Effects of an Acute Bout of Moderate-Intensity Aerobic Exercise And High-Intensity Intermittent Exercise On Sleep During Night Shifts In Medical Shift Workers With Sleep Impairment: A Single-Blind Crossover Randomized Controlled Trial

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Project summary

This study aimed to explore the effects of a single bout of moderate- aerobic continuous exercise (MACE) and high-intensity intermittent exercise (HIIE) on sleep during continuous night shifts in medical shift workers with mild sleep impairment. Medical staff with sleep disturbances due to their night-shift work were randomized to either a treadmill walking session for 47 minutes with moderate intensity (the heart rate reaches 70~75% of the maximum heart rate), treadmill running section for 28 minutes with intermittent high-intensity (the heart rate reaches 90~95% of the maximum heart rate for 4 minutes and 50~70% for 3 minutes), or a quiet-rest control, 14 hours before undertaking a continuous night shift. Sleep quality was assessed by ActiGraph with subjective questionnaire for 1 night and 3 nights after exercise. Tests were performed (t-tests or $\chi 2$ tests) to test for differences between any two of the three intervention trials.

Introduction

Sleep impairment is a common problem among night shift workers (1-3). The prevalence of insomnia in shift workers ranged from 12.8% to 76.4%, higher than estimated for the general population. Moreover, a higher prevalence was observed among women(4, 5). Associations between sleep impairment and deleterious health outcomes have been established, including increased risk of mortality(6, 7), diabetes(8), metabolic syndrome(9), dementia(10), depression, and anxiety(11), as well as impaired quality of life(12). Sleep problems resulting from day and night shifts [5] and the nature of these shifts also contribute to the development of metabolic syndrome(13). The health risks associated with day and night shifts for healthcare workers have been well documented(2, 14, 15), which in turn has led to a reduction in the retention rate of healthcare workers who work shifts(16). Furthermore, the global demand for shift workers is increasing(17), and shift workers other than healthcare workers will also encounter such health problems.

In contrast, exercise has various health benefits, such as reducing the risk of cardiovascular disease and diabetes(18-20), and improving mental health(21, 22). Additionally, several reviews suggest that exercise effectively improves sleep quality and reduces sleep complaints(23-26). A scoping review demonstrated that diverse types of physical activity were effective for improving sleep in many populations, even in the elderly and in co-morbid or perinatal populations(27). However, little research has been conducted on shift worker populations.

Previous research tended to focus on the effects of regular exercise on sleep outcomes(27, 28). Despite the efforts of the World Health Organization (WHO) and countries around the world to promote exercise(29), regular exercise is still challenging for many middle-aged people with busy families and jobs, or even medical staff who work day and night shifts. In recent years, it has been estimated that over 70% of the global population has failed to achieve the weekly exercise recommendations set forth by the World Health Organization (WHO)(30). It is reasonable to assume that if a single bout of exercise can alleviate the sleep disturbance caused by night shift work, it would be significant benefit to night shift workers who may not have the time or resources to engage in regular exercise. A meta-analytic review revealed that both acute and chronic exercise increased slow wave sleep (SWS) and total sleep time, decreased sleep onset latency and REM sleep(31). Furthermore, research has shown that single exercise sessions comprising light or moderate aerobic exercise and HIIE are conducive to improved sleep quality(32, 33). Nevertheless, no studies have been conducted to investigate the effects of a single session of MACE and HIIE on the sleep of night-shift workers.

Several studies have demonstrated that HIIT can significantly increase ‘excess post-exercise oxygen consumption’ (EPOC)(34, 35). A systematic review showed that for the same energy expenditure of continuous and intermittent exercise, intermittent exercise produced higher EPOC than continuous exercise, and these data suggest that for a given energy expenditure, intermittent exercise may be more effective than continuous exercise in reducing body fat(36). Therefore, this study hypothesizes that higher EPOC with greater energy consumption may assist night shift workers to achieve better sleep.

This study aimed to investigate whether a single session of MACE or HIIE would have a favorable impact on the sleep of night shift workers over the subsequent days.

