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Utilizing Breathing Techniques to Maximize Training Performance

Peyton Cater

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UTILIZING BREATHING TECHNIQUES TO MAXIMIZE TRAINING PERFORMANCE

By

Peyton Cater

Bachelor of Arts
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A thesis submitted in partial fulfillment
of the requirements for the

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Department of Kinesiology and Nutrition Sciences
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Peyton Cater

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Department of Kinesiology and Nutrition Sciences

James Navalta, Ph.D.
Examination Committee Chair

Arpita Basu, Ph.D.
Examination Committee Member

Dharini Bhammar, Ph.D.
Examination Committee Member

Jenifer Utz, Ph.D.
Graduate College Faculty Representative

Kathryn Hausbeck Korgan, Ph.D.
Graduate College Dean

ABSTRACT

Utilizing Breathing Techniques to Maximize Training Performance

Anaerobic exercise causes metabolic acidosis to occur in the muscle, which is unfavorable for sustaining high intensity activity, as fatigue starts to set in. In order to compensate for the onset of fatigue produced by an acidic environment, respiratory alkalosis, induced by hyperventilation, can be performed to mitigate these effects. In contrast, research has shown that slowing down the breath rate, such as a two second inhale and three second exhale, has led to an increase in performance outcomes. **Purpose**: To investigate power output and the physiological responses after implementation of different breathing techniques during the recovery periods of intermittent high intensity cycling. **Methods**: Ten recreationally active participants (four females and six males) performed 10 sets of 10 second standing sprints on a WattBike with 60 seconds of recovery between sets. In a counterbalanced, crossover design, participants implemented a breathing condition (hyperventilation, downregulation, and unregulated breathing) during the recovery periods of the exercise protocol. Hyperventilation was performed in the last 30 seconds of each recovery period at a breathing rate of 60 breaths per minute (bpm) to decrease the end-tidal partial pressure of carbon dioxide ($P_{ET}CO_2$). Downregulation was performed immediately following the sprint set and began with 8 quick breaths at a rate of 60 bpm followed by slowing down the breath rate to a two second inhale and four second exhale for the remainder of the recovery period. Mean and peak power outputs were examined for each sprint set to compare how the breathing conditions affected training performance over time.

Results: No significant difference in mean and peak power outputs were found between conditions (mean power: p = .485, peak power: p =.148) and no significant condition x time interaction was found for mean (p = .553) and peak power outputs (p =.341).

Conclusion: Neither hyperventilation nor downregulation attenuated the decrease in power output across sprint sets, indicating that implementing these breathing conditions may not be useful for improving training performance. However, it is possible that these breathing techniques need to be practiced and perfected over time to elicit performance enhancements.

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CHAPTER 1

INTRODUCTION

Utilizing the breath as a tool to enhance ability and efficiency has emerged as a method for improving sport and performance. Techniques such as hyperventilation and deep breathing have been used to offset fatigue, and positively affect performance outcomes (Sakamoto, 2014; Gray, 2018). It remains unclear, however, whether or not these different breathing techniques positively affect repeated sprint training protocols. Therefore, continuing to investigate different breathing techniques and how they affect training and physiology may be beneficial for developing strategies to improve performance.

A major mechanism of fatigue during high intensity exercise is excessive hydrogen ion [H+] release from ATP hydrolysis via an increased rate of anaerobic glycolysis (Green, 1997; Robergs, 2004). The increase in [H+] decreases intramuscular pH and impairs the energy supplying systems of phosphocreatine (PCr) and anaerobic glycolysis (McMahon, 2002), and results in metabolic acidosis. A proposed strategy to offset the fatigue that results from metabolic acidosis during high intensity exercise is hyperventilation. Hyperventilation is an excessive rate and depth of respiration that leads to a large decrease in the partial pressure of carbon dioxide (PCO_2), thereby eliminating more CO_2 than is produced. Hyperventilation thus increases blood pH, leading to respiratory alkalosis (Fujii, 2015) and may be able to offset fatigue and attenuate the decrements in performance that are seen over time.

Very few studies have examined the effects of hyperventilation on performance, and based on the current literature, it is not certain whether or not hyperventilation can offset fatigue. A few studies have shown that hyperventilation has the ability to reduce aerobic metabolism and increase anaerobic metabolism when implemented during anaerobic sprint protocols (Dobashi, 2017; Fuji, 2015; Sakamoto, 2014), however these metabolic compensations did not affect peak and mean power output (Fuji, 2015; Dobashi, 2017). In contrast, when implemented during the recovery periods of intermittent sprints, it has been shown that hyperventilation attenuates the decrease in power output (Sakamoto, 2014). Along with hyperventilation, deep breathing, slow and controlled breathing that aims to downregulate heart rate and facilitate recovery, has been identified as another possible breathing strategy to enhance performance. It has been implemented before swimming races (Jacob, 2015) and tennis drills (Cupeiro, 2017), however only slight, non-significant improvements in performance were found.

With the uncertainty of the current research, incorporation of breathing techniques during training is worth further exploring. The purpose of this study is to investigate the physiological responses and performance outcomes of different breathing techniques implemented during intra-set recovery periods on repeated sprints. In a randomized, crossover design, two experimental breathing techniques, hyperventilation and downregulation, along with a control condition, will be implemented during the recovery periods of multiple sprint sets. I am examining whether different breathing techniques have a positive effect on power output during repeated sprint training, as well as its effects on physiological variables. The primary hypothesis of this study is that hyperventilation and a downregulation breathing technique implemented during the recovery periods of repeated sprint sets will both attenuate the decrease in power output that occurs over multiple sprint sets. The secondary hypothesis is that a downregulation breathing technique implemented during the recovery periods of intermittent sprints will lead to a lower heart rate during the recovery periods than hyperventilation and control conditions.

CHAPTER 2

REVIEW OF LITERATURE

Introduction

Strategies to improve performance are constantly being examined, and one such strategy is the incorporation of breathing techniques. As an essential mechanism of human function, and with its effects on acid-base balance, it is important to examine how breathing affects performance. Researchers have implemented various breathing techniques, such as hyperventilation and deep breathing, across different performance modalities to investigate whether it is capable of improving performance.

Fatigue is one of the most important determinants when looking at performance, making it beneficial to analyze strategies that may counteract the mechanisms of fatigue. One such mechanism that has been proposed is the accumulation of hydrogen ions [H^+] (Robergs; Green, Glaister; Bishop). Anaerobic exercise results in an accumulation of [H^+] from glycolytic metabolism, and leads to metabolic acidosis (Robergs, 2004). It is thought that the decrease in blood pH from [H^+] accumulation impairs the glycolytic pathway, leading to fatigue (Glaister, 2005). Therefore, increasing the extracellular buffering capacity could prevent fatigue by offsetting the acidity associated with high intensity exercise. Numerous studies have also shown that utilizing oral supplementation of sodium bicarbonate ($NaHCO_3$) leads to improvements in performance due to its ability to increase the extracellular buffering capacity and offset fatigue (Bishop, 2005; Gough, 2018; Dalle, 2019; Driller, 2012; Miller, 2016).

However, to avoid the use of exogenous interventions, other studies have implemented hyperventilation to induce respiratory alkalosis (Sakamoto 2014; Fuji, 2015; Dobashi, 2017; Chin, 2007; Morrow, 1988; Jacob, 2015; Cupeiro, 2017; Forbes, 2007). Respiratory alkalosis is characterized by an increase in blood pH and a decrease in the end tidal partial pressure of carbon dioxide (PETCO$_2$) induced by hyperventilation. One study has demonstrated an increase in performance when hyperventilation was implemented during the recovery periods of repeated all-out sprints (Sakamoto, 2014; Jacob, 2015), while others that implemented hyperventilation during their protocols saw no improvement in performance (Sakamoto, 2018; Fuji, 2015; Dobashi, 2017; Cupeiro, 2017). Interestingly, other studies have examined the effects of deep breathing protocols and found an improvement in performance (Gray, 2018). Currently, it is unclear whether breathing techniques, such as hyperventilation and deep breathing, are sufficient strategies to improve performance. Therefore, the aim of this review is to examine the implementation of different breathing techniques on the physiological responses associated with hyperventilation (PETCO$_2$, oxygen uptake, blood lactate, [H$^+$], blood pH) and whether it can influence performance outcomes.

$P_{ET}CO_2$

During exercise, hyperventilation is a compensatory mechanism for lowering CO$_2$. Physical activity leads to a buildup of CO$_2$, which leads to an increase in the arterial partial pressure of CO$_2$ (PCO$_2$) (Bussotti, 2008). Therefore, an increase in respiration is required to offset the increase in PCO$_2$ and lower acidosis. Different methods are used to induce the decrease in PCO_2 through a reduction of $PETCO_2$ below 25mmHG. A normal range of $PETCO_2$ is 35-40mmHG. Some studies found that twenty minutes of hyperventilation implemented before exercise lead to a decrease in $PETCO_2$ (Fuji, 2015; Dobashi, 2017; Chin, 2007,2010; Forbes, 2007), while others implemented shorter hyperventilation periods ranging from 15-45 seconds (Sakamoto, 2014, 2015, 2018; Cupeiro, 2017; Jacob 2015). All methods achieved the desired effect by manipulating the respiratory rate. Longer hyperventilation protocols were able to achieve a lower $PETCO_2$ by using a respiratory rate between 30-40 breaths per minute and tidal volume of one liter (Dobashi, 2017; Fuji, 2015), or by analyzing $PETCO_2$ and maintaining ~20mmHG by displaying breath by breath data on a computer screen (Chin, 2007,2010; Leithauser, 2016, Forbes, 2007). Shorter hyperventilation protocols used higher respiratory rates of 60 breaths per minute (Sakamoto, 2014, 2015, 2018) lasting 30 seconds (Davies, 1986; Sakamoto, 2014, 2015), or 15 and 45 seconds (Sakamoto, 2018) and also achieved a $PETCO_2$ between 20-25mmHG. No studies reported subjects feeling discomfort, lightheadedness, or dizziness upon hyperventilation.

Oxygen Uptake

It appears that hyperventilating before and during exercise leads to a reduction in oxygen uptake (Chin, 2007), suggesting a decreased adaptation of muscle oxygen consumption. Forbes et al. supported these findings by showing a slower breakdown of muscle phosphocreatine (PCr) with hyperventilation compared to normal breathing during moderate intensity plantar-flexion exercise (Hyp, 39 s [SD 22]; Con, 32 s [SD 22], P 0.05), and also showing that the amplitude of the response was greater (Hyp, 26 %

[SD 4]; Con, 22 % [SD 6]). Because the amplitude of the PCr response reflects the amount of ATP supply, a greater amplitude indicates greater ATP supply from substrate-level phosphorylation and decreased ATP supply from oxidative phosphorylation.

