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Original Research Article

Effects of Green Environment on Anaerobic Performance

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ABSTRACT

Purpose: Previous studies suggest that "Green" (outdoor) exercise improves psychological and physiological performance when compared to indoor exercise. However, there is a lack of research comparing anaerobic performance in an outdoor versus indoor environment. The purpose of this study was to examine the effects of different environmental settings on anaerobic performance as measured by a Wingate test. We hypothesized that Rating of Perceived Exertion (RPE) and the Fatigue Index (FI) will be lower, while Peak Power Output (PPO) and Average Power Output (APO) will be greater in the "Green" (outdoor) environment compared to an indoor environment. **Methods:** A single-blind crossover study was conducted with 18 participants between the ages of 18-30 who met ACSM's guidelines for physical activity. Participants completed a Wingate protocol on a cycle ergometer in both an indoor and outdoor setting. Power, heart rate, and RPE measurements were collected to compare indoor versus outdoor performance. **Results:** All subjects were able to complete both indoor and outdoor Wingate sessions. PPO for the indoor (831.53 ± 248.81 W) and outdoor (904.10 ± 336.94 W) sessions were significantly different ($p < 0.05$. APO for the indoor (425.15 ± 117.67 W) environment and outdoor (438.59 ± 127.16 W) environment were significantly different ($p < 0.05$). FI was not significantly different ($p > 0.05$) between indoor (39.59 ± 9.76%) and outdoor (40.75 ± 9.69%) sessions. RPE was not significantly different between indoor (7.67 ± 0.97) and outdoor conditions (7.89 ± 1.13) ($p > 0.05$). Furthermore, post-Wingate heat rate was not significantly different ($p > 0.05$) for indoor (178.39 ± 23.17) versus outdoor (173.00 ± 19.85) environments. **Conclusion:** These findings suggest that a green (outdoor) environment enhances anaerobic performance, specifically peak and average power output during a Wingate test. However, a green environment does not appear to influence fatigue index or RPE.

KEYWORDS: Anaerobic Endurance, Green Exercise, Wingate.

Introduction

Green exercise is defined as physical exercise that occurs outside in natural environments[1]. Green exercise has been shown to improve the psychological outcomes of moderate-intensity cycling in a green setting, and could be an effective way of improving physical activity levels[2]. Psychological improvements that directly affect performance can have many applications for both the athletic and clinical populations. It was found that exercise in a pleasant, green, environment versus an indoor environment may have a greater effect on blood pressure, an important measure of cardiovascular health, and on measures that are relevant to mental health with authors concluding that green exercise has important implications for public and environmental health[1]. A study examining the occlusion of senses on mood, rating of perceived exertion (RPE), and heart rate found that when senses were occluded, there was a greater decline in mood versus individuals who exercised with all senses available. Additionally, RPE and heart rate were elevated in the sensory occluded group[3]. This suggests that senses are necessary to maintain lower RPE and heart rate while exercising and also suggests that indoor exercise (where some of these senses may be blocked) may lead to a decline in performance versus outdoor exercise. Ceci et al. found that at equivalent RPE for indoor treadmill running and outdoor field running, subjects were able to exercise at a greater running velocity, heart rate, and blood lactate concentration in an outdoor environment[4]. This result suggests that outdoor exercise may allow individuals to exercise at a greater intensity, while feeling lower levels of exertion, suggesting that there are greater performance capabilities in the outdoor setting.

While there may be conflicting results regarding the extent to which green exercise can benefit an individual's psychological state and physiological performance capabilities, results strongly suggest that green exercise can provide performance benefits that cannot be obtained in an indoor environment. While studies have examined the benefits of green exercise on overall health, including psychological health and aerobic performance, there is a lack of studies analyzing the potential ergogenic effects of a green environment on anaerobic performance. Thus, the question arises: does a green environment enhance anaerobic performance? Many sports such as weightlifting, ice hockey, or track cycling rely significantly on the anaerobic system and competition in these sports can occur either in a green or indoor environment. Hence the potential findings of this study could be used to increase and achieve peak performance in sports with high anaerobic demands with the use of the appropriate environment.

