The Effect of Green LED Light Exposure on Isometric Exercise Performance

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Abstract

Athletic performance is the doorway to many opportunities, from professional sports to leading a healthy lifestyle. Fatigue is known as the leading factor preventing people from training to their full capacity and obtaining their desired athletic ability. Evidence has shown that exposure to green light lowers chronic, tactile pain and possibly increases athletic performance in track athletes. This study investigated the effect of exposure to green LED light on an isometric exercise performance. Participants (N=15) performed 3 unilateral dumbbell holds (LDH) with their dominant hand after one practice set with their non-dominant hand. The participants were randomly split up into two different groups; Group one was exposed to green LED light first while Group two was exposed to white LED light first. After at least four days the participants performed the same exact procedure with the only change being the light they were exposed to. We found that green LED light increased the duration participants were able to perform the LDH hold by 10.05%; participants exposed to the green light had an average LDH hold for 75.3 seconds as opposed to white light where the average was 69 seconds (P=0.01). These results have implications for utilizing green LED light for athletic training, specifically in regards to isometric strength training. Further research is needed to determine the extent to which utilizing green LED light can benefit athletes and people in general. More research needs to be done to see if these results translate to other types of training.

Introduction

People naturally strive to improve their athletic performance—whether it's to enhance overall health, pursue a career in professional sports, or simply gain more confidence in public. With ongoing advancements in technology, increased access to biomechanical data, and the development of new training methods, this goal is becoming increasingly achievable. In recent years, research has explored not only the surprising influence of environmental factors, such as vegetation and exposure to green light, on athletic performance, but also the critical role of targeted physical preparation. Among these methods, strength training has emerged as one of the most effective strategies for enhancing both physical capability and overall athletic potential [1].

Strength training is a type of workout regimen designed to promote muscle hypertrophy, increased strength, increased muscle tone and endurance by overloading muscle groups through repeated contractions or static holds [2]. Strength training can also improve cardiovascular health, tendon strength, ligament strength, bone density, metabolism, and lactate threshold, [3]. The type of strength training program used varies, depending on the goal of each individual. Circuit training is a workout method that involves performing a series of weight training exercises, each separated by short, timed rest intervals. Circuit training targets strength building and muscular endurance [4] . Hypertrophy training creates microscopic tears in muscle fibers through repeated contractions using challenging weight. This process stimulates the repair and growth of muscle tissue, resulting in an increase in the size of skeletal muscles due to the enlargement of individual muscle cells [5]. Isometric strength training utilizes a static contraction of muscle without change in muscle length or joint angle; examples include static wall sits, planks or static lunges [6]. Isometric exercises help maintain strength, aid recovery, prevent injuries, improve stability and balance, and build muscle endurance [7]. The different types of strength training used have demonstrated beneficial effects on athletic performance by enhancing athletic ability, reducing the risk of injury, improving recovery and supporting overall health [8]. Strength training has become a main focus for many coaches and athletes around the world due to the beneficial effects on athletic performance, furthering the possibility of obtaining a scholarship to universities, becoming a professional athlete, or just becoming a better competitor on the field.

Pain and fatigue are both byproducts of physical exertion occurring during strength training when surpassing what the individual human body is accustomed to [9]. Although these two entities coexist, they are two separate and distinct concepts. Pain can be defined as a feeling of either throbbing, sharp, or burning discomfort in a localized area; for example, throbbing pain in the right shoulder [10]. Fatigue is defined as a subjective feeling of exhaustion due to a range of factors and is for the most part generalized throughout the whole body [11]. Athletes can experience both of these entities with vigorous training regimens established to challenge their athletic ability. Training pain and fatigue can often be misinterpreted as tissue injury or illness by the athlete causing them to prematurely yield to the exercise without obtaining the optimal benefits [9]. It has been observed that an athlete's ability to tolerate higher training loads is more dependent on their central nervous system in comparison to their cardiovascular system, indicating the brain may restrict the body's ability to perform at a higher level [9]. Each individual's central nervous system has the ability to tolerate weight training depending on social, cultural, psychological and environmental factors [9]. A coach, for example, could motivate athletes to push past their mental limits, while on the other hand, it is possible one can be influenced by their peers to yield prematurely.