Twenty minutes of hyperventilation implemented before a Wingate Anaerobic Test (WAnT) also lead to a reduction in oxygen uptake compared to the control. Fuji et al. (2015) showed an oxygen uptake of 1.55 ± 0.52 vs. 1.95 ± 0.44 L/min ($P < 0.001$), between hyperventilation and control, respectively. Dobashi et al. (2017) also showed a reduction in oxygen consumption after 20 minutes of hyperventilation ($P < 0.001$). In addition, Sakamoto et al. showed a reduction when 45 seconds (2018) of hyperventilation was implemented before repeated sprints, but not when 15 (2018) or 30 (2014) seconds was implemented. The reduction in oxygen uptake seen in some studies suggest a leftward shift in the oxyhemoglobin dissociation curve causing a decrease in oxygen delivery to muscle tissue. These results suggest a reduction in aerobic metabolic rate and a compensatory increase in anaerobic metabolic rate. Based on the findings by Sakamoto et al. (2014, 2018), it is possible that the length of the hyperventilation period may affect how it influences oxygen uptake, suggesting that the longer hyperventilation protocols lead to a reduction in oxygen uptake and muscle oxygen consumption.

Blood Lactate

To further elucidate these findings, hyperventilation can lead to a larger increase in blood lactate. A higher accumulation of blood lactate seen during hyperventilation suggests a slower uptake of lactate and an increase in anaerobic metabolic rate. It was found that blood lactate was higher post-exercise in the hyperventilation condition compared to normal breathing after a single bout of WAnT (Fuji, 2015: Dobashi, 2017), but not in subsequent bouts of WAnT (Dobashi, 2017). In contrast, no significant differences between hyperventilation and normal breathing were seen in blood lactate concentrations after a single WAnT test (Leithauser, 2016), during and after a repeated sprint protocol (Sakamoto, 2014), after 45 seconds of maximal effort sprints (Morrow, 1988) and after a tennis drill (Cupeiro, 2017). These equivocal findings make it difficult to understand the effects of hyperventilation on blood lactate concentrations. It is possible that the exercise protocol and the way in which hyperventilation is achieved influences how hyperventilation affects blood lactate. Aside from one study, the studies that saw increases in blood lactate implemented a WAnT as their exercise protocol which consists of a max effort 30 second sprint, as well as twenty minutes of hyperventilation. The studies that found no differences consisted of either longer sprint protocols (Morrow, 1988) or intermittent high intensity activity with 30 seconds of pre-exercise hyperventilation (Sakamoto, 2014). This suggests that a change in blood lactate concentration may depend on activity type and length of hyperventilation, favoring longer hyperventilation protocols and 30 second sprints.

$[H^+]$ and Blood pH

The accumulation of $[H^+]$ as a result of ATP hydrolysis during exercise leads to a decrease in blood pH and thus results in metabolic acidosis. It is postulated that the metabolic acidosis that occurs may affect intermittent sprint performance (Bishop, 2012) via inhibition of phosphorylase and phosphofructokinase (PFK) (Glaister, 2005), which are essential enzymes in anaerobic glycolysis. Chin et al. (2007) showed that 20 minutes of hyperventilation before moderate intensity exercise resulted in a significantly greater decrease in the amount of $[H^+]$ from baseline to the post-hyperventilation period and during exercise (36 ± 0.1 vs. 23 ± 0.2 vs. 25 ± 0.1) compared to normal breathing (33 ± 0.3 vs. 31 ± 0.3 vs. 34 ± 0.3). Consequently, blood pH levels significantly increased ($P < 0.05$) from baseline to end of exercise in the hyperventilation condition (7.44 ± 0.02 vs. 7.54 ± 0.03) compared to normal breathing (7.48 ± 0.04 vs. 7.41 ± 0.02). In support of these findings, Forbes et al. (2007) showed the same trend in $[H^+]$ levels from baseline to post-hyperventilation and during moderate intensity plantar flexion exercise compared to normal breathing, with a significant difference between conditions ($P < 0.05$). Both studies illustrated that hyperventilation was able to reduce the amount of $[H^+]$ from the end of the hyperventilation accommodation period (20 mins) to the end of exercise and during the recovery period better than normal breathing.

Implementing hyperventilation for 30 seconds before repeated sprints also resulted in higher blood pH compared to normal breathing ($p = 0.007$) (Sakamoto, 2014), however not when implemented for 15 or 45 seconds before repeated sprints

(Sakamoto, 2018). Blood pH was also not different between 30 seconds of hyperventilation and normal breathing after repeated maximal isokinetic knee extensions (Sakamoto, 2015). However, when a 15 minute hyperventilation protocol was implemented before a WAnT, pH was higher immediately pre and post test (P = .000) (Leithauser, 2016). Morrow et al. (1988) also found that 15 minutes of hyperventilation performed both before and after a 45 second sprint lead to higher pH values than did normal breathing performed before and after. It appears that implementing longer periods (15-20 minutes) of hyperventilation before exercise leads to higher pH levels during various forms of anaerobic work. However, the lack of significant results when shorter hyperventilation lengths (15s vs. 30s vs. 45s) are used suggests that short periods of hyperventilation may not affect blood pH levels.

Performance Outcomes

Based on the physiological responses that occur as a result of hyperventilation, it has been speculated whether hyperventilation is capable of improving performance outcomes. Sakamoto et al. (2018) implemented short and long duration breathing methods of 15s and 45s at a respiratory rate of 60 breaths per minute and showed no improvement in repeated pedaling sprint performance. However, in a previous study by Sakamoto et al. (2014) using the same exercise protocol, 30s of hyperventilation at 60 breaths per minute attenuated the decrease in power output from first to last sprint. The control vs. hyperventilation, first-to-last sprint, decrement was -6.4% vs. -3.9%, respectively, for peak power, and -8.2% vs. -5.5%, respectively, for mean power. Sakamoto et al. (2015) also evaluated maximal knee extension performance where maximal voluntary isokinetic concentric knee extensions were performed for 12 repetitions x 8 sets at 60°/s, followed by 25 reps x sets at 300°/s. When hyperventilation was implemented in between sets, they found a significant increase in torque output at 60°/s for the first and fourth sets only ($P = 0.032$ and $P = 0.040$, respectively), which lacks sufficient evidence that hyperventilation can attenuate a decrease in torque output over multiple sets.

It also appears that hyperventilation does not improve WAnT performance. Fuji et al. (2015) and Dobashi et al. (2017) showed no differences in peak power output and mean power output between 20 minutes of hyperventilation and normal breathing conditions. However, Leithauser et al. (2016) showed a significant increase in peak and mean power output between 15 minutes of hyperventilation and normal breathing ($p = .017$), suggesting that an improvement in cycling performance is due to hyperventilation. Based on these studies, it remains unclear whether hyperventilation can improve WAnT performance.

Only a few studies have examined sport specific exercise with hyperventilation and these studies implemented a 30 second hyperventilation protocol. Cupeiro et al. (2017) investigated the effects of hyperventilation on an intermittent tennis drill and found no significant difference in running speed ($P=0.664$) and mean stroke speed ($P=0.958$) between conditions. Jacob et al. found that compared to normal breathing, hyperventilation increased the average velocity of a 50-meter front crawl (1.79 ± 0.14 vs. 1.81 ± 0.13 m/s, respectively, $P < 0.01$). However, a limitation of both studies includes that neither study measured $PETCO_2$ or PCO_2 to ensure respiratory alkalosis. To add, Jacob et al. defined hyperventilation as 6 cycles of maximal breathing (2 seconds of maximal inspiration followed by 3 seconds of maximal expiration), which contradicts typical hyperventilation protocols that require a faster rate of breathing to elicit respiratory alkalosis.

Another study that aimed to improve performance investigated the effects of using deep breathing before a 50 yard and 100-yard freestyle sprint (Gray, 2018), using the same protocol as mentioned above (two second inhalation and three second exhalation). Although not significant, it was found that 30 seconds of deep breathing decreased 50-yard swim time compared to normal breathing (28.18 ± 1.59 vs. 28.45 ± 1.90 secs), which could still be crucial in actual competition. These results are in line with the results of Jacob et al. (2015). Therefore, it is possible that slow, deep breathing, as opposed to hyperventilation, may have positive effects on performance, however, there is limited research on deep breathing, and therefore warrants more research.

Conclusion

The current research has shown that incorporating hyperventilation before anaerobic exercise and during the recovery periods of intermittent sprints can potentially offset fatigue and improve performance. However, research hasn’t shown whether hyperventilation can improve other types of performance. Specifically, it is unclear whether hyperventilation is able to improve sport specific performance, such as tennis and swimming. It appears that hyperventilation may only be able to improve intermittent sprints of short duration (< 30 seconds). There is also convincing evidence that hyperventilation may be able to increase the anaerobic metabolic rate, indicating that implementing hyperventilation may be a useful strategy for training. It is possible that over time, training with hyperventilation will increase performance via an increase in anaerobic metabolism. However, utilizing hyperventilation and deep breathing practices has not been extensively studied and warrants further investigation. Future studies will need to examine how the length of different hyperventilation protocols and different modalities of anaerobic exercise affect fatigue and performance.

CHAPTER 3

METHODOLOGY

Participants

Prior to conduction of the study, a G*power analysis was run to determine sample size for a within factors repeated measures ANOVA. An effect size of 0.16 was used based on repeated measures criteria, as well as a power of 0.8, 3 groups, 10 measurements, and a correlation of 0.9, revealing a sample size of 9. This study was approved by the University of Nevada, Las Vegas Institutional Review Board. Ten healthy, recreationally active participants (4 females and 6 males) with a mean age of 24.1 years (SD = 2.81) participated in this study. Participants were screened for activity level using the International Physical Activity Questionnaire (IPAQ) and had to obtain a moderate or high score to participate in this study. Participants were recruited from the University of Las Vegas student population and screened using the ACSM Health Risk Questionnaire to determine inclusion. Their average body mass, height, and BMI were 72.7 ± 15.64 kg, 169.7 ± 11.56 cm, and 24.84 ± 2.95 kg/m^2, respectively. In a counter-balanced, crossover design, participants underwent three different breathing conditions: hyperventilation, downregulation, and unregulated breathing (control). A familiarization session was also included for a total of four visits, where participants gave written informed consent, filled out inclusion questionnaires, and practiced the exercise protocol under unregulated breathing conditions, as well as practiced the breathing conditions while seated.

Apparatus and Task

The experiment was performed in the UNLV Exercise Physiology Laboratory and each visit took approximately 30-60 minutes. Participants performed the exercise protocol on a WattBike Pro (Wattbike; Nottingham, UK) and the WattBike app (Apple; iPhone XS) was connected to the bike to determine power output across sets. During the recovery periods, participants implemented the corresponding breathing condition and a MR 500 Quartz Metronome (Matrix; Korea) was used to set the breath rate. Participants were fitted with a face mask to measure breath by breath expired gases using TrueOne 2400 metabolic system (Parvo Medics; Salt Lake City, UT, USA). An H9 Telemetry HR monitor (Polar USA; Bethpage, NY, USA) and a PC-60B fingertip pulse oximeter (Creative Industry; Shenzhen, China) were also worn to measure heart rate and peripheral oxygen saturation throughout the entire exercise protocol.