This inquiry into the potential benefits of a green environment on anaerobic performance can be further examined by utilizing the Wingate test to measure anaerobic performance. Anaerobic performance can be defined as the maximal amount of ATP produced through anaerobic metabolism during short, maximal exercise. The Wingate test is a 30 second maximal anaerobic exertion test that can be performed on the upper or lower body. Wingate testing can quantify an individual's anaerobic abilities by providing values for Peak Power Output (PPO), Average Power Output (APO), and Fatigue Index (FI).

- PPO: the peak power output, for one second, during a Wingate test.
- APO: the average power output

during the duration, 30 seconds, of a Wingate test

- FI: A measure of anaerobic endurance; the percent difference between the maximum five second power and the minimum five second power produced during a Wingate test. Ex. A lower FI means an individual has greater anaerobic endurance compared to an individual with a greater FI.

Wingate testing has been shown to have high test-retest reliability with reliability coefficients for peak lactate and heart rate values of 0.93 and 0.94, respectively[5]. As such, Wingate testing has been proven to be the gold standard in measuring anaerobic capacity in clinical and athletic populations[6]. When a Wingate test is performed using the lower body, the test is conducted on a cycle ergometer. There have been various procedures investigating the effects of extraneous factors on Wingate test outcomes. Reiser et al. conducted a study comparing the differences between completing the Wingate test standing versus sitting[7]. The authors found that a sitting protocol will produce a more uniform and consistent anaerobic capacity test for all athletes of various backgrounds. On the other hand, a standing protocol will produce biased and inconsistent data, especially for experienced cyclists. For obtaining optimum performance during the Wingate test, Pujol et al. examined if listening to music during the test would enhance performance outcomes during a Wingate Test[8]. Listening to music was shown to have no effect on performance.

Due to extensive research suggesting psychological and physiological benefits in increasing performance for both clinical and athletic population, the purpose of this study was to further expand upon the potential benefits of green exercise by examining the effects (if any) of a green environment on anaerobic performance. More specifically, how does an indoor versus outdoor (green) setting affect anaerobic power, as quantified through a Wingate test? As such, we hypothesized that participants will have greater anaerobic performance (as quantified by Peak Power Output, Average Power Output, and Fatigue Index) while reporting lower RPE in a green environment. On the other hand, Wingate tests in an indoor environment will result in decreased anaerobic performance with greater RPE.

Methods

Participants

18 participants, 10 males and 9 females, ages 18-30 participated in this study. Table I describes the demographic of the subjects. All participants met ACSM's guidelines for physical activity and were also screened for cardiovascular health risk factors. Subjects were asked to wear the same or similar clothing for both Wingate test sessions. Participants completed all test sessions without issue. This study was approved by the Human Research Committee at Western Colorado University. Each participant signed an informed consent form prior to participation.

Table 1. Demographic of subjects

Subjects	Age (years)	Height (cm)	Weight (kg)
N = 18: 10 males, 8 females	22.61 ± 3.03	174.67 ± 7.38	74 ± 16.05

Note: Values are average ± standard deviation

Reliability and Validity

In regard to the reliability and validity of our testing methodology, the Wingate test has been shown to have high test-retest reliability with reliability coefficients for peak lactate and heart rate values of 0.93 and 0.94 respectively[5]. The Wingate protocol is considered to be a gold standard in measuring anaerobic capacity in clinical and athlete populations[6].

Experimental Design

This was a single-blind, crossover study in which participants completed two Wingate tests four days apart. Participants were randomly assigned to either the OUTSIDE or INSIDE group during an initial meeting. Prior to the testing sessions, all participants were carefully informed of the testing protocol, potential risks of the study, familiarized with the cycle ergometer, and voluntarily signed Western Colorado University's consent to participate form. Additionally, all participants' questions were answered. The indoor environment was inside the High-Altitude Performance (HAP) Lab, in a corner with only grey walls and grey shades to block any outside views. The outdoor environment was outside of the HAP Lab underneath a tree on a sidewalk surrounded by an open field with a clear view of mountains. The INSIDE group completed their first Wingate test in the indoor environment, then completed their second Wingate test in the outdoor environment, four days apart. The OUTSIDE group completed their first Wingate test in the outdoor environment, then four days later completed their second Wingate test in the indoor environment. Participants were split into these two groups to help eliminate any carryover effects from the first to the second test. Figure 1 shows the study design and timeline of the testing protocol.

