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Original article

Acute short-term dim light exposure can lower muscle strength endurance

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Abstract

Background: Since it has been shown that spending 18 h under dim light conditions can result in reduced handgrip endurance, it was questioned whether or not a shorter exposure to dim light (i.e., 1 h) would have similar influence upon muscular endurance. Therefore this study compared the number of weighted knee extension lifts that could be done after spending 1 h in either dim or bright light.

Methods: Participants (5 women, 11 men, college students 19−26 years) performed knee extension lifts to exhaustion with a load approximating 40% of their body weight. The lifts to exhaustion were measured immediately following 1 h of exposure to each of the following three conditions: dark (DL), room light (RL), and room light plus 5 mg melatonin (RLM). A minimum of 48 h separated each condition, and all participants started the exposures in a rested fed condition.

Results: Average (±SD) number of knee extension lifts for RL (62.0 ± 22.0) was significantly ($p < 0.05$) greater than DL (51.4 ± 14.7) and RLM (57.8 ± 22.9). The number of RLM knee extension lifts was not significantly different from DL. Exposure to 1 h of dim light immediately prior to activity can result in a reduction in thigh muscle endurance. The decline in performance to short-term dim light exposure was similar to that found following longer-term exposure.

Conclusion: It appears that light intensity can influence muscle endurance, however, at this time this effect cannot be directly related to endogenous melatonin production.

Keywords: Blood glucose; Blood pressure; Heart rate; Knee extension endurance; Light intensity; Melatonin

1. Introduction

It is not uncommon for shift workers to maladapt to working at night and sleeping during the day. This maladaptation can result in a multitude of negative symptoms including poor work performance and reduced alertness during night work and poor daytime sleep at home.[1] These negative consequences have been shown to be reversed through treatments utilizing bright light exposure and exogenous melatonin supplementation.[1] Not surprisingly, since bright light exposure and exogenous melatonin supplementation have improved shift work performance, there have been investigations into the influence that these treatment modalities have upon exercise performance. Unfortunately, the results of the aforementioned exercise performance investigations have been inconclusive.

With respect to muscular strength and endurance, it has been shown that the number of low intensity elbow flexions performed to exhaustion is 20%−40% greater when subjects worked with eyes open compared with eyes closed.[2] Further, when complete exhaustion was reached with closed eyes, opening of the eyes resulted in an immediate return of a work capacity.[2] Correspondingly, Zhang and Tokura[3] compared 8 h of exposure to either 5000 lux (lx) or 50 lx followed by 4 h of dim light (50 lx) and 10 h of dark exposure (sleep) upon handgrip endurance exercise. They found that the bright light exposure significantly increased the number of contractions by more than 20%.[3] Supplementing with melatonin to mimic hormonal responses to dark exposure, on the other hand, has

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not been shown to influence muscular strength and endurance. In 2001, Lagarde et al.[4] administered 5 mg of melatonin after eastbound air travel across seven time zones, and found no change (pre- to post-flight) in handgrip strength, squat jump, or multiple jump tests. In addition, Atkinson and colleagues[5] found that a melatonin dose of 5 mg had no effect upon grip strength. Similarly, Mero et al.[6] found no significant differences, following either 6 mg of melatonin or placebo ingestion, in the total volume of the weight lifted in high volume (25 sets of 70%−85% of 1 RM) lifting session consisting of bench press, lateral pull down, knee flexion, knee extension, and squat. In addition there were no significant differences in maximal squat, bench, or vertical jump measurements.[6]