Procedure

The exercise protocol consisted of 10 sets of 10 second standing maximum sprints on a WattBike with 60 seconds of light active recovery between sets. Pedal resistance was found using the WattBike's programmed 30 second power test, which simulates the Wingate Anaerobic Test (WAnT). Upon entering the participant's weight, the program provided a resistance (1-9) based on the weight entered. Both breathing protocols (hyperventilation and downregulation) were instructed to inhale through the nose and exhale through the mouth. During the hyperventilation condition, hyperventilation occurred in the latter 30 seconds of each recovery period up until the acceleration period began preceding the sprint. In order to induce respiratory alkalosis, the breathing rate was set at a cadence of 60 breaths per minute using a metronome (Sakamoto, 2014). During the downregulation condition, eight breaths at a rate of 60 breaths per minute (full nasal inhales and forceful mouth exhales) were performed immediately following each sprint set. Slower breaths then followed the eight quick breaths at an inhale: exhale ratio of 1:2, which was standardized to a two second inhale and four second exhale and was performed throughout the rest of the recovery period until the acceleration period began. To control the breath rate, participants watched a clock located on the wall in front of them to time the inhales and exhales. The control condition consisted of unregulated, spontaneous breathing throughout the entire recovery period, with no instruction on how to breath.

Upon entering the laboratory, participants sat for five minutes and baseline heart rate and oxygen saturation was obtained. Each test began with a 10-minute cycle warm-up at 60rpm and half of the participants prescribed WattBike resistance sprint load. Following the warm-up, a single 10 second sprint set at the prescribed sprint resistance was performed for practice, followed by 3 minutes of rest. During the rest period, participants were fitted with a face mask that was connected to the metabolic cart. The participant began pedaling 30 seconds before the onset of the first sprint and a five second acceleration period was performed before each sprint to ensure maximum power was being performed throughout the ten second sprint. During the recovery periods, participants were allowed to sit on the bike and instructed to pedal lightly to keep the WattBike connected to the app. The following were measured during the recovery periods: heart rate (recorded at the end of each recovery period- about ten seconds before each sprint), peripheral oxygen saturation (recorded immediately after each sprint (SPO_2-1) and within the last 15 seconds of the recovery period (SPO_2-2)), and rating of perceived breathlessness (RPB) using the modified Borg dyspnea scale (asked immediately after each sprint). Respiratory rate (RR), minute ventilation (V_E), expired tidal volume (V_T), end-tidal partial pressure of carbon dioxide ($P_{ET}CO_2$), volume of oxygen inhaled (VO_2), and volume of carbon dioxide exhaled (VCO_2) were measured throughout the entire protocol. Peak and mean power output were measured during each sprint set using the WattBike app. The participant then chose his/her cooldown and the test was terminated once heart rate returned below 100 beats per minute (bpm).

Statistical Analysis

Statistical analysis was performed using SPSS software (Version 26.0 for Windows, IMB, Inc., Chicago, IL, USA). A test-retest of reliability was analyzed using intraclass correlation for the mean and peak power outputs using the familiarization values. Mean baseline values for mean and peak power outputs (first sprint set) were measured using a one-way ANOVA to compare similarity between conditions. Mean and peak power outputs were analyzed using a 3x10 repeated measures ANOVA to test for the main effects of condition (control vs. hyperventilation vs. downregulation), time (sprint set number) and their interaction (time x condition).

All remaining variables were also analyzed using a 3x10 repeated measures ANOVA (RR, V_E, V_T, SPO_2-1 and RPB) and a 3x9 repeated measures ANOVA ($P_{ET}CO_2$, VO_2, VCO_2, SPO_2-2, and HR) to test for condition, time, and condition x time interaction. $P_{ET}CO_2$ values were averaged for the last 30 seconds of each recovery period (nine recovery periods) to compare the effects of hyperventilation to control and downregulation. Ten second pre-sprint and post-sprint RR, V_E, and V_T values were averaged between seconds 40-50 of the recovery period as to not account for the five second acceleration period that occurred before each sprint. The ten second post-sprint values were averaged across the first ten seconds after each sprint. VO_2 and VCO_2 were averaged across the entire 60 second recovery period.

For cases where the assumption of sphericity was violated, significance was determined using the Greenhouse-Geisser adjustment. When a significant condition x time interaction was found, a one-way ANOVA was used to compare differences using Bonferroni corrections. When a significant time or condition effect was found, mean differences were determined using pair-wise comparisons with Bonferroni corrections. For all statistics, significance was accepted at $p < .05$. Effect sizes in the form of eta squared (η^2) were calculated where $0 .01< \eta^2 < 0.06$ indicates a small, $0.06< \eta^2 < 0.14$ a moderate, and $\eta^2 > 0.14$ a large effect.

CHAPTER 4

RESULTS

4.1 Power Output

Mean first sprint baseline values between conditions were not significantly different for mean power ($p = .796$, $\eta^2 = .129$) or peak power ($p = .899$, $\eta^2 = .089$). The test-retest reliability of mean and peak power outputs using intraclass correlation can be seen in Table 1. There was not a significant condition x time interaction for mean ($p = .553$, $\eta^2 = .075$) or peak power ($p =.357$, $\eta^2 = .108$). A significant time effect for mean ($p <.05$ $\eta^2 = .437$) and peak power outputs ($p < .05$, $\eta^2 = .333$) was found, however, with Bonferroni corrections, the pairwise comparisons revealed no significance between any time points (see figures 1 and 2).

Sprint Set	Intraclass Correlation	95% Confidence Interval	
		Lower bound	Upper bound
1	0.934	0.757	0.983
2	0.946	0.799	0.986
3	0.894	0.631	0.973
4	0.946	0.800	0.986
5	0.972	0.893	0.993
6	0.923	0.722	0.980
7	0.920	0.713	0.980
8	0.908	0.676	0.976
9	0.921	0.717	0.980
10	0.911	0.685	0.977

Table 1. ICC for mean power output values between unregulated and pretest (familiarization).

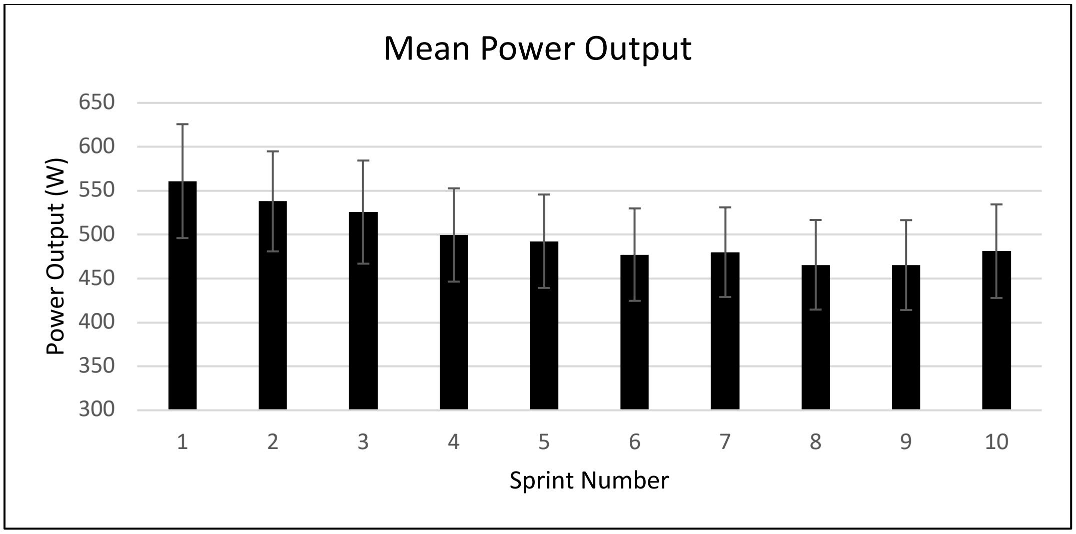

Figure 1. Mean power output. Mean power output over time from participants (N = 10) who completed 10-sec maximal cycle sprints with 60-sec active rest intervals while performing different breathing protocols during recovery. Error bars represent standard errors.

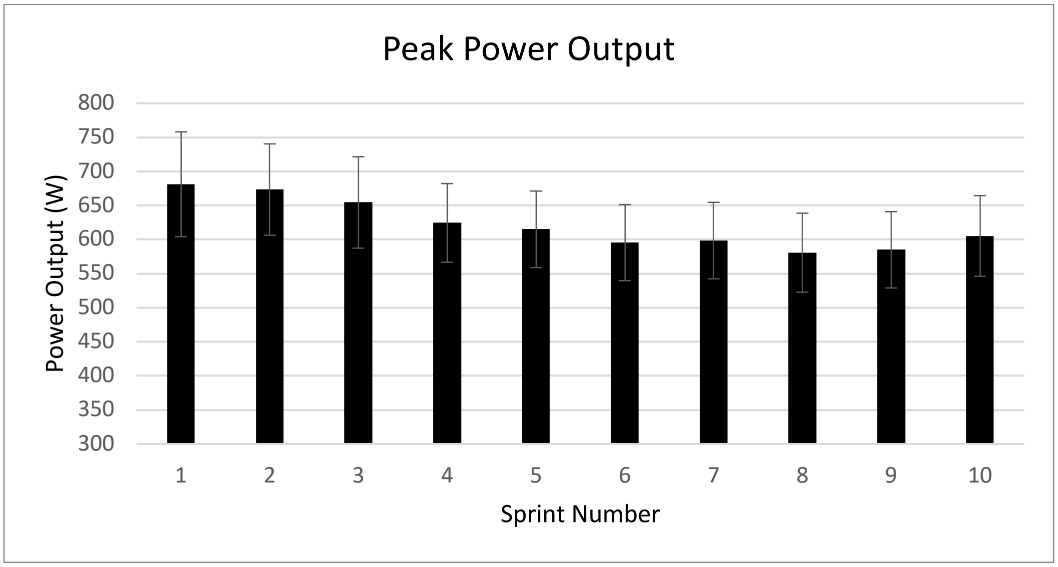

Figure 2. Peak power output. Peak power output over time from participants (N = 10) who completed 10-sec maximal cycle sprints with 60-sec active rest intervals while performing different breathing protocols during recovery.

4.2 $P_{ET}CO_2$

A significant condition x time interaction ($p < .05$, $\eta^2 = .318$) was observed for end-tidal partial pressure of carbon dioxide, indicating an effect of breathing conditions on $P_{ET}CO_2$ from first to last sprint. It was found that there was a significant difference between unregulated and hyperventilation ($p < .05$) and hyperventilation and downregulation ($p < .05$) in recovery period one. Recovery period two showed a significant difference between all three conditions and recovery periods 3-9 showed a significant difference between unregulated and downregulation ($p < .05$) and hyperventilation and downregulation ($p < .05$), see figure 3.

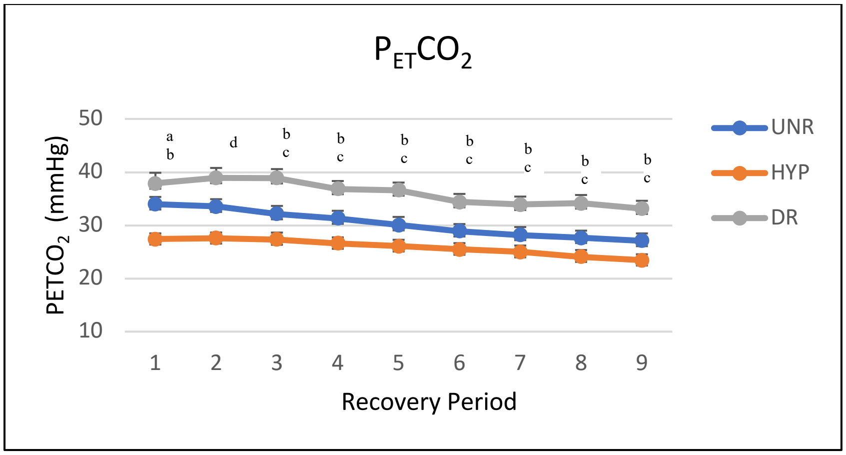

Figure 3. Mean $P_{ET}CO_2$. Mean end-tidal partial pressure of carbon dioxide averaged over the last 30 seconds of each recovery period. a = significant difference between unregulated and hyperventilation, b = significant difference hyperventilation and downregulation, c = significant difference between unregulated and downregulation. d = significant difference between all three conditions.