Baseline testing was completed before the participant's first Wingate test in the HAP Lab. Height and weight were taken with what the participant would wear during the test; participants were asked to wear the same clothing for both tests. Once height and weight were completed, participants were then equipped with a heart rate monitor and asked to be seated in a chair for approximately five minutes to acquire their resting heart rate and resting blood pressure before beginning the warm-up protocol.

Participants completed an identical warm-up protocol for both tests. Warm-ups consisted of a dynamic stretching routine followed by a cycling warm-up on the cycle ergometer. The dynamic stretch routine included a quadricep, hamstring, glute and hip stretch, followed by high knees and butt kickers. Participants would then pedal for two minutes, unweighted, on the cycle ergometer at their preferred cadence before a practice sprint of 160 RPM for males and 150 RPM for females. This was followed by one minute of pedaling prior to the test.

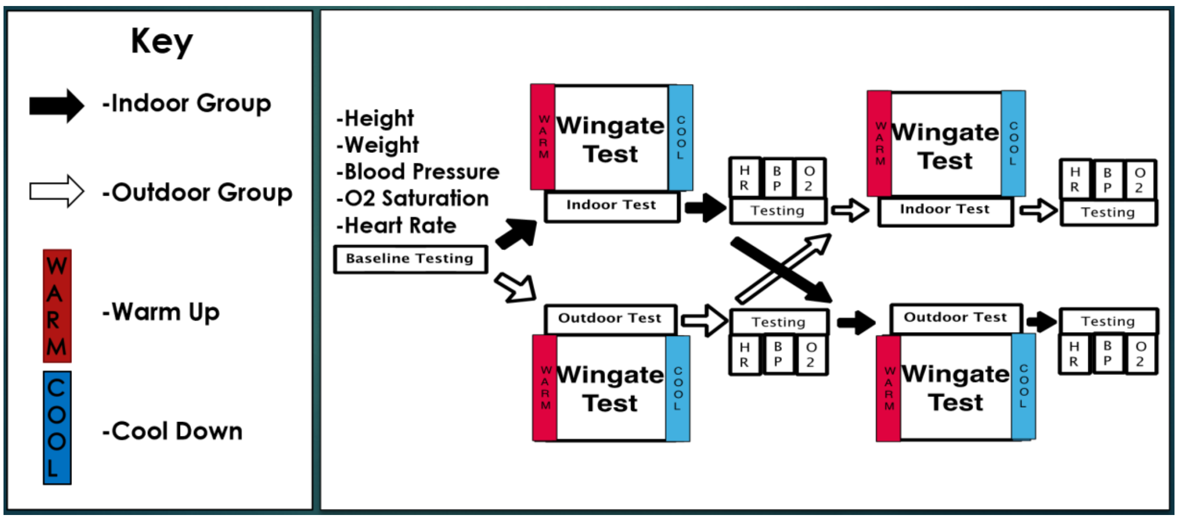

Figure 1: Shows the study timeline. The INDOOR group follows the black arrow path. The OUTDOOR group follows the white arrow path. Each group began with baseline testing followed by the first Wingate test with the proper warm up and cool down protocol. Post-test testing consisted of heart rate (HR), blood pressure (BP) and oxygen saturation (O2). The environments were then switched for the second Wingate test. Another round of baseline testing was completed, consisting of HR, BP and O2. The second Wingate test was completed with the same guidelines and protocols as the first test.

Wingate Test

Due to the findings of Resier et al., the sitting protocol was adopted for the purposes of this study. Resistance of the cycle ergometer was set to 6.4% times the subject's body weight (kg). Subjects were instructed to pedal to the target cadence (revolutions per minute; RPM), 160 RPM for males and 150 RPM for females, to begin the test. Once the test began, subjects were encouraged by the research team, via positive vocal encouragement, to produce a maximal effort for the entirety of the 30 second test. Subjects were notified when there were 15 seconds and five seconds remaining in the test.

