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EFFECT OF HIGH INTENSITY INTERVALS 24HR PRIOR TO A SIMULATED 40 KM TIME TRIAL

A Thesis
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ALAN GARVICK

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at Appalachian State University
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Abstract

EFFECT OF HIGH INTENSITY INTERVALS 24HR PRIOR TO A SIMULATED 40 KM TIME TRIAL

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Previous endurance exercise studies suggest that a high-intensity low-volume taper period improves performance over a low-intensity taper period. However, few, if any, studies have examined different exercise intensities in the two days preceding a race, a period often manipulated during training. **PURPOSE:** To compare performance in a simulated 40km cycling time trial (TT) 24hr after a high-intensity interval – low volume cycling session (HII), commonly described as an “openers,” or a low-intensity effort session (LIE). **METHODS:** Eight subjects (6 males/ 2 females, 29.6±4.5 yrs, $VO2_{max}$ 57.4±1.08 $ml \cdot kg^{-1} \cdot min^{-1}$) completed two simulated 40km time trials following the familiarization 40km TT (FAM). The FAM trial was completed 5-10 d prior to the first performance trial. Performance trials, HII and LIE, were completed in a random crossover repeated measures design. Subjects rested the day before FAM, HII, and LIE trials to mimic normal pre-race structure. HII consisted of 1hr of cycling (15-min warm up at 63% of FAM power (FAMp)), three 1-min efforts at 150% FAMp separated by 5-min at 63% FAMp, three 30-sec efforts at maximum FAMp separated by 5-min at 63% FAMp, and 15.5-min cool down at 65%

FAMp). LIE consisted of 1hr cycling at 35% FAMp. Time to complete the TT, average power, VO_2, respiratory exchange ratio (RER), and rating of perceived exertion (RPE) were measured. **RESULTS:** Neither time to completion nor average power differed between HII and LIE trials (63.2±3.51 min vs. 62.9±4.09 min, $p=0.545$; 219±36.3 watts vs. 222±38.6 watts, $p=0.374$). The time taken to reach each 5km interval over the 40km distance did not differ between trials ($p=0.362$). The pattern of change in VO_2, RER, and RPE did not differ between trials ($p=0.775$, $p=0.281$, $p=0.508$, respectively). **CONCLUSION:** Despite previous reports that high-intensity low-volume taper paradigms improve performance over a low-intensity taper, exercise performance, average power, VO_2, RER, and RPE did not differ in trained cyclists during 40km time trials completed 24hr after HII and LIE sessions.

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First, I would like to thank my wife Sarah for her patience in my academic career. I could not have done this without her support.

To my chairperson, Dr. Shanely, thank you for pushing me to get this done and for all of your guidance and help.

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Lastly thank you to my family at Hatchet Coffee for helping me maintain a positive mindset and reminding me of the awesome things yet to come.

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Foreword

The abstract for this thesis will be submitted to the American College of Sports Medicine (ACSM) for their annual meeting in May 2018. The abstract formatting thus follows the ACSM guidelines. The paper follows ACSM's Medicine and Science in Sports and Exercise formatting.

Chapter 1: Introduction

A multitude of strategies are employed in endurance athletics to maximize race day performance. Strategies such as carbohydrate loading and optimal training load tapering are well researched, while other training nuances employed by athletes and coaches remain under-studied. One such method of race-day performance enhancement often used, especially amongst competitive cyclists, is the completion of an "opener" workout the day before a race. Such workouts are often completed after a day or short period of rest to "open" the legs up and prevent a feeling of "staleness". Opener workouts often consist of a one to two-hour cycling session at an easy to moderate intensity with a few intense efforts lasting between 30 seconds and five minutes. The actual ability of such a workout to enhance subsequent performance is not known. Despite this, numerous references to such a workout are seen in the cycling training literature. The popular training manual *Training and Racing With a Power Meter* describes a similar workout that the authors call a "race tune-up" (1).

While direct studies of opener workouts may not exist, other areas of research may help to explain why such workouts could benefit performance and have become a standard in bicycle racing training paradigms. Such areas include muscle glycogen kinetics surrounding exercise, optimal warm-up structure, and models of optimal tapering strategies.

While the duration of rest between an opener workout and a race, as compared to the rest between a warm-up and a race, is much longer, there is scientific evidence that a high-intensity warm-up may increase subsequent endurance performance (3, 7). Also of note, Shepley et al., found that middle distance runners not only performed better but had a variety of positive physiological adaptations (increased O_2 consumption, red blood cell count, and citrate synthase activity) to a taper that consisted of high intensity but low volume work as compared to a low-intensity taper and a rest-only taper (20). Despite these findings, no studies have been conducted to determine the degree to which an opener workout improves subsequent cycling performance.

The current study examines the effect of an opener workout, or high-intensity interval – low volume cycling session, (HII) completed 12-24hr prior to a simulated 40km cycling time trial. I hypothesized that HII would decrease time to completion and increase average power output over the duration of the time-trial in trained cyclists as compared to a time-trial completed with a low intensity effort (LIE) the day before.