4.3 RR, V_E, and VT

A significant condition x time interaction was observed for both pre-sprint ($p < .001$, $\eta^2 = .840$) and post-sprint RR ($p < .05$, $\eta^2 = .339$). For pre-sprint RR, there was no significant difference between any two conditions at sprint one ($p > .05$), however there was a significant difference between all three conditions at every time point after ($p < .05$), see figure 4. For post-sprint, there was a significant difference between unregulated and downregulation ($p < .05$) and hyperventilation and downregulation ($p < .05$) for the first four sprints. A significant difference occurred between unregulated and downregulation ($p < .05$) for sprint five and six, and no significant differences occurred between any conditions from sprint 7-10, indicating differences between conditions in earlier sprint sets but not later sprint sets (see figure 5).

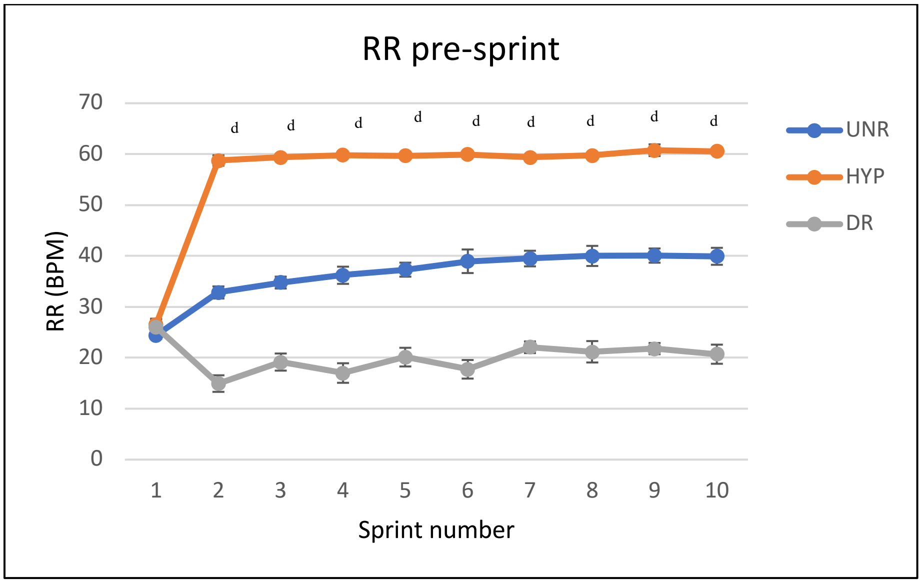

Figure 4. Changes in respiratory rates preceding each sprint set. Breath by breath data was averaged over ten seconds and taken between the 40 second and 50 second mark so as to not account for the acceleration period that preceded each sprint. d = significant difference between all three conditions.

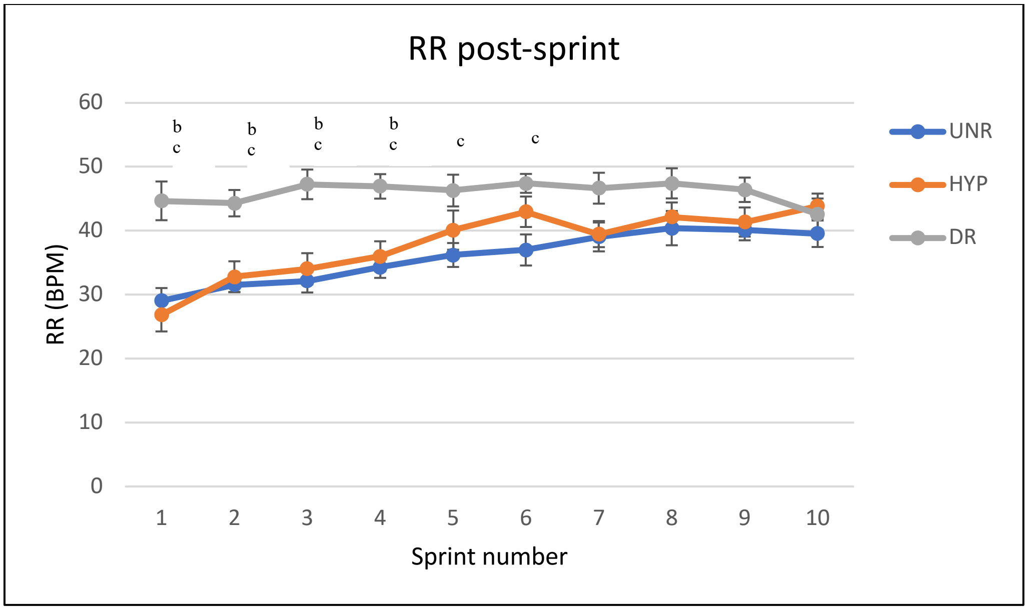

Figure 5. Changes in respiratory rates recorded immediately after each sprint set. Breath by breath data was averaged over the first ten seconds following each sprint. b = significant difference hyperventilation and downregulation, c = significant difference between unregulated and downregulation.

A significant condition x time interaction was observed for pre-sprint ($p = .001$, $\eta^2 = .347$) but not for post-sprint V_E ($p = .112$, $\eta^2 = .180$). For pre-sprint V_E, there was no significant difference between any two conditions at sprint one ($p > .05$), however there was a significant difference between downregulation and unregulated ($p < .05$) and between downregulation and hyperventilation ($p < .05$) at every time point after (see figure 6). A significant time effect was observed for post-sprint V_E ($p < .001$, $\eta^2 =.806$), indicating an increase in V_E over time, with earlier sprint sets having significantly lower values than later sprint sets (see figure 7).

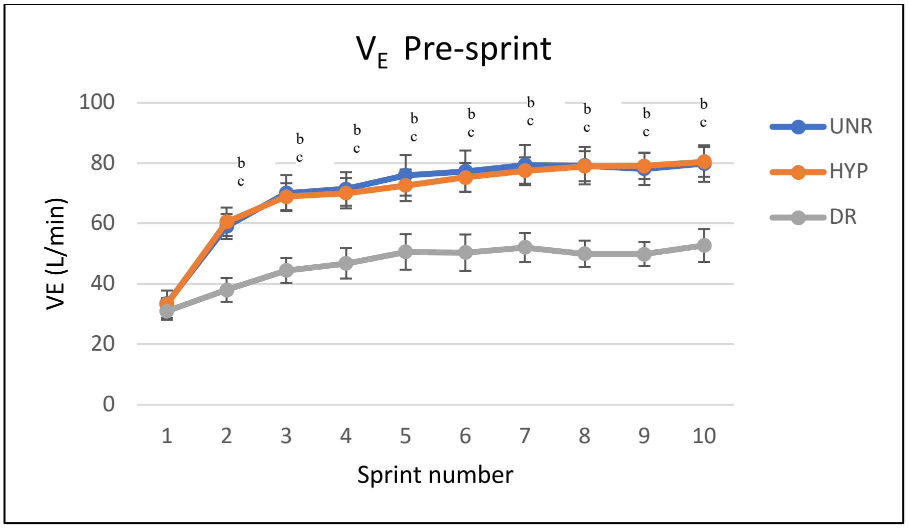

Figure 6. Changes in minute ventilation preceding each sprint set. Breath by breath data was averaged over ten seconds and taken between the 40 second and 50 second mark so as to not account for the acceleration period that preceded each sprint. b = significant difference hyperventilation and downregulation, c = significant difference between unregulated and downregulation.

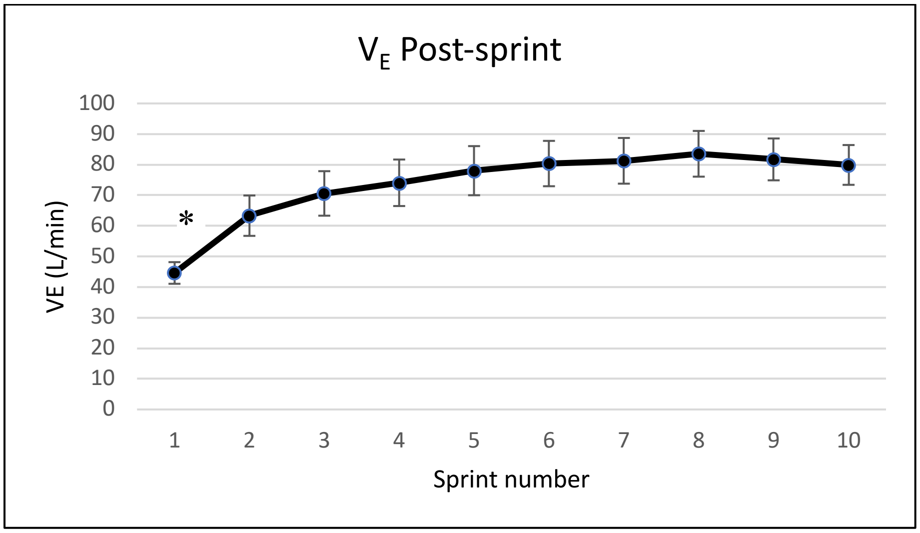

*Figure 7. Changes in minute ventilation recorded immediately after each sprint set. Breath by breath data was averaged over the first ten seconds following each sprint. *Recovery period one was significantly lower than recovery periods 2-9.*

A significant condition x time interaction was observed for pre-sprint V_T ($p = .001$, $\eta^2 = .448$) but not for post-sprint V_T ($p = .156$, $\eta^2 = .160$). For pre-sprint V_E, there was no significant difference between any two conditions at sprint one ($p > .05$), however there was a significant difference between all three conditions at every time point after ($p < .05$). See figure 8. A significant time effect was observed for post-sprint V_T ($p < .001$, $\eta^2 = .671$), with the first sprint set being significantly different than all other sprint sets ($p < .05$) and a significant difference between sprint two and all other time points ($p < .05$). Starting at sprint three, significant differences between the sprint immediately following the one before did not exist, but there were significant differences between earlier and later sprint sets ($p < .05$, see figure 9).