Sources of Data

The Wingate test was administered on a Monark 894E Anaerobic Wingate Ergometer Bicycle. Data was collected from the Monark Anaerobic test program, which provided data regarding peak power output (PPO), average power output (APO), and data to calculate fatigue index (FI) for each participant.

Process of Data Collection

For each participant at rest, information was gathered about age, height, weight, resting heart rate and resting blood pressure. After the practice sprint on the cycle ergometer during the warm-up protocol, pre-test measurements were taken for heart rate and blood oxygen saturation. Immediately post-test, heart rate, blood oxygen saturation and rate of perceived exertion were measured. From the Monark Anaerobic Test program PPO, APO, and FI were all collected.

Statistical Analyses

A comparison of mean data between indoor and outdoor environments was conducted utilizing paired t-tests for the PPO, APO, and FI. Heart rate was compared for resting, pre-test and post-test between environments. RPE was compared for post-test between environments. All data was analyzed using the Statistical Package of the Social Scientists (SPSS) analysis from IBM. A paired sample t-test was utilized with a probability level of p set at 95% was used to show statistical significance.

Results

All subjects were able to complete both indoor and outdoor Wingate sessions. No subjects fainted or complained of lightheadedness at the conclusion of the test sessions. There were three primary markers for anaerobic performance that were measured and reported. These measurements include PPO, APO, and FI. In addition to these measurements, resting, pre-test, and post-test heart rate were recorded as well as rate of perceived exertion, blood pressure, blood oxygen saturation, and temperature during the Wingate tests. Blood pressure and blood oxygen saturation are not reported and were used to primarily ensure that subjects were not in danger of fainting (orthostatic measures) at the conclusion of the Wingate test.

Peak Power Output

PPO is defined as the maximum amount of power, in watts, that a subject could achieve for one second during the Wingate test. Figure 2 represents the average of all PPO for subjects in the indoor and outdoor environment. There was a significant difference between the indoor and outdoor environment with the p-value equal to 0.017. The average PPO for the indoor environment was 831.53 ± 248.81 W. The average PPO for the outdoor environment was 904.10 ± 336.94 W.

Average Power Output

APO is defined as the maximum amount of power, in watts, that a subject could achieve for 30 seconds during the Wingate test. Figure 3 represents the average of all APO for subjects in the indoor and outdoor environment. There was a significant difference between the indoor and outdoor environment with the p-value equal to 0.049. The average APO for the indoor environment was 425.15 ± 117.67 W. The average APO for the outdoor environment was 438.59 ± 127.16 W.

Fatigue Index

FI is defined as the percent power loss between max five second power and minimum five second power. It is a measure of anaerobic endurance with greater FI values indicating lower anaerobic endurance and lower FI values indicating greater anaerobic endurance. FI was calculated accordingly[9]:

$$FI = \left(\frac{Highest\ average\ 5\ second\ power - Lowest\ average\ 5\ second\ power}{Highest\ average\ 5\ second\ power}\right) \text{ x } 100$$

Figure 4 represents the average of all FI values for subjects in the indoor and outdoor environment. There was no significant difference between the indoor and outdoor environment with the p-value equal to 0.56. The average FI for the indoor environment was 39.59 ± 9.76%. The FI for the outdoor environment was 40.76 ± 9.69%.

Heart Rate, Rating of Perceived Exertion, and Temperature

All average values for heart rate measurements, RPE and temperature as well as their associated significance are reported in Table II. Heart rate was measured at three points during a test period: resting, pre-test, and post-test. Average resting heart rate for the indoor environment was 72.56 ± 14.52 beats per min (BPM) while the average resting heart rate for the outdoor environment was 69.72 ± 8.53 BPM. This difference was not significant with a p-value of 0.294. Average pre-test heart rate for the indoor environment was 123.11 ± 20.29 BPM while the average pre-test heart rate for the outdoor environment was 116.72 ± 15.72 BPM. This difference was not significant with a p-value of 0.069. Average post-test heart rate for the indoor environment was 178.39 ± 23.17 BPM while the average post-test heart rate for the outdoor environment was 173 ± 19.85 BPM. This difference was not significant with a p-value of 0.117.

