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Original article

# Sleep quality improved following a single session of moderate-intensity aerobic exercise in older women: Results from a pilot study

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**Abstract**

*Background*: Poor sleep quality is associated with adverse effects on health outcomes. It is not clear whether exercise can improve sleep quality and whether intensity of exercise affects any of the effects.
*Methods*: Fifteen healthy, non-obese (body mass index = 24.4 ± 2.1 kg/m$^2$, mean ± SD), sedentary (<20 min of exercise on no more than 3 times/week) older women (66.1 ± 3.9 years) volunteered for the study. Peak oxygen consumption ($VO_{2peak}$) was evaluated using a graded exercise test on a treadmill with a metabolic cart. Following a 7-day baseline period, each participant completed two exercise sessions (separated by 1 week) with equal caloric expenditure, but at different intensities (60% and 45% $VO_{2peak}$, sequence randomized) between 9:00 and 11:00 am. A wrist ActiGraph monitor was used to assess sleep at baseline and two nights following each exercise session.
*Results*: The average duration of the exercise was 54 and 72 min, respectively at 60% (moderate-intensity) and 45% $VO_{2peak}$ (light-intensity). Wake time after sleep onset was significantly shorter ($p = 0.016$), the number of awakenings was less ($p = 0.046$), and total activity counts were lower ($p = 0.05$) after the moderate-intensity exercise compared to baseline no-exercise condition.
*Conclusion*: Our data showed that a single moderate-intensity aerobic exercise session improved sleep quality in older women.


*Keywords:* Actigraphy; Activity counts; Exercise; Older adults; Sleep quality; Wake after sleep onset

## 1. Introduction

Poor sleep quality is associated with adverse effects on health outcomes.[1,2] A large proportion of older adults tend to have poor, fragmented sleep quality such as waking up frequently.[3] The 2003 National Sleep Foundation survey showed that one third of adults aged 64 years and older have at least one sleep-related complaint such as difficulty falling asleep, being awake a lot during the night and waking up too early.[4]

Exercise is often considered a non-pharmacological approach that could have beneficial effects on sleep. This is supported by epidemiologic studies showing an association between self-reported exercise and better sleep.[5,6] Additionally, some evidence indicates that aerobically fit individuals have shorter sleep-onset latencies, less wake time after sleep onset, and higher sleep efficiency than their sedentary peers,[7] and increased fitness has been associated with improvements in subjectively-assessed sleep.[8] However, results from experimental exercise studies have been mixed. Several studies have shown a positive impact on self-reported sleep among older normal sleepers following exercise training protocols, including 30-min 67%–70% or 30%–40% heart rate reserve of cycling for 3 times/week,[9] daily 30-min walking, calisthenics, or dancing,[10] and 60-min Tai Chi practice twice a week.[11] Positive effects of exercise on sleep have also been

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found in studies of seniors who had mild to moderate sleep problems.[12–16]

Fewer studies of older adults have assessed sleep objectively via polysomnography or actigraphy. Among these studies, beneficial effects of exercise have been shown in older adults following 60%–85% peak heart rate 5 days/week 35–40 min each session,[17] and 60-min moderate-intensity running 3 days/week;[18,19] however, daily 30 min of mild to moderate physical activity[10] or one afternoon session of 40–42 min of exhaustive aerobic exercise did not influence sleep.[7] Thus, studies in older adults have presented inconsistent results regarding the effects of exercise on sleep, which may be related to variations in exercise intensity, volume, and time between exercise and sleep,[20,21] as well as whether sleep was assessed subjectively or objectively.

A few studies in young adults have examined whether the intensity of a bout of exercise alters its effects on sleep: one study found no differences in sleep latency or number of awakenings between exercise bouts at 70% for 30 min and 40% peak oxygen consumption ($VO_{2peak}$) with the same exercise dose;[22] another study showed that sleep onset latency, wake after sleep onset, rapid eye movement sleep onset, sleep efficiency and slow-wave sleep after treadmill running at 45%, 55%, 65%, and 75% for 40 min were not different from those after no-exercise control.[23] Due to age-related physiological changes,[24] exercise may have different effects in older adults from young adults. However, no study has been designed to determine whether the intensity of exercise influences any effect on sleep in older adults. Thus, the purpose of this study was to determine whether light- and moderate-intensity acute exercise sessions that meet public health recommendations for older adults (moderate-intensity activities, accumulate at least 30 or 60 min/day to total 150–300 min/week),[25,26] improve objectively measured sleep quality in a group of healthy women 61–74 years of age using a crossover design.