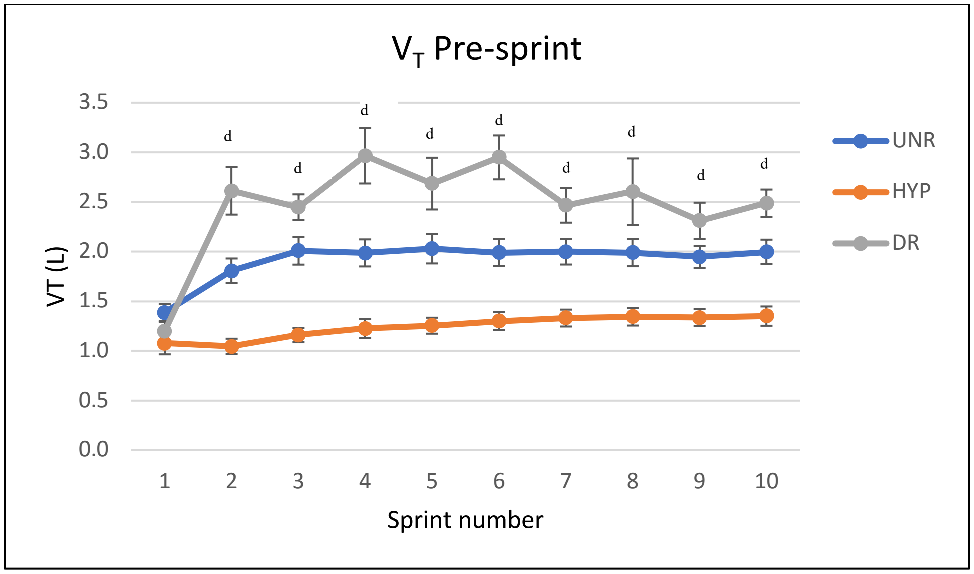

Figure 8. Changes in tidal volume preceding each sprint set. Breath by breath data was averaged over ten seconds and taken between the 40 second and 50 second mark so as to not account for the acceleration period that preceded each sprint. d = significant difference between all three conditions.

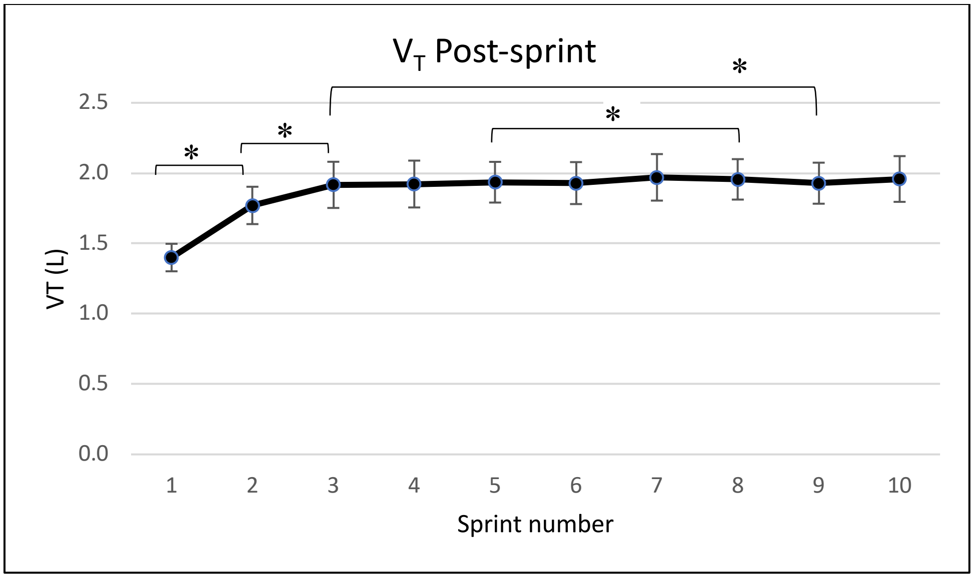

*Figure 9. Changes in tidal volume recorded immediately after each sprint set. Breath by breath data was averaged over the first ten seconds following each sprint. *Represents a significant difference between time points.*

4.4 VO_2 and VCO_2

There was no significant condition x time interaction for VO_2 ($p = 0.354$, $\eta^2 = .109$ and $p = .656$, $\eta^2 = .064$, respectively) or VCO_2 ($p = 0.130$, $\eta^2 = .203$ and $p = .412$, $\eta^2 = .100$, respectively). However, a significant time effect was observed for both VO_2 ($p < .001$, $\eta^2 = .737$) and VCO_2 ($p < .001$, $\eta^2 = .625$), with a significant increase in VO_2 ($p < .05$) and VCO2 ($p < .05$) after the first recovery period (see figures 10 and 11). No significant difference was observed between any other recovery periods for VO_2 and VCO_2.

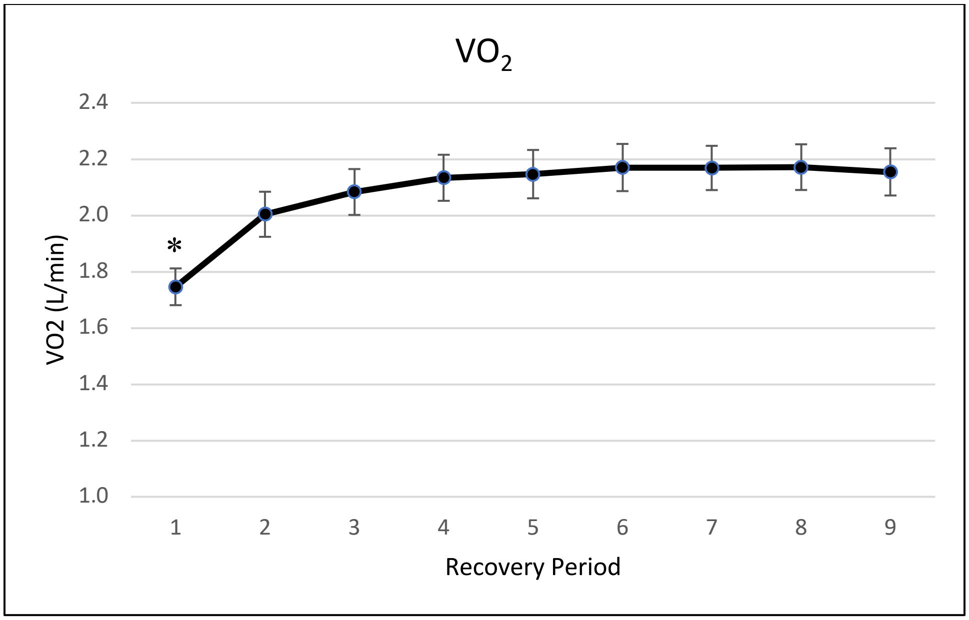

*Figure 10. Changes in VO_2 across sprint sets. Changes in VO_2 were from participants (N = 10) who completed 10-sec maximal cycle sprints with 60-sec active rest intervals while performing different breathing protocols during recovery. Numbers were averaged over the entire recovery period. *Recovery period one was significantly lower than recovery periods 2-9.*

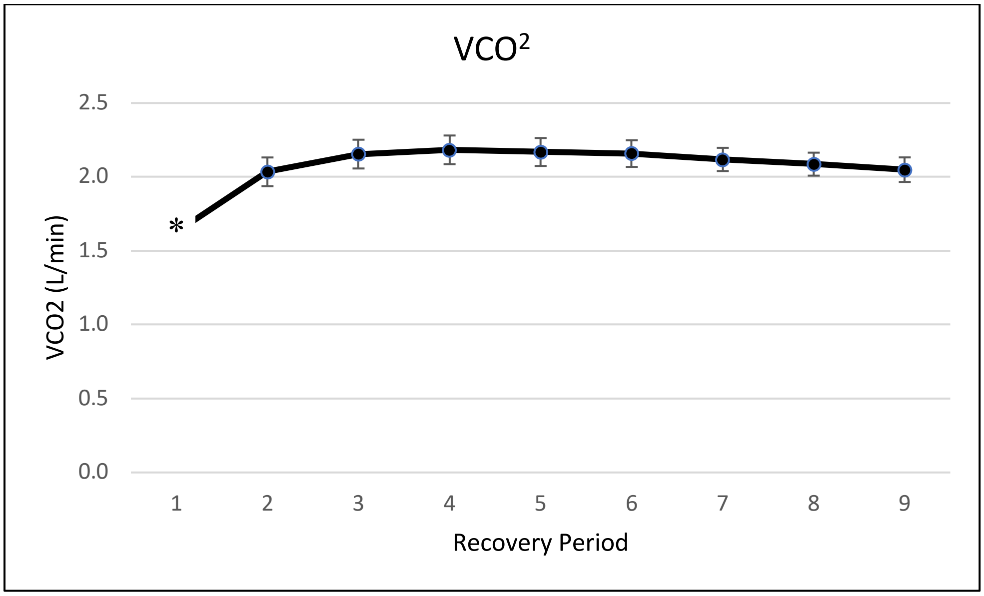

*Figure 11. Changes in VCO_2 across sprint sets. Changes in VCO_2 were from participants (N = 10) who completed 10-sec maximal cycle sprints with 60-sec active rest intervals while performing different breathing protocols during recovery. Numbers were averaged over the entire recovery period. *Recovery period one was significantly lower than recovery periods 2-9.*

4.5 SPO_2, HR and RPB

No significant condition x time interaction was observed for SPO_2-1(p = .354, η^2 = .112) or SPO_2-2 (p = .334, η^2 = .116). A significant condition effect was observed for SPO_2-2 ($p < .05$, η^2 = .520) with a significantly higher SPO_2 in hyperventilation compared to downregulation ($p < .05$) and a significantly higher SPO_2 in control compared to downregulation ($p < .05$), see figure 12.

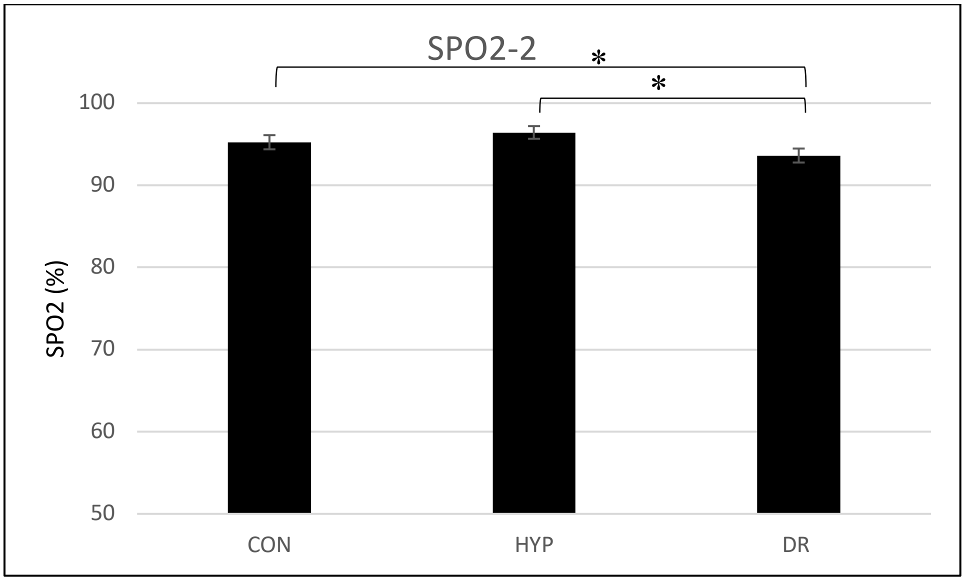

*Figure 12. Differences in oxygen saturation levels between conditions. Oxygen saturation was recorded at the end of the recovery period (~15 seconds preceding the sprint). * Represents a significant difference between conditions.*

No significant condition x time interaction was observed for HR (p = .336, η^2 = .116), however a significant time effect was found ($p < .001$, η^2 = .810), with HR significantly increasing across time until time point six (see figure 13). No significant condition x time interaction was observed for RPB (p = .472, η^2 = .085), however a significant time effect was found ($p < .001$ and p = .793), with RPB increasing across time (see figure 14).