Rating of perceived exertion (RPE) was based on a 1 - 10 scale, with 1 being considered as "very, very light exercise", 5 being considered "moderate exercise", and 10 being considered "maximal effort". The average indoor RPE was 7.67 ± 0.97 while the average outdoor RPE was 7.89 ± 1.13. This difference, however, is not significant with a p-value of 0.386.

Temperature was recorded at the start of each Wingate test for each subject. The average indoor temperature was 22.17 ± 0.71 °C while the average outdoor temperature was 13.00 ± 1.46 °C. The difference in temperature between environmental conditions was significant with a p-value < 0.001.

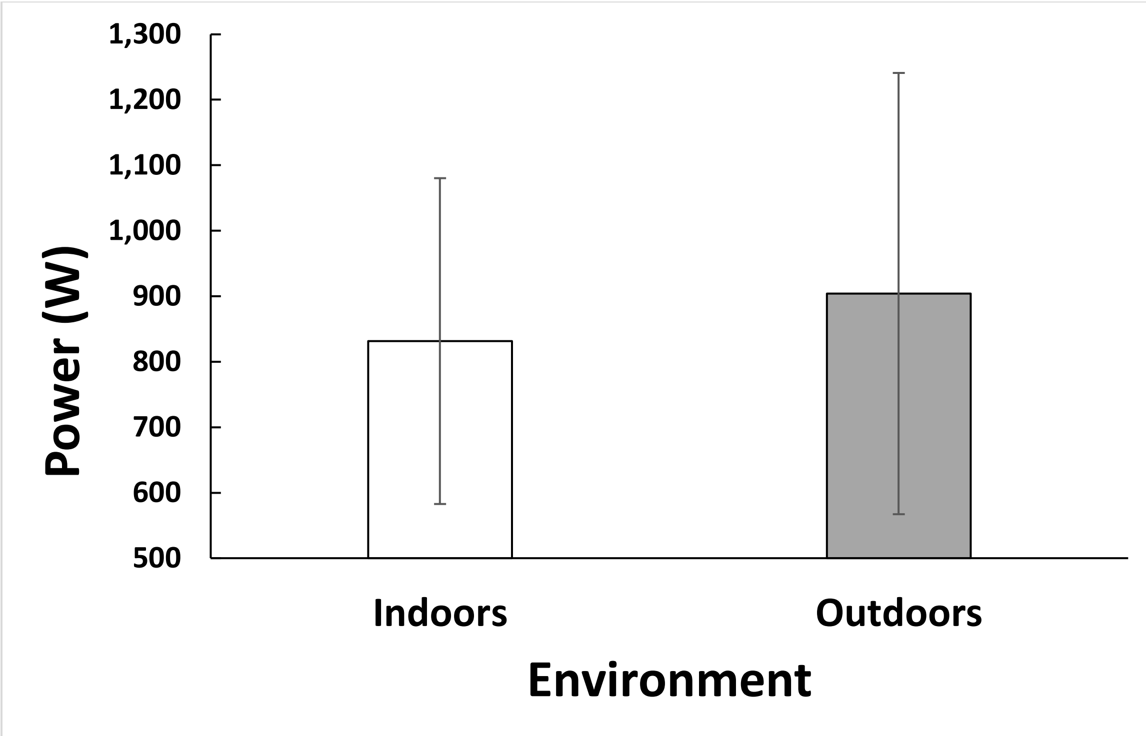

Figure 2. Peak power of subjects comparing indoor versus outdoor test environments. *Significant difference between environmental conditions (P < 0.05).