## 2. Methods

### *2.1. Subjects and screening evaluations*

This study was an ancillary to a study designed to examine the effects of exercise intensity on non-exercise activity thermogenesis in older women (ClinicalTrials.gov identifier: NCT00988299). Fifteen healthy, non-obese, older women volunteered for this study (Table 1). This study was approved by the Institutional Review Board of Washington University School of Medicine in St. Louis, MO, USA, and written informed consent was obtained from all subjects before participation in the study. None of the subjects smoked and all were weight stable (±1 kg) and sedentary (<20 min of exercise no more than 3 times/week) for at least 3 months before entering the study.

All subjects completed a comprehensive medical examination, including a detailed self-reported history, physical examination, a resting electrocardiogram, standard blood tests, and an oral glucose tolerance test performed by physicians and nurses in Washington University Clinical Research Unit. Blood tests included: complete metabolic panel, complete blood count, and thyroid stimulating hormone. Standard cutoffs that are used in the hospital and associated clinics for normal values were used to include or exclude subjects. For example, the normal ranges for the following blood variables are: white blood cell count, 4.5–13.5 K/μL; red blood cell count, 3.90–5.30 M/μL; hemoglobin, 11.5–16.0 g/dL; thyroid stimulating hormone (TSH), 0.46–4.70 μIU/mL; blood urea nitrogen (BUN), 5–25 MG/dL; blood creatinine, 0.50–1.00 MG/dL; aspartate transaminase (AST), 8–39 U/L; and alanine aminotransferase (ALT), 9–52 U/L. Subjects with diabetes, impaired fasting glucose, or impaired glucose tolerance based on American Diabetes Association criteria[27] were excluded from the study. None of the subjects had evidence of illness, self-reported insomnia, or were taking medications known to affect sleep or to assist sleep. Their daily caffeine intake was less than 500 mg.

Table 1
Subject characteristics.

| | Mean ± SD | Range |
|---|---|---|
| Age (year) | 66.1 ± 3.9 | 60.0–74.0 |
| Body weight (kg) | 66.9 ± 8.4 | 52.5–81.9 |
| Body mass index (kg/m$^2$) | 24.4 ± 2.1 | 19.9–28.8 |
| $VO_{2peak}$ (mL/kg/min) | 22.3 ± 4.2 | 14.6–29.7 |

### *2.2. Study protocol*

$VO_{2peak}$ was evaluated during a graded exercise test on a treadmill. Heart rhythm and rate were continuously monitored (Marquette MAX-1; ParvoMedics, Sandy, UT, USA) and expired air was analyzed by using a metabolic cart (TrueOne 2400; ParvoMedics). Subjects walked at a constant speed and the inclination of the treadmill was increased by 3% every 2 min until volitional exhaustion and/or two of the following criteria were achieved: respiratory exchange ratio ≥1.15; heart rate greater than the age-predicted maximum (220−age (year)); or plateau in $VO_2$.

Each subject performed two treadmill walking sessions between 9:00 and 11:00 am following an overnight fast. One walking session was at light intensity (45% $VO_{2peak}$) and one at moderate intensity (60% $VO_{2peak}$) with randomized sequence, separated by at least 1 week. A snack bar (NatureValley, 250 kcal) was provided before the exercise sessions. The two exercise sessions were performed on same day of the week for each individual to reduce the influence of variation in daily schedule on outcomes. No travel across time zone occurred during the 2 weeks prior to the exercise sessions. During the exercise, expired air was analyzed periodically by using a metabolic cart (TrueOne 2400) to ensure the appropriate exercise intensity was achieved. The duration of exercise was variable and ended when subjects have spent 3.5 kcal (14.7 kJ) energy per kg body weight, based on the volume of the oxygen consumed. We chose an equal exercise energy expenditure relative to body weight for all subjects rather than a fixed time period to reduce the influence of body