2. Methods

2.1. Design

The study was conducted in a single-blind, repeated-measures, three-armed crossover design, and participants were randomly assigned to the MACE trial, the HIIE trial, and the control (COL) trial for the survey, with a minimum of 21 days between the three trials. To eliminate the impact of individual physical differences, a crossover trial was conducted with the same group of subjects. This study compared MACE, HIIE, and a controlled trial to determine the effects of different exercises on subjective, objective sleep quality, and autonomic nervous activity in workers engaged in night shift work. The primary outcome was the results of subjective and objective sleep quality, and the secondary outcome was autonomic nervous activity. The study started on 10/12/2022 and ended on 31/08/2024.

2.2. Participants

Potential participants were recruited from six hospitals in central Taiwan through hospital and internet advertisements. Only women were recruited in this study because previous research indicates more sleep difficulties in females than in males. Those who were interested in the study were invited to attend an orientation meeting if they met the following eligibility criteria: medical staff who have worked at least three consecutive night shifts; reporting sleep disturbed during the night shift; age between 20 and 64 years; not taking sleep/psychotropic medications; no clinical diagnosis of sleep apnea or other sleep disorder; and not exercising regularly (ie, below 60 minutes per week). Twenty-six medical staff participated in the preliminary meeting, at which the researchers described the study purpose, procedure, and the exercise program and rest condition. These potential participants completed the Satisfaction with Life Scale (SWLS) and initial sleep assessments. The SWLS is a simple self-administered psychometric properties questionnaire to examine the mental health of individuals and the possible risk of depression or other psychiatric diseases(37-39). The initial sleep assessment was made through the Chinese version of the self-reported 5-item Athens Insomnia Scale (AIS-5)(40), and sleep recording watch ActiGraph (wActiSleep, Pensacola, Florida, United States) on the nondominant hand for 4 nights just before night shifts. This study aimed to investigate the effects of a single session of exercise on individuals with sub-optimal sleep quality; thus, individuals were included if they scored above 5 on the AIS-5(40) or had a sleep efficiency below 85%(41) before their first night shift. Among the 26 potential participants, 3 did not meet the criteria and 4 decided not to attend the study. Finally, of the 19 subjects, 1 withdrew after the MACE trial, 2 withdrew after the controlled trial, and 2 withdrew after both the MACE trial and the controlled trial because they could not fit into the schedule, resulting in a sample size of 14 participants. A simple randomization method was used to randomize participants into three groups using Microsoft 365-Excel (Microsoft, Redmond, Washington, United States). They were randomly assigned to either a MACE-HIIE-control (n = 5), HIIE-control-MACE (n = 5), or control-MACE-HHIT (n = 4) , as shown in Figure 1. All participants were aware of their group assignment. Participants who attended the study were rewarded with TWD 2500 (approximately USD 78). All participants completed the study. Previous research has indicated a minimum of 12 participants per group is able to detect a small effect size of physical activity on sleep outcome with setting beta at 20% and alpha at 5%(32, 42, 43). The study was approved by the institutional review board of China Medical University Hospital, Taiwan (CMUH111-REC2-186), and the study was performed in accordance with good clinical practice and the ethical standards as laid down by the Declaration of Helsinki. Written and informed consent was obtained from all subjects at the beginning of the study.

2.3. Protocol

2.3.1. Experimental Procedure

The subjects were arranged to receive a sleep recording watch ActiGraph (non-dominant hand), heartbeat variability monitor (Polar V800，Kempele，Finland, dominant hand and chest strap) and fill in the sleep questionnaire, and also taught how to use the sleep recording watch and heartbeat variability monitor, before 12 p.m. on the day before the start of the continuous night shift. Arrive at the laboratory of the National Taiwan Sports University at 10:00 in the morning on the day when the night shift starts. The experimental process were explained first, and treadmill training (MACE, or HIIE) will begin at 10:30. The control group were reading books and newspapers. The purpose is to make subjects naturally want to sleep in the evening before going to work. Studies have confirmed that such a sleep period is helpful for night shift workers' cognition, concentration and sleep (44). Each treadmill session was performed individually and was supervised by a certified instructor from the National Taiwan Sports University. In addition, sleep logs and sleep watches were filled in, monitored and evaluated using Google questionnaires from the day before the start of the training course to the third night after the end. The subjects were instructed not to consume alcohol or participate in organized physical activities (e.g. training and exercise) for at least 24 hours before each experiment and during data collection. After getting up on the third night, return the two forms.