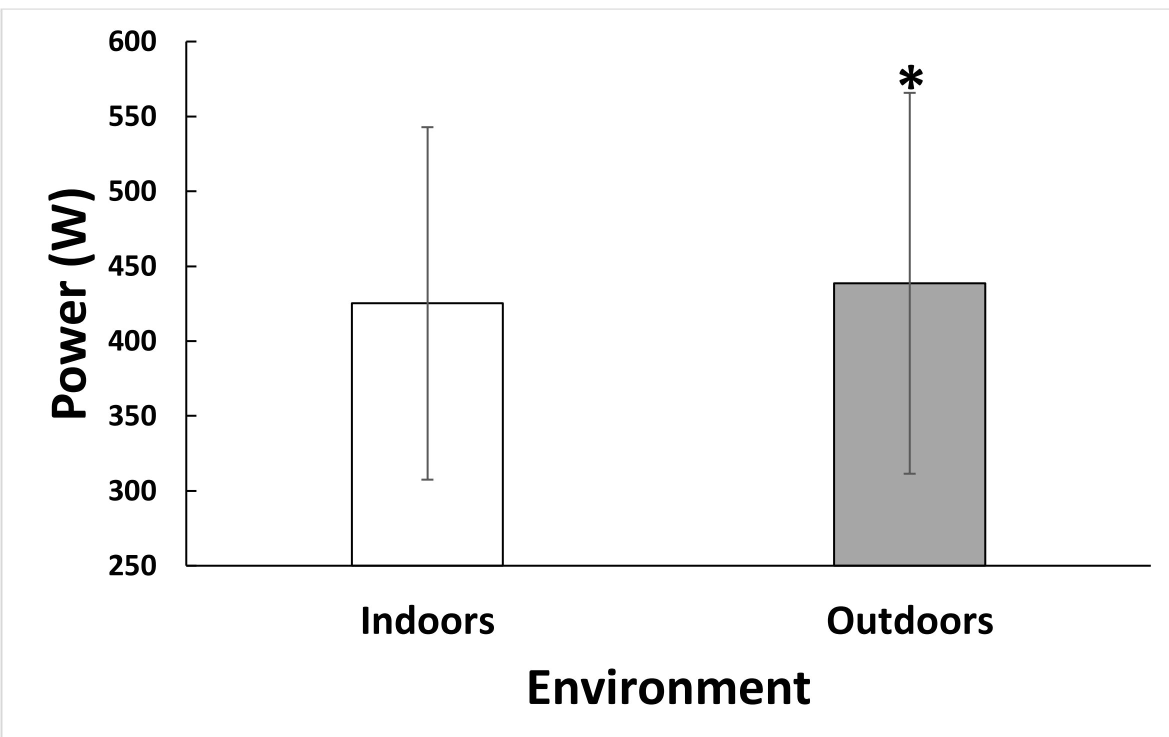

Figure 3. Average power of subjects comparing indoor versus outdoor test environments. *Significant difference between environmental conditions (P < 0.05).