Using the fact that the central nervous system plays a major role in pain and fatigue tolerance, researchers search for other ways to push the body past their previous athletic limits by controlling the brain's susceptibility to pain. Studies have shown people who are exposed to green scenery, such as a highly vegetative outdoor area when compared to a less vegetative indoor area, have a faster walking pace and a lower perception of effort while walking [12]. Studies have also depicted similar results when it came to running: participants perceived a lower self reported physical exertion when running outside and performed better as opposed to running indoors on a treadmill [13]. A study done by the Western Colorado University also found that the peak power output (most amount of watts produced) while cycling was higher when outdoors than indoors by 70.57 watts. They also found that the average watts produced while cycling was also higher when outdoors compared to indoors [14]. Improved performance potentially has correlation with the antinociceptive effects that exposure to green light provides. Research on green light therapy has shown that rodents exposed to green light at 525 nm ocularly for a prolonged amount of time (over 8 hours a day for 3-5 days), at an intensity of 200 lux, had an increase in their tactile pain thresholds through a natural process of opioid excretion through the endogenous opioid system. This is due to the antinociceptive effects from these released opioids [15].When ocular green light therapy was used to treat chronic pain in patients, it was observed that there was a decrease in the activity of the anterior cingulate cortex (ACC) region of the brain which is responsible for pain signaling and can contribute to anxiety and depression if in a hyperactive state [16]. Green light therapy helps prevent hyperactivity of the ACC which helps reduce the development of chronic pain [16]. This suggests that this decreased activity in this region of the brain could correlate to athletes feeling less pain while exercising with the same weight while viewing green light, allowing them to push further than they would be able to in the absence of green light therapy.

In the present study, we focused on the effect of green light exposure on the time the participant could perform isometric exercise. We gave participants a unilateral dumbbell hold (LDH) task while they were exposed to either green LED light or white LED light as a control condition. We investigated whether green LED light would affect the duration in which the participants could maintain the LDH exercise indicating enhanced ability to sustain physical effort. We did this by comparing the time they held the dumbbell while viewing green LED light to white LED light. We hypothesized that participants exposed to green LED light would hold the isometric hold for a longer duration than when exposed to white light.

Methods

In this study we recruited 15 participants, ages 15-18 (9 females, 6 males). The data was collected at Shattuck St. Mary's (SSM) Preparatory School under the BioScience Signature Program. This study was approved by SSM's Research Ethics Review Board. All participants were required to fill out a consent form prior to their participation in the study. All participants indicated on the consent form that they were free of any shoulder injuries prior to the study.

