82–1.13	0.66
MVPA in past 30 days vs. not	1.21	0.99–1.84	0.05
Smoker vs. non-smoker	0.65	0.53–0.79	<0.001
Diabetes vs. not	0.77	0.62–0.95	0.02
Hypertensive vs. not	0.74	0.64–0.85	<0.001

MSA, muscle strengthening activities; MVPA, moderate-to-vigorous physical activity.

The American Academy of Sleep Medicine (http://www.aasmnet.org/) indicates that vigorous late-night exercise may lead to inadequate sleep hygiene by facilitating increased physiological arousal. Empirical research does indeed support exercise-induced nocturnal sympathetic system stimulation; (Hynynen et al., 2010) however, there is little support of late-night exercise impairing overall sleep quality (O'Connor et al., 1998; Youngstedt et al., 1999; Yoshida et al., 1998). Notably, we were not able to evaluate this in the present study as the NHANES physical activity questions did not evaluate when during the day the physical activity took place.

The mechanisms through which physical activity may be associated with sleep are continuing to be refined and developed. Presently, the prevailing hypotheses are that physical activity may positively influence sleep via temperature down-regulation and the need for tissue restoration following exercise. Regarding the latter, and in accordance to the restoration theory of sleep (Adam and Oswald, 1983), sleep may help the body repair exercise-induced tissue damage occurring during wakefulness. Future mechanistic work is needed, but the present findings suggest that, even independent of aerobic-based physical activity, engagement in muscular strengthening activities is associated with optimal sleep duration. This is an encouraging finding as, if corroborated by future prospective and experimental work, muscular strengthening activities may serve as a non-pharmacological, behavioral-based alternative to aerobic physical activity to help facilitate improved sleep among individuals.

The major strength of this investigation was the novel examination of the association between engaging in muscular strengthening activities and sleep using a national sample of adults. A limitation to the present study includes the crude assessment of engagement in muscular strengthening activities. This relatively crude measure may have underestimated the association between muscular strengthening activities and sleep as crude measures typically attenuate associations. Another limitation is the cross-sectional study design, which precludes any causal inferences. Therefore, we cannot fully discount the plausible explanation that people who achieve optimal sleep levels may be more willing (perhaps via increased energy levels) to engage in muscular strengthening activities. Future work should also utilize objective measures of sleep (e.g., polysomnography) and muscular strength (e.g., knee extensor strength as a marker for lower extremity strength) and statistically control for other potential confounding variables, such as light exposure, which were not measured in the 2005–2006 NHANES cycle.

In summary, engagement in muscular strengthening activities was associated with recommended levels of sleep, independent of engagement in aerobic-based physical activity. Future mechanistic work is needed to improve our understanding of the mechanisms through which muscular strengthening activities may influence sleep duration. If confirmed by future work, then promotion of muscular strengthening activities by clinicians should occur not only for improvements in other aspects of health (e.g., cardiovascular benefits), but also to help facilitate optimal sleep duration among their patients. These findings may provide adults with a non-pharmacological, behavioral-based alternative to aerobic physical activity to help facilitate improved sleep.

Conflict of interest statement

None.

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