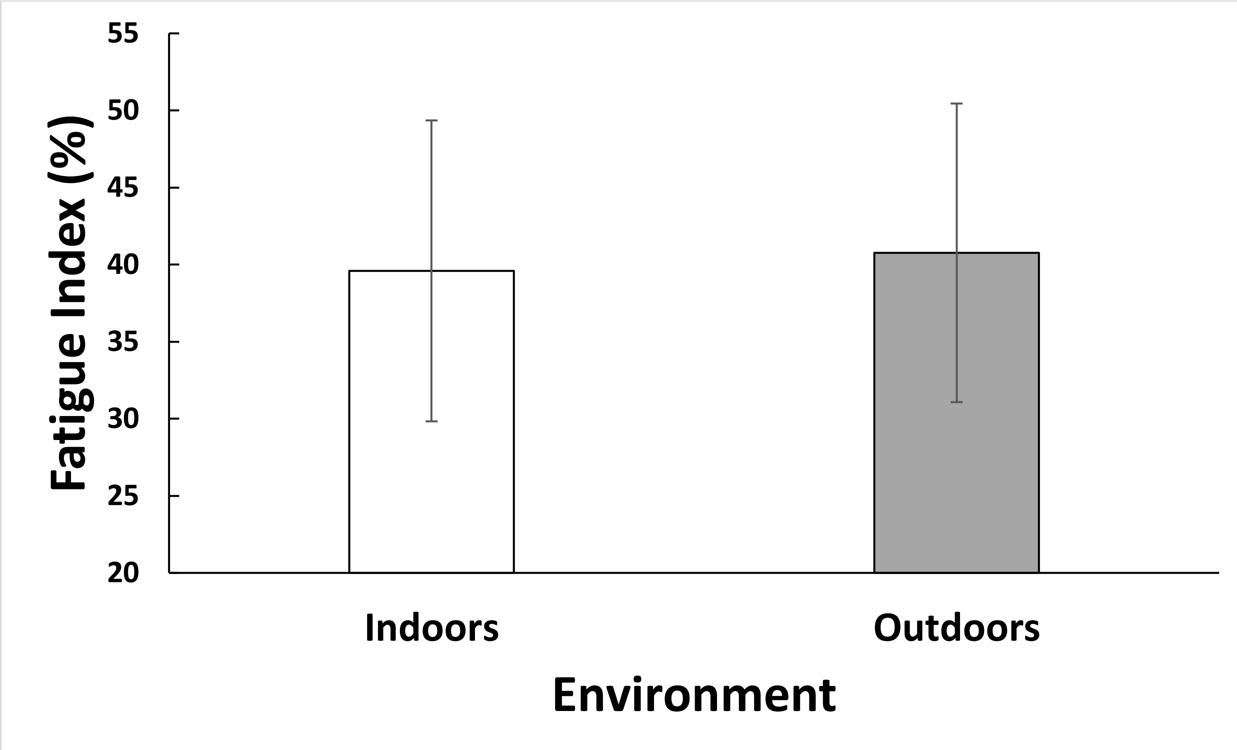

Figure 4. Fatigue index of subjects comparing indoor versus outdoor test environments. No significant difference between indoor and outdoor environment was found.

Table 2. Inside versus outside environment: average resting heart rate, pre-test heart rate, post-test heart rate, rating of perceived exertion, and average environmental temperature.

Variable	Indoors	Outdoors	Significance
Resting Heart Rate (BPM)	72.56 ± 14.52	69.72 ± 8.53	0.294
Pre-Test Heart Rate (BPM)	123.11 ± 20.29	116.72 ± 15.72	0.069
Post-Test Heart Rate (BPM)	178.39 ± 23.17	173.00 ± 19.85	0.117
Rating of Perceived Exertion (1 – 10)	7.67 ± 0.97	7.89 ± 1.13	0.386
Temperature (°C)	22.17 ± 0.71	13.00 ± 1.46	<0.001

Note: Values are average ± standard deviation

Discussion

The major finding from this study is that a green environment appears to enhance anaerobic performance versus an indoor environment as made evident by: 1) greater PPO in the green environment versus the indoor environment 2) greater APO in the green environment versus indoor environment. These increases in PPO and APO were observed despite no significant difference in pre-test and post-test heart rate as well as subject reported RPE.

Peak Power Output and Average Power Output

It appears that in a green environment, subjects were able to produce, on average, greater PPO and APO than subjects in the indoor environment. Previous research has observed similar increases performance in a green environment, but in the realm of aerobic exercise. Mireas et al. observed that in a green environment, subjects completing a 40-km cycling time trial were able to produce a higher average power and have a lower time to completion compared to an indoor environment[10]. Furthermore, it is possible that there is a psychological benefit in exercising in a green environment, which may allow for greater sensory stimulus leading to increased performance. Focht et al. found that individuals who exercised in an outdoor environment reported improvements in affective responses, pleasant affective states, and general enjoyment compared to an indoor setting. These results suggest that the environment, especially one that can enhance general enjoyment through various sensory stimuli may have performance enhancing effects[11]. It is possible that in addition to the general enjoyment that an outdoor environment may provide, the additional sensory stimulus may distract the exercising individual from the discomfort that may be associated with exercising. The increased enjoyment paired with distraction from the workout's discomfort may allow individuals to enhance their performance by exercising at a higher intensity while experiencing a lower RPE.

Fatigue Index

No significant difference was observed between the indoor and outdoor group in regards to fatigue index. In this study, participants were not controlled for intake of caffeine, sleep, or hydration levels, which in previous studies have shown to have performance altering effects depending on dosage[12-14]. However, there is evidence that caffeine ingestion, amount of sleep prior to testing, and hydration status do not affect FI during a Wingate test[15-17]**.** FI may not have been altered regardless of environment because of the nature of how FI is calculated. Since FI is calculated based on peak and minimum five second power, the relative increases in the individuals' maximum and minimum power outputs will maintain the same difference regardless of environment or other variable such as caffeine, sleep, or hydration status. In other words, in the outdoor environment, individuals in our study were able to produce a greater five second power and have greater five second minimum power, when compared to their indoor power outputs. As such, while power production was greater in the outdoor environment the relative difference between five second maximum and minimum power remained similar as made evident by an insignificant difference in FI.