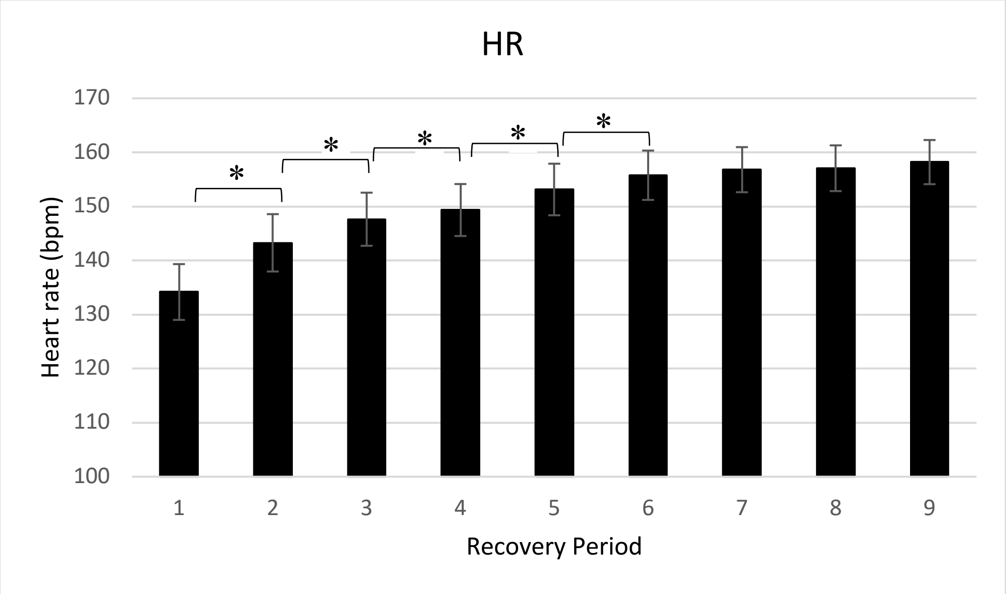

*Figure 13. Changes in heart rate across recovery periods. Participants (N = 10) completed 10-sec maximal cycle sprints with 60-sec active rest intervals while performing different breathing protocols during recovery. HR was recorded at the end of each recovery period (~10 seconds preceding each sprint). * Represents a significant difference between recovery periods.*

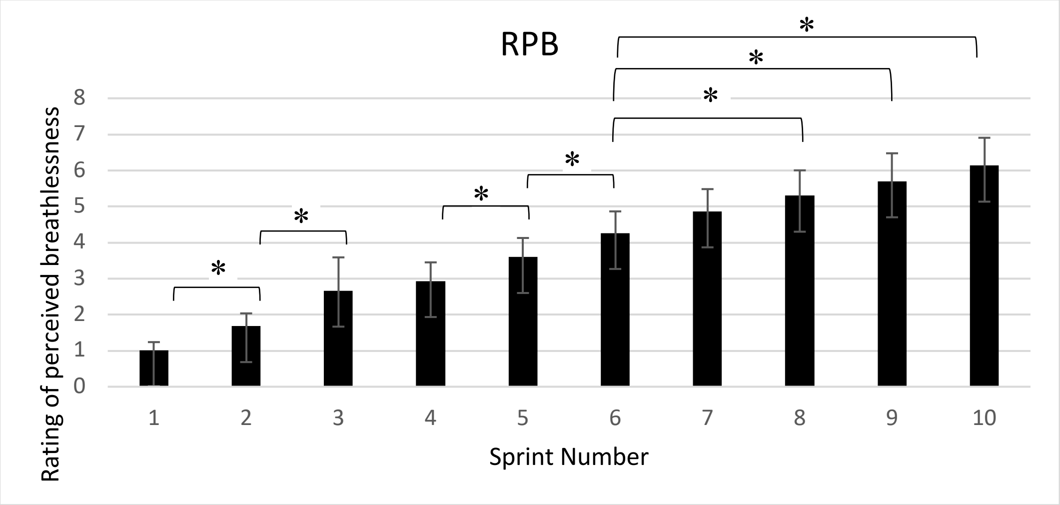

*Figure 14. Changes in rating of perceived breathlessness across sprint sets. Participants (N = 10) completed 10-sec maximal cycle sprints with 60-sec active rest intervals while performing different breathing protocols during recovery. RPB was recorded immediately following each sprint. * Represents a significant difference between sprint sets.*

CHAPTER 5

DISCUSSION

The purpose of this investigation was to determine the effect of different breathing techniques on repeated power output. It was hypothesized that hyperventilation and downregulation breathing techniques implemented during the recovery periods of repeated sprint sets would attenuate the decline in power output over multiple sprint sets. The main findings of this study are that while hyperventilation and downregulation breathing techniques can be successfully employed to affect changes in specific respiratory parameters, they do not directly translate to benefits in power output on repetitive anaerobic cycle sprints.

As expected, whether participants implemented hyperventilation, downregulation or unregulated breathing during repeated high intensity sprints, all experienced a decrease in power output over time, however there was no difference in power output between conditions at any time point. Therefore, the decrease in power output across sprint sets was not attenuated by hyperventilation or downregulation breathing techniques. As intended, a respiratory rate of ~60 bpm for hyperventilation was achieved, and as expected, it was found that downregulation produced a significantly lower respiratory rate of ~20 bpm. A significant difference in $P_{ET}CO_2$ existed between all conditions, as intended for hyperventilation to stimulate respiratory alkalosis ($P_{ET}CO_2$ < 25mmHg). However, it should be noted that the hyperventilation condition did not reach below a $P_{ET}CO_2$ of 25 mmHg until the sixth sprint set, even though respiratory rate reached ~60 bpm as intended for hyperventilation.

A respiratory rate of 60 bpm for 30 seconds was shown to induce respiratory alkalosis with a $P_{ET}CO_2$ below 25mmHg (Sakamoto, 2014), however, this study did not obtain the same results for early sprint sets. In contrast, due to the slowing of respiratory rate, downregulation induced a $P_{ET}CO_2$ of ~36mmHg. In early sprint sets, downregulation had a significantly higher post-sprint RR, which was expected since the downregulation protocol started with 8 breaths at a rate of 60 bpm and since the post-sprint RR was averaged over the first ten seconds immediately following each sprint. Towards later sprint sets, post-sprint RR was similar across all conditions, which could be due to the increased ventilatory demand from exhaustion over time, making the difference between conditions negligible.

Research has shown that V_T mediates the association between V_E and VCO_2 (Nicolo, 2018), thus affecting $P_{ET}CO_2$. To account for this, studies inducing respiratory alkalosis have controlled V_T (Sakamoto, 2014; Leithäuser, 2016; Dobashi, 2017). In the present study, pre-sprint V_T was significantly lower in hyperventilation (figure 8), due to the increased breathing frequency, and conversely, pre-sprint V_T was significantly higher in the downregulation condition due to the decreased breathing frequency. The present study did not control for pre-sprint V_T, which may account for the higher than expected $P_{ET}CO_2$ seen in the hyperventilation condition during early sprint sets. Neither breathing condition had an effect on post-sprint V_T (figure 9). Although there was an inverse relationship between V_T and RR, V_E was significantly higher in control and hyperventilation conditions compared to the downregulation condition. There was no difference between hyperventilation and control (figure 8), which was also seen in Fuji et al. (2015). However, because there was no difference in power output between the control and hyperventilation conditions, this could indicate that the downregulation condition had a better V_E efficiency when compared to unregulated breathing and hyperventilation. In other words, participants were able to produce the same amount of power output while moving less air.

It has been suggested that a potential mechanism of fatigue is the metabolic acidosis that occurs from the accumulation of [H+], which may impair the glycolytic pathway. Therefore, it is relevant to analyze methods that effect acid-base balance. Studies have shown that sodium bicarbonate ingestion (Bishop, 2005; Gough, 2018; Dalle, 2019; Driller, 2012; Miller, 2016) leads to an increase in blood pH and reduction in fatigue, consequently leading to an increase in performance. Sodium bicarbonate acts upon the bicarbonate buffering system causing a shift in equilibrium and leading to metabolic alkalosis. Hyperventilation also acts on this buffering system by excreting excess CO_2, which leads to respiratory alkalosis. Although the current study did not measure blood pH, previous studies have shown an increase in blood pH from implementing hyperventilation before anaerobic exercise (Sakamoto, 2014; Leithauser, 2016). The increase in respiratory rate from hyperventilation leads to a decrease in the arterial partial pressure of carbon dioxide (Sakamoto, 2014; Leithauser, 2016), thus resulting in the increase in blood pH.

In contrast to hyperventilation, the downregulation condition consists of slowing down respiratory rate. This technique aimed to improve heart rate recovery, however the lack of difference in HR between conditions shows that downregulation had no effect on heart rate recovery. Downregulation may or may not have an effect on acid-base balance. With a higher PETCO2 and lower VE, it appears that downregulation may have an opposite effect on blood pH. It would therefore be interesting to see how slowing down the breath during the recovery periods of anaerobic exercise effects blood pH levels. By investigating the opposing techniques in comparison to blood pH, a closer look into how much acidosis effects fatigue may be seen.

There were no differences in VO_2 and VCO_2 after the first sprint and hyperventilation showed significantly higher oxygen saturation levels (taken at the end of the recovery period) than downregulation, however there was no difference in oxygen saturation between hyperventilation and unregulated conditions. Hayat et al. (2006) found that hyperventilation lead to an increase in oxygen saturation levels, however, in this study, it is unclear that hyperventilation produces higher oxygen saturation levels compared to unregulated breathing. It did, however, produce higher levels than the downregulation protocol. Higher oxygen saturation levels indicates lower oxygen release to the tissues and the higher oxygen saturation levels seen in the hyperventilation condition falls in line with previous studies examining oxygen uptake into muscle tissue. Chin et al. (2007) showed a slowing of pulmonary oxygen uptake when hyperventilation was implemented before moderate intensity cycling and in a later study when hyperventilation was implemented before knee extensions (Chin, 2010).

There was also no difference in RPB between conditions, indicating that neither hyperventilation nor downregulation affected the perception of breathlessness throughout the exercise protocol. Although the present study did not find that the breathing techniques implemented in the recovery periods of intermittent sprints enhanced training performance, other studies did find an improvement in performance from hyperventilation (Sakamoto, 2014, Leithäuser, 2016). It is therefore unclear whether hyperventilation can enhance power output. Sakamoto et al. (2014) performed the same exercise protocol as the one in the present study, while Leithäuser et al. (2016) performed Wingate Anaerobic Tests. Considering the similar exercise protocols, a potential reason for the conflicting findings between the present study and Sakamoto et al. (2014) may be the difference in population samples. Sakamoto et al. used power athletes while the present study used recreationally active participants. With the exhaustive nature of the exercise protocol, it is possible that power athletes are a better sample population. Too add, in contrast to previous studies, the population sample in the current study consisted of both males and females, and it did not analyze for sex differences. Although the inclusion of males and females likely has no effect on the results of power output, it would be interesting to examine if any differences between males and females exist within any of the respiratory variables.