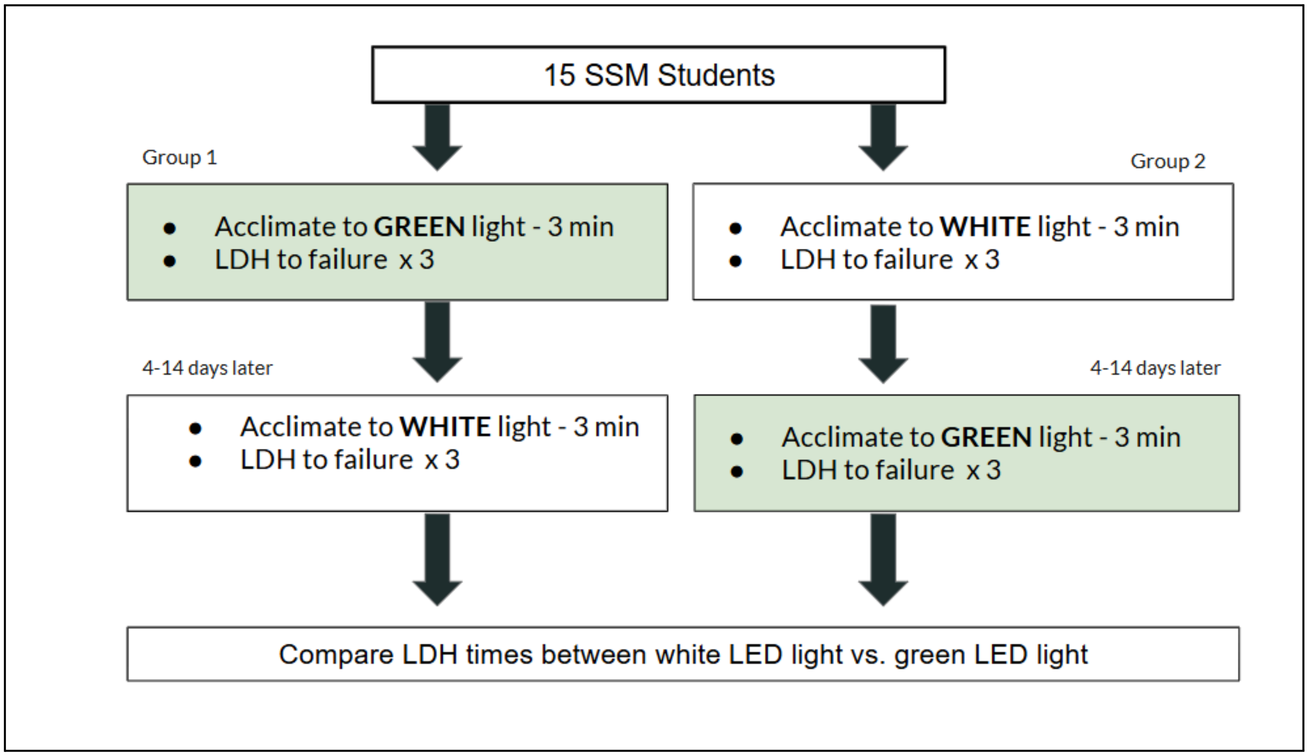

Fig 1: Schematic representation of experimental design.

Equipment

Three white LED lights from a white LED strip (JM-BG-YK-06M, JNGMAIR) along with three green lights from a green LED strip (B50N1, Yungo) were taped into the front inner portion of the virtual reality (VR) Goggles (NVRG-02, NOON). Both lights were set to 225 lux intensities using a LED dimmer (CA-K-018-BK, Weideer). All of the materials were purchased on Amazon. Each participant sat erect with their feet flat on the floor and the dominant arm extended out laterally as close to a 90 degree angle as possible, The poster behind the subject was marked at the 90 degree angle between their dominant arm and the upper lateral side of the torso on the coronal plane. This poster was made using a protractor, measuring tape and a marker. We also extended a stick vertically on the poster indicating 80 degrees as our failure point. Participants were given a 5 pound dumbbell for their unilateral dumbbell hold.

Procedure

Participants were randomly divided into two groups. Group one was exposed to green light in the first trial and white light in the second trial (Group 1, Session A). Group 2 was exposed to white light in the first trial and green light in the second trial (Group 2, Session B) (Fig 1). Participants were seated in the chair with their back against the backrest and their feet flat on the floor. Participants were then asked which hand they wrote with (“dominant” hand). The LDH was explained and demonstrated, followed by a practice session.

Practice set

Participants were told: *“You will sit in the chair and put the GLED goggles on without light. You will raise your arm laterally and completely straighten—there should be no bend at your elbow. Once you are at 90 degrees I will hand the dumbbell to your non-dominant hand.”* The researcher demonstrated the correct technique, and participants were asked to demonstrate that they understood how to perform the LDH. Participants performed the LDH with their non-dominant arm to failure during the practice session. They were informed that time would not be recorded, but they were to continue until failure. Once they reached failure, they lowered the dumbbell to the floor. “Failure” was defined as the point when the participant could no longer maintain the required joint angle (e.g., elbow fell below a threshold of 80°). When the elbow passed this point, the timer was stopped, and participants were instructed to lower the dumbbell to the floor.

Session 1: Training and Experimental Session 1

For the experimental LDH with the dominant arm, participants were informed that they would wear goggles and view either white or green LED light, depending on their assigned group. Goggles were placed on the participant’s head, and comfort and fit were adjusted as needed. The participants proceeded to sit, optically viewing the green light or white light at 225 lux for three minutes. The light was emitted from the goggles 1.9 inches from their eyes. Then the five-pound dumbbell was provided to the dominant hand while the arm was abducted at 90 degrees, and participants were seated with their back flush against the chair and feet flat on the floor. Participants simultaneously began the LDH until failure while the timer was started. When failure was reached, the timer was stopped, and participants were instructed to lower the dumbbell. The time was recorded. This part of the trial process was repeated three times to evaluate the long term fatigue. Participants were then asked to schedule a date and time for the next session. Participants were informed that they were free to leave. The dumbbell, chair, and goggles were sanitized.