Heart Rate and RPE

Despite greater anaerobic performance in the outdoor environment compared to the indoor environment, there was no significant difference in heart rate and RPE among subjects. However, there is a trend suggesting that outdoor heart rate was lower at resting and pre-test, but more importantly post-test. While outdoor subjects produced greater PPO and APO, heart rates were trending lower post-Wingate test. Previous studies have shown that heart rate was lower in some subjects who exercised in a cold setting, which may explain why lower heart rate were observed in subjects during the outdoor Wingate test[18]. Furthermore, contrary to our results, previous studies have shown that in green environments RPE was lower than in indoor environments[10]. This again, may be attributed to the lower temperature of the environment. The increased cold stress may have slightly increased the RPE of the outdoor subjects, however, this did not appear to affect the anaerobic performance of the subjects.

Temperature

There was a significant difference in environmental temperature with the outdoor environment being approximately 9°C lower in temperature than the indoor environment. Previous studies had found that subjects who completed a Wingate tests in temperature of -2 to -22 °C experience a 40 W decline in PPO and APO compared to subjects who completed Wingate tests in 10-32 °C[19]. While the subjects in this study did not experience a similarly drastic difference in temperature during the Wingate tests, it is possible that the stimulus of the outdoor environment may have been able to elicit a significant anaerobic performance enhancement to override the decrements due to the cold stimulus. Consequently, anaerobic performance in the outdoor may have been greater than observed had the temperature in the outdoor environment been similar to the indoor environment.

Limitations

Due to scheduling constraints and weather in the Gunnison Valley during the fall months, equivalent indoor temperature was difficult to achieve in the outdoor environment. As such, future research regarding the benefits of a green environment on anaerobic performance should control for temperature to accurately compare the difference due to the environment.

Additionally, sleep, hydration levels, caffeine in-take, and training were not controlled for in this study. While previous literature suggests that these factors do not affect fatigue index, there may be other performance measure decrements or improvements if subjects achieve less sleep, are hypohydrated, or fatigued from training prior to testing. Furthermore, caffeine has been shown to have ergogenic effects in regard to performance. As such, this may lead to an increase in performance during a Wingate test. These variables should be further explored in conjunction with a green environment to examine if there are deleterious or ergogenic effects when properly controlled for.

Applications

Green exercise, when used in the appropriate setting and situation, may be able to enhance the experience of activities or enhance performance. The increase in psychological stimulation may be helpful for those suffering with depression or mental illness[20]. As suggested in this study, a green environment can enhance anaerobic performance, which has applications in enhancing anaerobic training as well. Since individuals are able to produce greater amounts of power, the associated training stress will increase. This increase in training stress suggests that the individual may need a stronger adaptive response to recover from a more intense exercise bout. As a result, once recovered, the individual who exercised in an outdoor environment may have greater and more significant adaptations, leading to increased performance, compared to an individual who may have exercised in an indoor environment.

Conclusion

The purpose of this study was to examine how the difference in environment (green, outdoor versus indoor) would affect anaerobic performance as measured by PPO, APO, and FI during a Wingate test. We had hypothesized that in the green, outdoor environment subjects would produce greater peak and average power outputs while achieving a lower fatigue index and reporting lower RPE when compared to subjects in an indoor setting. The results revealed that in the outdoor environment subjects could produce greater PPO and APO. However, there was no significant difference in FI or RPE when comparing subjects in the indoor versus outdoor environment. Furthermore, while there was a trend of greater resting, pre-test, and post-test heart rate in the indoor environment when compared to the outdoor environment, the differences observed were not statistically significant. Future research may explore the control of temperature, caffeine ingestion, sleep, hydration status, and training status to more accurately measure the benefits of a green environment on anaerobic performance.

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