Similar inconsistencies have been found when the exercise mode has been cycling. One of the first studies to look at the effect of light exposure on cycling measured changes in body temperature, body mass, and salivary lactic acid.[7] The subjects were under either dim (50 lx) or bright light (5000 lx) intensities for 6 h. They then exercised 60 min on a cycle ergometer at 60% maximal oxygen uptake in a light intensity of 500 lx. The main findings were significantly smaller increases in both core temperature and salivary lactic acid after exposure to 5000 lx. In 2000, O'Brien and O'Connor[8] examined three light intensities upon average power output during an all-out 20-min bout of cycling. They found no statistically significant differences in total power output between 1411 lx, 2788 lx, and 6434 lx. Similar findings were seen by two groups in 2001. Tetsuo and Takeomi[9] examined the effect 90 min in either 5000 lx or 50 lx had on supramaximal cycle performance and energy supply. After the 45 s supramaximal exercise, they observed that the different light exposures had no effect on power output, blood lactate concentration, or blood ammonia concentration. Blood glucose (BG) concentration immediately after supramaximal exercise, however, was significantly lower after bright light exposure. Ohkuwa et al.[10] also examined the effect 90 min in either 5000 lx or 50 lx had on supramaximal cycle performance and energy supply. Additionally, they measured catecholamine responses. Similar to the Tetsuo and Takeomi[9] findings, the different light exposures did not affect power output, lactate, ammonia, or plasma norepinephrine levels. On the other hand, BG concentration immediately after exercise and plasma epinephrine during the resting period were significantly lower after bright light exposure. Contrasting results were found by Kantermann et al.[11] They investigated the effects that 160 min of either 4420 lx or 230 lx had upon 40-min cycling at anaerobic threshold. They found total work was significantly higher in bright light as well as heart rate (HR) and blood lactate. Like the majority of the light intensity studies, melatonin supplementation does not appear to have a significant influence on cycling performance. In 2001, Atkinson et al.[12] fed 5 mg of melatonin or placebo before sleep. The following morning, the time to complete a 4-km time trial on a cycle ergometer was measured, and the mean differences between treatments was less than 1%. In another study, Atkinson and colleagues[5] again measured 4-km cycling time after 5 mg melatonin or placebo supplementation. Cycling time trials were done at both 75 min and 375 min post supplementation. The researchers again found melatonin had no effect on cycling performance.

The above research studies differ with respect to working musculature, activity modality, and light intensity exposure times. Therefore, it is not surprising that some results are conflicting. Overall it would appear that high intensity work is not affected by differing light exposures when the work is performed under the same light conditions. In addition, it appears that the impact of dark exposure on high intensity work is similar regardless of whether the work is done with either the arms or legs. On the other hand, it would appear that long-term dim light exposure prior to doing low intensity endurance arm work will result in a reduced work output. The influence of either long- or short-term dim light exposure prior to doing low intensity endurance work with the legs, however, has never been investigated. Therefore, the purpose of this study was to investigate low intensity leg muscular endurance following 1 h of exposure to dim light.

2. Methods

2.1. Participants

Participants consisted of 11 male (age = 24 ± 2 years, height = 182 ± 9 cm, body mass = 87 ± 16 kg) and five female (age = 20 ± 1 years, height = 169 ± 4 cm, body mass = 65 ± 7 kg) college students. Informed written and verbal consent was obtained from each participant prior to taking part in the experiment, and the appropriate institutional human participants review committee approved the study. The participants were not allowed to see the results until the study was completed.

2.2. Study overview

Participants visited the laboratory under three different conditions on 3 different days in a balanced randomized order. The three conditions varied with respect to laboratory light intensity and melatonin supplementation. The dark condition (DL) was 1 h of quiet sitting in the dark (<50 lx), the normal light condition (RL) was 1 h of quiet sitting under normal room light, and the third condition (RLM) was 1 h of quiet sitting in normal room light following the ingestion of 5 mg of melatonin. Since work performance could be confounded by changes induced by either sudden waking or continual striving to stay awake, a 1-h exposure time was chosen after preliminary tests showed that after 1 h in the dark it became exceedingly harder for a person to stay awake. Additionally, Mero et al.[6] showed melatonin levels to peak around 60 min post ingestion; therefore melatonin was administered immediately before the 1-h exposure to ensure that melatonin levels were high during the endurance test. A minimum of 48 h separated each condition. Each person was asked to maintain the same daily sleeping, dietary, and exercise routines for the duration of the study. Finally, all participants were asked to eat the same meal at the same time of day, and the meal needed to be within 1−2 h before their visit to the laboratory.