Too add, it is possible that the high difficulty of implementing these breathing techniques requires more practice than a single familiarization session. More practice is needed to learn how to slow down the breath, such as that of the downregulation protocol, after such an exhaustive exercise such as intermittent sprinting. Feedback received from participants after the study indicated that the downregulation condition was difficult to implement, especially in later sprint sets, as respiratory rate starts to increase. Also, proper breathing mechanics (diaphragmatic breathing) has an influence on the central nervous system, so it is important that breathing techniques be performed properly in order to induce positive effects. Ma et al. (2017) found increased attention span and decreased cortisol levels after 20 intensive sessions of diaphragmatic breathing. Therefore, when utilizing breathing techniques for enhancing performance, practicing a breathing technique one time is most likely not enough to learn and implement proper breathing mechanics, thus resulting in no performance enhancements. If a participant is not diaphragmatic breathing trained, the positive effects of hyperventilation and downregulation breathing techniques could be diminished. Future studies should look at how utilizing breathing techniques in training over long periods of time would affect performance, so that a learning affect can occur.

A few limitations exist within the present study. It is worthy to note that no baseline measurements were obtained for any respiratory variables, and the effects of the breathing conditions could not be analyzed comparing them to a resting state. Also, as briefly mentioned, the exhaustive nature of the exercise protocol may have had a large influence on the outcome of the results. The recreationally active participants in this study did not have experience with intense power-focused exercise. Therefore, the exercise protocol may be more suited for power athletes in order to control for the large differences in power output among participants, as well as the psychological effects that go along with an exercise protocol of this nature. Due to the high intensity required for repeated maximum sprints, it may be difficult for recreationally active individuals to push themselves to their maximum potential for each sprint, especially in later sprint sets. Because power athletes are used to this type of training, they would have been a better population sample to pick from. Time of day likely had no effect on the power output and respiratory outcomes, as all but two sessions were completed between 11:00am and 2:30pm.

Also, the lack of control over the breathing conditions during the exercise protocol presents as a limitation. Employing a research team with dedicated responsibilities may increase the ability to control for breathing conditions, as it is critical to watch for time and record data. In the present study, instead of a single researcher it would have been best to have two or three researchers so that breathing rate and efficiency could have been properly assessed throughout the protocol and feedback could have been administered. Motivation could have also helped push participants in later sprints to fulfilling their maximum sprint potential.

The present results show that while the hyperventilation and downregulation breathing techniques affect some respiratory measures, they ultimately have no effect on repeated anaerobic power output. It is possible that training in these breathing techniques could be necessary to enhance training. Future studies should examine the use of these techniques over long periods of time for sufficient practice. Nevertheless, our findings indicate that acute hyperventilation and downregulation breathing employed in individuals untrained in these techniques do not confer a benefit to repeated high intensity cycle exercise.

APPENDIX I

INFORMED CONSENT

INFORMED CONSENT
Department of Kinesiology and Nutrition Sciences

TITLE OF STUDY: The Effects of Different Breathing Techniques on Intra-set Recovery
INVESTIGATOR(S): Dr. James Navalta, Peyton Cater
For questions or concerns about the study, you may contact Dr. Navalta at 702-895-2344

For questions regarding the rights of research subjects, any complaints or comments regarding the manner in which the study is being conducted, contact **the UNLV Office of Research Integrity – Human Subjects at 702-895-2794, toll free at 888-581-2794 or via email at IRB@unlv.edu.**

Purpose of the Study

You are invited to participate in a research study. The purpose of this study is to investigate the physiological and performance effects of different breathing techniques implemented during the recovery period of repeated sprints.

Participants

You are being asked to participate in the study because you are between the ages of 18-40, and you are a healthy, active non-smoking adult. There will be an initial screening questionnaire, and based on this questionnaire, you may be asked not to participate. You will be excluded from this study if you have orthopedic, cardiovascular, respiratory, or metabolic conditions, or are a current smoker.

Procedures

If you volunteer to participate in this study, you will be asked to do the following:

You will have 4 scheduled visits (48-72 hours between visits):

- Visit 1
  - Read and fill out Informed Consent and questionnaires (ACSM health risk, IPAQ, 24-hr activity recall)
  - Collection of anthropometric data (height, weight, body fat percent) and age
  - Familiarization of exercise protocol: outlined below
- Visit 2, 3, & 4
  - You will be fitted with a mask and hooked up to a metabolic cart, and you will complete an exercise protocol that consists of 10 sets of 10 second maximal sprints on a Watt Bike with 60 seconds of recovery between sets.

- A 10 minute warm-up will start the exercise protocol and baseline heart rate (via heart rate monitor) and arterial oxygen saturation (via pulse oximeter) will be taken.
- During the recovery periods you will be asked to breath regularly, implement a hyperventilation technique to induce respiratory alkalosis, or implement a specialized breathing technique aimed to reduce heart rate.
    - Control condition: you will breathe normally throughout the entire recovery period.
    - Hyperventilation condition: in the latter 30 seconds of each recovery period, you will breath at a rate of 60 breaths per minute, which will be regulated by a metronome.
    - Specialized breathing condition: you will take 8 quick breaths at a rate of 60 breaths per minute immediately following each sprint, followed by slow, controlled breaths (2 second inhale, 4 second exhale) for the remainder of the recovery period.
- HR, arterial oxygen saturation and rating of perceived breathlessness (RPB) will be measured during each recovery period.
- Each exercise test will be terminated after the cool-down
- You will complete each breathing protocol on separate occasions, separated by 48-72 hours.

Benefits of Participation

There is very little direct benefit to the subject for completing a sprint interval test. Individuals may find benefit in the breathing strategies used in this study to include in their own exercise regimen. It is our hope that these breathing techniques will demonstrate a positive influence on performance and physiology, allowing new strategies to emerge for performance improvements.

Risks of Participation

There are risks involved in all research studies and with high intensity exercise. It is possible that discomfort may occur during the test including muscle soreness, nausea, breathlessness, dizziness, and lightheadedness. There is also a possibility of passing out due to hyperventilation or the specialized breathing technique. You may also feel discomfort wearing a face mask during the exercise protocol (used to assess respiratory variables). However, the American College of Sports Medicine has stated that the risk of death during or immediately after an exercise test is less than or equal to 0.01%, while the risk of an acute myocardial infarction is less than or equal to 0.04%. Data from these surveys included a wide variety of healthy AND diseased individuals. Since you are an apparently healthy adult between the ages of 18 – 40 years and are considered “low-risk” according to the American College of Sports Medicine guidelines, no medical supervision is necessary during the exercise test. The test will be terminated if you exhibit signs of major discomfort or are not adapting well to the protocol.

Cost /Compensation

You will be compensated $20 once you have completed the entirety of the study. The study will take about 30 minutes per visit for a total of 120 minutes for the entire study. You will have to provide your own transportation to and from the lab.

Confidentiality

All information gathered in this study will be kept as confidential as possible. No reference will be made in written or oral materials that could link you to this study. All records will be stored in a locked facility at UNLV for three years after completion of the study. After the storage time the information gathered will be destroyed by shredding of paper documents and deletion of electronically saved records.

Voluntary Participation

Your participation in this study is voluntary. You may refuse to participate in this study or in any part of this study. You may withdraw at any time without prejudice to your relations with UNLV. You are encouraged to ask questions about this study at the beginning or any time during the research study.

Participant Consent

I have read the above information and agree to participate in this study. I have been able to ask questions about the research study. I am at least 18 years of age. A copy of this form has been given to me.

______________________________________ _________________
Signature of Participant Date

____
Participant Name (Please Print)

APPENDIX II

AHA/ACSM HEALTH RISK QUESTIONNAIRE

AHA/ACSM Health Risk Questionnaire
Assess your health status by marking all *true* statements

History
You have had:
____ a heart attack
____ heart surgery
____ cardiac catheterization
____ coronary angioplasty (PTCA)
____ pacemaker/implantable cardiac
____ defibrillator/rhythm disturbance
____ heart valve disease
____ heart failure
____ heart transplantation
____ congenital heart disease

Symptoms
____ You experience chest discomfort with exertion
____ You experience unreasonable breathlessness
____ You experience dizziness, fainting, or blackouts
____ You take heart medications

Other health issues
____ You have diabetes
____ You have asthma or other lung disease
____ You have burning or cramping sensation in your lower legs when walking short distances
____ You have musculoskeletal problems that limit your physical activity
____ You take prescription medication(s)
____ You are pregnant

Cardiovascular risk factors
____ You smoke, or quit smoking within the previous 6 months
____ Your blood pressure is >140/90 mm Hg
____ You take blood pressure medication
____ Your blood cholesterol level is >200 mg/dL
____ You have a close blood relative who had a heart attack or heart surgery before age 55 (father or brother) or age 65 (mother or sister)
____ You are physically inactive (i.e., you get <30 minutes of physical activity on at least 3 days per week)
____ You are > 20 pounds overweight

____ None of the above

APPENDIX III

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

LONG LAST 7 DAYS SELF-ADMINISTERED FORMAT

FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health–related physical activity.

Background on IPAQ
The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

Using IPAQ
Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments.

Translation from English and Cultural Adaptation
Translation from English is encouraged to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at www.ipaq.ki.se. If a new translation is undertaken we highly recommend using the prescribed back translation methods available on the IPAQ website. If possible please consider making your translated version of IPAQ available to others by contributing it to the IPAQ website. Further details on translation and cultural adaptation can be downloaded from the website.

Further Developments of IPAQ
International collaboration on IPAQ is on-going and an International Physical Activity Prevalence Study is in progress. For further information see the IPAQ website.

More Information
More detailed information on the IPAQ process and the research methods used in the development of IPAQ instruments is available at www.ipaq.ki.se and Booth, M.L. (2000). Assessment of Physical Activity: An International Perspective. Research Quarterly for Exercise and Sport, 71 (2): s114-20. Other scientific publications and presentations on the use of IPAQ are summarized on the website.

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.
Think about all the vigorous and moderate activities that you did in the last 7 days. Vigorous physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Moderate activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal.

PART 1: JOB-RELATED PHYSICAL ACTIVITY

The first section is about your work. This includes paid jobs, farming, volunteer work, course work, and any other unpaid work that you did outside your home. Do not include unpaid work you might do around your home, like housework, yard work, general maintenance, and caring for your family. These are asked in Part 3.

1. Do you currently have a job or do any unpaid work outside your home?
Yes
No Skip to PART 2: TRANSPORTATION

The next questions are about all the physical activity you did in the last 7 days as part of your paid or unpaid work. This does not include traveling to and from work.

2. During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, heavy construction, or climbing up stairs as part of your work? Think about only those physical activities that you did for at least 10 minutes at a time.