Session 2: Training and Experimental Session 2

Participants were met 4-14 days after the first session, steps (above) were repeated. Subjects in Group 1 then participated in session B, Group 2 participated in session A.

Results

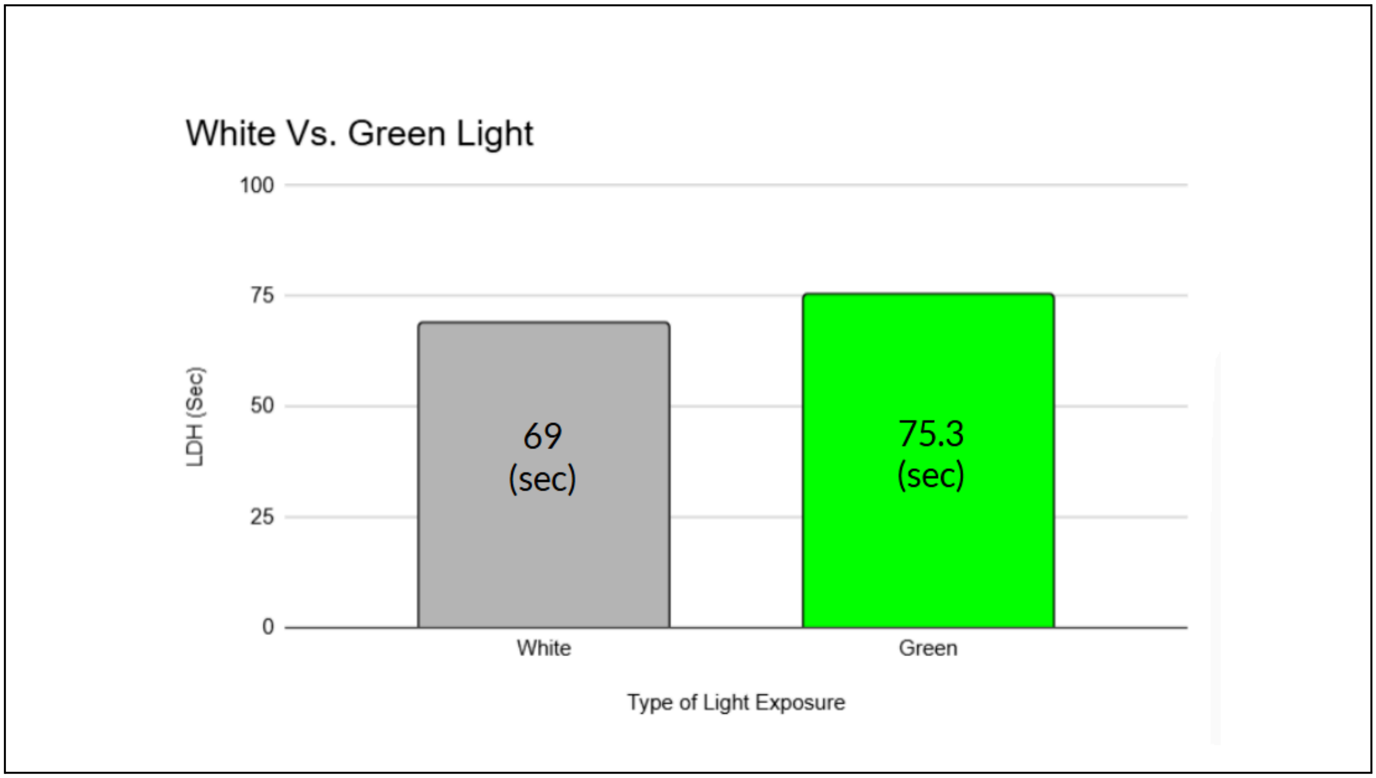

Fig 2: Comparison of average LDH time (sec) of subjects exposed to green and white LED light

Difference in average seconds of LDH hold between GLED trials and white LED trials. We conducted a paired-samples t-test with 15 participants to compare performance under GLED light and white light conditions. There was a significant difference in the LDH hold average time between the two trials ($p=0.01$). The mean duration of the isometric LDH exercise under GLED lighting was 75.3 seconds, whereas the mean time under white light was 69.0 seconds, representing a 10.05% increase in completion time under GLED conditions (Fig 2). The analysis yielded a t-value of 2.98 and a p-value of 0.01. These results indicate a statistically significant difference between the two lighting conditions ($p < 0.05$). Therefore, we reject the null hypothesis and conclude that green LED light has a positive effect on isometric exercise performance (LDH) in adolescents.