A washout period of at least three weeks separated each training session from the measurement because female subjects must be tested between days 1 and 10 of the menstrual cycle. This has been the case for cortisol responses to sleep restriction. It has been shown to vary with the menstrual cycle (45).

2.3.2. Intervention

The following two interventional exercises have been proven by previous studies to consume equal amounts of calories(46). During exercise, by adjusting the inclination and speed of the treadmill, the subject's heart rate reaches the target heart rate and target exercise intensity (Rating of Perceived Exertion, RPE) 1-10 points set according to different sensation of subjects (A score of 1 is very relaxed, while a score of 10 is exhausting and almost impossible to continue) (47). If neither the target heart rate nor the target RPE can be achieved, heart rate will be the preferred indicator of intensity. All exercises were performed in an air-conditioned room, with the room temperature controlled at 25 degrees Celsius and a humidity of 60%, with electric fans blowing towards the subjects. If the subjects need to drink water during exercise, they can drink water, and the researchers will provide canned mineral water.

Moderate-Intensity Aerobic Exercise Trial

Participants were asked to walk or run on a treadmill at moderate intensity for 52 minutes (3 minutes of warm-up at 50~70% of age-predicted maximal heart rate (MaxHR), 47 minutes of walking at 70~75% of MaxHR, and 2 minutes of cool-down) at 10:30 in the morning before going to work. Age-predicted maximum heart rate was calculated as 220-age according to the Fox equation (48). Walking speed was adjusted to maintain heart rate at target levels. The speed of the treadmill was between 3.0–6 km/h and the RPE=3/10.

High-Intensity Intermittent Exercise Trial

The first 3 minutes, walking on the treadmill slowly speeds up until the heart rate reaches 50~70% of the MaxHR and RPE=3/10, and then maintains the heart rate at 50~70% of the MaxHR for 10 minutes. Main exercise (high-intensity interval training): 4 minutes of exercise with the heart rate reaching 90~95% of the MaxHR and RPE=5/10, followed by 3 minutes of cool-down exercise (50%~70% of the MaxHR). Four consecutive sets, totaling 28 minutes. 2 minutes of cool-down exercise (50%~70% of the MaxHR). Total exercise time was 43 minutes for the HIIE trial.

Control Trial

Members of the control group attended at the same times of day. They were instructed to sit quietly on their own during this period in a separate room where water, books, newspapers, and magazines were available and were accompanied by a research assistant.

2.3.2. Measure Of Sleep

Participants wore a wrist ActiGraph (wActiSleep, Pensacola, Florida, United States) on the nondominant hand 4 sleep periods from the sleep before exercise to the sleep third sleep after exercise intervention (before the third night duty). The sleep data were obtained from ActiGraph monitors and analyzed by ActiLife software version 6 using the Cole-Kripke algorithm, including eight sleep indices (sleep latency, total counts, sleep efficiency, total sleep time [TST], wake after sleep onset [WASO], number of awakenings, length of awakenings, time in bed)(49, 50). Participants also recorded the time they went to bed and woke up to enable coordinate checks with the actigraphic data. Daily sleep quality was measured using a question that was chosen because it was easy to conceptualize, simple to understand, and less burdensome for participants. The question asked was: On a scale of 0-10, with 0 being the worst sleep and 10 being the best, rate the quality of the previous sleep(51).

Participants self-reported age, marital status, exercise habits, smoking, caffeine and alcohol consumption, and chronic diseases. Height and weight were measured from which body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters (kg/m2).

2.4. Statistical Analysis

Descriptive statistics of data use median and interquartile range (IQR) to describe the distribution of continuous variables. This method is effective in describing the concentration trend and the degree of variability of the data, and is particularly suitable for data with a non-normal distribution.

The between-exercise factor was intervention (MACE, HIIE and control trials) and the within-subjects factor was time points were analyzed. The Wilcoxon signed-rank test is used to compare data between two groups. This test is a non-parametric method for comparing the median difference between two related samples or pairs of data that can be analyzed without assuming that the data conform to a normal distribution.

All statistical tests were performed using the two-tailed test with a significance level (α) of 0.0 which were performed with SAS software (version 9.4; SAS Institute Inc., Cary, NC, USA).

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