_____ days per week
No vigorous job-related physical activity. Skip to question 4

3. How much time did you usually spend on one of those days doing vigorous physical activities as part of your work?
_____ hours per day
_____ minutes per day

4. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate physical activities like carrying light loads as part of your work? Please do not include walking.
_____ days per week
No moderate job-related physical activity. Skip to question 6

5. How much time did you usually spend on one of those days doing moderate physical activities as part of your work?
_____ hours per day
_____ minutes per day

6. During the last 7 days, on how many days did you walk for at least 10 minutes at a time as part of your work? Please do not count any walking you did to travel to or from work.
_____ days per week
No job-related walking. Skip to PART 2: TRANSPORTATION

7. How much time did you usually spend on one of those days walking as part of your work?
_____ hours per day
_____ minutes per day

PART 2: TRANSPORTATION PHYSICAL ACTIVITY

These questions are about how you traveled from place to place, including to places like work, stores, movies, and so on.

8. During the last 7 days, on how many days did you travel in a motor vehicle like a train, bus, car, or tram?
_____ days per week
No traveling in a motor vehicle. Skip to question 10

9. How much time did you usually spend on one of those days traveling in a train, bus, car, tram, or other kind of motor vehicle?
_____ hours per day

_____ minutes per day

Now think only about the bicycling and walking you might have done to travel to and from work, to do errands, or to go from place to place.

10. During the last 7 days, on how many days did you bicycle for at least 10 minutes at a time to go from place to place?
_____ days per week
No bicycling from place to place. Skip to question 12

11. How much time did you usually spend on one of those days to bicycle from place to place?
_____ hours per day
_____ minutes per day

12. During the last 7 days, on how many days did you walk for at least 10 minutes at a time to go from place to place?
_____ days per week
No walking from place to place. Skip to PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

13. How much time did you usually spend on one of those days walking from place to place?
_____ hours per day
_____ minutes per day

PART 3: HOUSEWORK, HOUSE MAINTENANCE, AND CARING FOR FAMILY

This section is about some of the physical activities you might have done in the last 7 days in and around your home, like housework, gardening, yard work, general maintenance work, and caring for your family.

14. Think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, chopping wood, shoveling snow, or digging in the garden or yard?
_____ days per week
No vigorous activity in the garden or yard. Skip to question 16

15. How much time did you usually spend on one of those days doing vigorous physical activities in the garden or yard?
_____ hours per day
_____ minutes per day

16. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate activities like carrying light loads, sweeping, washing windows, and raking in the garden or yard?
_____ days per week
No moderate activity in the garden or yard. Skip to question 18

17. How much time did you usually spend on one of those days doing moderate physical activities in the garden or yard?
_____ hours per day
_____ minutes per day

18. Once again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate activities like carrying light loads, washing windows, scrubbing floors and sweeping inside your home?
_____ days per week
No moderate activity inside home Skip to PART 4: RECREATION, SPORT AND LEISURE-TIME PHYSICAL ACTIVITY

19. How much time did you usually spend on one of those days doing moderate physical activities inside your home?
_____ hours per day
_____ minutes per day

PART 4: RECREATION, SPORT, AND LEISURE-TIME PHYSICAL ACTIVITY

This section is about all the physical activities that you did in the last 7 days solely for recreation, sport, exercise or leisure. Please do not include any activities you have already Mentioned.

20. Not counting any walking you have already mentioned, during the last 7 days, on how many days did you walk for at least 10 minutes at a time in your leisure time?
_____ days per week
No walking in leisure time. Skip to question 22

21. How much time did you usually spend on one of those days walking in your leisure time?
_____ hours per day
_____ minutes per day

22. Think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do vigorous physical activities like aerobics, running, fast bicycling, or fast swimming in your leisure time?
_____ days per week
No vigorous activity in leisure time. Skip to question 24

23. How much time did you usually spend on one of those days doing vigorous physical activities in your leisure time?
_____ hours per day
_____ minutes per day

24. Again, think about only those physical activities that you did for at least 10 minutes at a time. During the last 7 days, on how many days did you do moderate physical activities like bicycling at a regular pace, swimming at a regular pace, and doubles tennis in your leisure time?
_____ days per week
No moderate activity in leisure time. Skip to PART 5: TIME SPENT SITTING
25. How much time did you usually spend on one of those days doing moderate physical activities in your leisure time?
_____ hours per day
_____ minutes per day

PART 5: TIME SPENT SITTING

The last questions are about the time you spend sitting while at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. Do not include any time spent sitting in a motor vehicle that you have already told me about.

26. During the last 7 days, how much time did you usually spend sitting on a weekday?
_____ hours per day
_____ minutes per day

27. During the last 7 days, how much time did you usually spend sitting on a weekend day?
_____ hours per day
_____ minutes per day

This is the end of the questionnaire, thank you for participating.

APPENDIX IV

24-HOUR HEALTH HISTORY

Date: ________________

Subject Number:________ **Height: _______ cm _______ inches**

Weight: ____________ kg ____________lb Location of visit: UNLV

/CLS

Do you have: Head cold Nasal Congestion Headache Sore Throat Digestive Upset Intestinal Disorder General Fatigue Muscle Soreness	**Yes** **No**	**How do you feel?** Good Fair Not so good Bad	**# of hours sleep_______** **How was your sleep?** Normal Wakeful Restless	**# of hours since eating:_________** **What did you eat?** ___________________________ ___________________________ ___________________________
Medicine taken in last 24 hours: __________________ __________________ __________________	**Any leg cramps Since last activity?** **Yes** **No**		**Physical activity in last 24 hours:** ____________________ ____________________ ___________________	**Any unusual physical activity in last 24 hours?** ___________________________ ______________________ ______________________
Alcohol consumption in last 24 hours: __________________ __________________ __________________			**Caffeine intake in last 24 hours:** ____________________ ____________________ ____________________	**Any tobacco use in last 24 hours?** _____________________ _____________________ _____________________

Last menstrual period date (if applicable): ________

**** Take weight at each visit.**

APPENDIX V

DATA COLLECTION SHEETS

Subject #

Date:_________________

FAM CON HYP DR

Baseline HR	
Baseline SpO2	
Baseline RPB	

SpO2	first 5s	last 15s
Recovery period 1		
Recovery period 2		
Recovery period 3		
Recovery period 4		
Recovery period 5		
Recovery period 6		
Recovery period 7		
Recovery period 8		
Recovery period 9		
Recovery period 10		

RPB	first 5s
Recovery period 1	
Recovery period 2	
Recovery period 3	
Recovery period 4	
Recovery period 5	
Recovery period 6	
Recovery period 7	
Recovery period 8	
Recovery period 9	
Recovery period 10	

Subject #:	
Age	
Body weight (kg)	
Height (cm)	
Body comp	

Subject #:	
Age	
Body weight (kg)	
Height (cm)	
Body comp	

Subject #:	
Age	
Body weight (kg)	
Height (cm)	
Body comp	

Subject #:	
Age	
Body weight (kg)	
Height (cm)	
Body comp	

Subject #:	
Age	
Body weight (kg)	
Height (cm)	
Body comp	

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CURRICULUM VITAE

PEYTON CATER

pcater25@gmail.com

Education

Bachelor of Science in Health and Human Physiology
University of Iowa
Iowa City, IA
August 2013- May 2017

Master of Science in Exercise Physiology
University of Nevada Las Vegas
Las Vegas, Nevada
August 2018- May 2020 (Anticipated)

Professional experience

Graduate Assistant for Fitness (August 2018-May 2020)
Campus Recreational Services
University of Nevada, Las Vegas

Fitness Coach (January 2019-June 2019)
F45
Henderson, Nevada

Personal Trainer and Group Fitness Instructor (April 2016- July 2018)
Campus Recreational Services
University of Iowa

Funded Internal Grant Applications

2019	UNLV Graduate Student Research Funding (funded: $500)
2019	UNLV Graduate College (funded: $200)

Conferences Attended

NIRSA Regional Conference, Salt Lake City, UT, 2019

Southwest American College of Sports Medicine, Newport Beach, CA, 2019.

Abstracts

Accepted

Cater, P.C., Sertic, J.V.L., Davis, D.W., Barrios, B., Carrier, B., Salatto, R.W., Montes, J., Bodell, N.G., Manning, J.W., DeBeliso, M., Navalta, J.W. Evaluating the Validity of Heart Rate Measured by the Rhythm During Trail Running. Annual Meeting of the Southwest American College of Sports Medicine, Newport Beach, CA, 2019.

Sertic, J.V.L., **Cater, P.C**., Davis, D.W., Barrios, B., Carrier, B., Salatto, R.W., Montes, J., Bodell, N.G., Manning, J.W., DeBeliso, M., Navalta, J.W. Validating the Heart Rate Feature of the Motiv Ring on Outside Graded Terrain. Annual Meeting of the Southwest American College of Sports Medicine, Newport Beach, CA, 2019.

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Under Review

Sertic, J. V. L., Carrier, B., **Cater, P**. C., Barrios, B., Salatto, R. W., Navalta, J. W., Validation of Two Wearable Chest Straps for Heart Rate Monitoring During Mountain Biking. American College of Sports Medicine, May 2020, San Francisco, CA.

Barrios, B., Carrier, B., **Cater, P.C**., Sertic, J.V.L., Salatto, R.W., Navalta, J.W., Validation of Heart Rate Monitoring of Fenix 5 During Mountain Biking. American College of Sports Medicine, May 2020, San Francisco, CA, USA.

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Navalta, J. W., McGinnis, G. R., Manning, J. W., Salatto, R. W., Carrier, B., Davis, W. D., Sertic, J. V. L., **Cater, P. C**., Barrios, B., Malek, E. M., Caitlin, K. R., DeBeliso, M. Acute Beta-Alanine Supplementation and Pain Perception Before and After Hiking. American College of Sports Medicine, May 2020, San Francisco, CA.

Presentations

Professional Presentations

Breathing into Health, Performance, and Longevity
NIRSA Regional Conference
Salt Lake City, UT 2019

The Graduate Assistant Experience
NIRSA Regional Conference
Salt Lake City, UT 2019

Scientific Poster Presentations

Cater, Peyton C., Sertic, Jacquelyn V. L., Davis, Dustin W., Barrios, Brenna, Carrier, Bryson, Salatto, Robert W., Montes, Jeff, Bodell, Nathaniel, Manning, Jacob W., DeBeliso, Mark, Navalta, James W. Evaluating the Validity of Heart Rate Measured by the Rhythm During Trail Running. Annual Meeting of the Southwest American College of Sports Medicine, Newport Beach, CA, 2019.

Certifications

American Heart Association | First Aid/CPR/AED | 02/2020
American Council on Exercise | Certified Personal Trainer | 02/2020
American Council on Exercise | Certified Group Exercise Instructor| 08/2021
Xtreme Performance Training | Performance Breathing Certified Coach

References

Angela Leigh Charsha-Harney
Assistant Director of Fitness & Wellness
University of Iowa
Angela-charsha@uiowa.edu
319-384-0985

John McElrath
Program Coordinator for Fitness
John.mcelrath@unlv.edu
702-774-7126

Latoya Burdiss
Associate Director for Recreation Programs
University of Nevada Las Vegas
Latoya.burdiss@unlv.edu
702-774-7121

James Navalta
Associate Professor, M.S.
Graduate Coordinator
James.navalta@unlv.edu
702-895-2344