Discussion

The most effective type of medicine is preventive medicine, and physical exercise—regardless of one's background—is one of the most effective preventive measures against many diseases.

With the use of GLED light, we aim to reduce the fatigue that often accompanies this form of preventative care and increase the ability of individuals to perform these exercises, making it more accessible and sustainable for more people to achieve the well-being they deserve. The experiment we conducted indicates that there is a 10.05% increase in performance while executing the isometric exercise (LDH) when exposed to green light as opposed to white light. This aligns with other research which focuses on the positive effects of exercising in vegetative environments which correlates to green light due to the natural color of vegetation. When examining the effects of walking outdoors on the perception of physical exertion the subject experiences, it was concluded that walking in a natural environment their physical output was higher while their perception of physical exertion was lower as opposed to an indoor environment [12]. Similarly, athletes that trained on outdoor tracks reported a lower perceived effort compared with treadmill running [13]. Similarly, it has been observed that the level of vegetation in track fields is a huge indicator of athletic performance. Track athletes competing on more vegetative tracks have been reported to perform at a higher level in terms of track and field marks during their season as opposed to less vegetative tracks ($p=0.000$) [17]. It has been proven time and time again that outdoor exercise yields better results than indoor exercise. Clearly, green light exposure is a factor in decreasing perceived physical exertion and increased athletic performance.

Research specifically examining green light has shown elevated pain threshold as a result of visual exposure to GLED light. A study done at the University of Arizona showed that mice that were exposed to green light for 8 hours a day, 5 days a week experienced an increase in pain threshold when doing paw withdrawal testing compared to blue light, white light, room light, dark room light and no light [15]. Pain reduction from exposure to green light has also been observed in humans. Green light exposure was found to be an effective therapy to reduce pain intensity, frequency of headaches and impact of daily life on migraine patients when visually exposed to green LED light for one hour a day for four weeks, in conjunction with originally prescribed medication [18]. Visually administered green light therapy for 1-2 hours a day for 10 weeks viewed as ambient green light reduced and improved osteoarthritis pain and improved quality of life [19]. In our study we also viewed beneficial effects of green light in terms of the duration participants were able to hold LDH. Green light effects on antinociception is a possibility on why effects were observed in more vegetative environments.

The process in which antinociception occurs was widely unknown until 2023 when a study was released in regards to examining the cerebral effects of green light on mice. It was observed that the V2M region of the visual cortex, located in the occipital lobe, sends excitatory (glutamatergic) signals to the anterior cingulate cortex (ACC), a part of the brain involved in pain perception. These signals activate GABAergic neurons which are the main inhibitory neurotransmitter in the brain within the ACC. In turn, these neurons release GABA, a neurotransmitter that reduces neural activity. This inhibition decreases the likelihood that neurons in the ACC will fire, ultimately helping to dampen the perception of pain [16]. While not directly measured in this study, it's possible that the effect of green light exposure on antinociception resulted in participants in this study to reach what we determined as failure later as their brain perceives less pain as research suggests that an athlete's capacity to handle higher training loads depends more on the central nervous system than on the cardiovascular system [9]. Despite all the research on pain there is little research examining green light exposure on perceived exertion and ability to perform exercise, specifically isometric training. Though the duration exposure time and the way green light was viewed differs, similar results were obtained. More research needs to be done with more definitive ways to obtain numerical data and to see if these results translate to other types of exercise.

This study has several limitations that should be considered when interpreting the findings. First, 15 participants is a relatively small sample size and reduces the generalizability of the results and limits statistical power. Second, no physiological or biochemical markers were used to objectively assess fatigue, making it difficult to fully understand the underlying mechanisms driving the observed effects. Additionally, the researcher was aware of the light viewed by the participants, which introduces a potential source of bias in outcome evaluation. Finally, the determination of task failure was not determined by a machine but by human perspective, which may have affected the consistency and reliability of the performance measurements.

For future studies it would be beneficial to examine green light exposure on other types of exercise such as hypertrophy training, circuit training or powerlifting. It would also be beneficial to allow the participants to acclimate to the green light for longer periods of time and find the optimal intensity and wavelength for this purpose.

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