Chapter 2: Review of Literature

Background

Competitive cyclists use a multitude of strategies in their training, recovery, and racing in an attempt to enhance race performance. While many of the training manipulations used by cyclists and their coaches are rooted in scientifically based principles, some areas are relatively unexamined. One particular area is in the often-employed "opener" or "race tune-up" workout completed the day before an event. These workouts are usually preceded by either a short period of tapering and reduced training or at least one or two rest or easy days prior to the opener workout (15). Such workouts usually involve a one to two-hour ride at an easy to moderate intensity with several short, high-intensity efforts within the ride. The opener concept is discussed in many cycling training manuals (1, 14, 10). However, a gap exists in the scientific literature supporting the use of opener workouts. Hunter Allen and Dr. Andrew Coggan include a detailed "Race Preparation: Classic Race Tune-up" workout in their book *Training and Racing with a Power Meter.* This workout includes 1-1.5 hr of total riding time at what they define as "endurance pace/56-75% of Functional Threshold Power (FTP)." Within the workout there are 3x1min efforts at >150% of FTP and 3x30sec "all-out" efforts with all efforts separated by at least 5min of rest. Allen and Coggan define FTP as the highest average power a rider can maintain for approximately one-hour in a quasi-steady state (1). In Dr. David Morris's book *Performance Cycling,* he recommends a rest day two days preceding a race and then a low-volume – high-intensity workout the day before a race (15). Similarly, in his widely popular book, *The Cyclist's Training Bible,* Joe Friel recommends structuring the week preceding a race so that the easiest day of the week is two days before the race and the day before the race is to include a short session with some race-like intensity efforts (11). While such workouts are commonly recommended and programmed as part of an athlete's training program, the scientific rationale is not always well established or clearly stated. Allen and Coggan suggest these type of workouts are designed to prime the muscular and cardiovascular system for an upcoming big effort (1). Again, no scientific basis exists to support this practice.

The actual effectiveness of an opener workout in improving performance has not been studied with cyclists. However, the use of opener workouts is supported by underlying physiological mechanisms, such as glycogen loading along, with the role of glycogen status in performance, the structure of warm-ups and priming workouts preceding an event, and optimal tapering strategies.

Muscle Glycogen

Muscle glycogen status is perhaps the most directly related rationale supporting the practice of opener workouts. A seminal study conducted by Bergstrom and Hultman in 1966 demonstrated that muscle glycogen synthesis after exercise was greatly enhanced as compared to without exercise when fed a high carbohydrate diet (5). In this study, the authors themselves cycled with one leg to exhaustion. They then obtained muscle biopsies immediately post-exercise and every morning 1, 2, and 3 days after the exercise bout while consuming a high carbohydrate diet. The muscle glycogen level of the exercised leg was significantly decreased immediately post-exercise compared to the control leg. At 24-hours post-exercise, the glycogen level of the exercised leg was significantly greater than the non-exercised control leg for both subjects. This pattern continued on the following two days of measurement where the glycogen content in the exercised leg was nearly twice that of the non-exercised leg (5). This early finding in post-exercise muscle glycogen repletion was highly impactful as it demonstrated the ability of exercised skeletal muscle to greatly increase its ability to uptake ingested carbohydrate and synthesize glycogen. At the time of this study, the mechanisms of enhanced glycogen synthesis were not known, but subsequent studies have elucidated the underlying mechanisms. Goodyear, et al. identified that exercise stimulated the translocation of GLUT4 from an intracellular pool to the plasma membrane, independent of the action of insulin (12). Any exercise involving rhythmic contraction of skeletal muscle can stimulate glucose uptake into the muscle, allowing for its storage as muscle glycogen. However, it has been shown that typical rates of muscle glycogen repletion are much higher in response to high-intensity exercise, as compared to low-intensity rhythmic exercise, even when optimal amounts of carbohydrate are supplied (17). The mechanisms behind this are not fully understood but higher blood glucose and insulin levels have been measured post-high-intensity exercise, possibly resulting in higher glycogen synthase activity (16). Also, high-intensity exercise depletes fast-twitch fibers of glycogen to a greater degree than slow twitch fibers. Fast-twitch fibers have a higher level of glycogen synthase, which also might help to explain the higher glycogen repletion rates following high-intensity exercise (17). A higher resting level of glycogen in fast-twitch fibers is beneficial as they are recruited with increasing glycogen oxidation as exercise intensity increases. These findings are of particular interest when considering the nature in which opener workouts are structured. As described above, these workouts often consist of several short, hard efforts of relatively high-intensity. In contrast, it is not as common for an easy ride to be recommended the day before a race.

Muscle glycogen and plasma glucose oxidation increase as exercise intensity increases, especially at levels in excess of 65% of VO_{2max} (19). While plasma glucose can be maintained through carbohydrate ingestion during exercise, muscle glycogen, on the other hand, cannot be maintained and at some point fatigue will occur due to muscle glycogen depletion, even if carbohydrate supplementation extends the time at which this fatigue occurs by keeping plasma glucose elevated (9). Elevated muscle glycogen levels pre-exercise are strongly correlated with increased time to exhaustion at 75% $VO_{2max.}$ Subjects time to exhaustion riding a bicycle ergometer at 75% VO_{2max} was three-fold greater (59min vs 189min) when fed a high-carbohydrate diet as compared to a low-carbohydrate diet resulting in low and high glycogen levels, respectively, pre-exercise bout (4). In any prolonged exercise bout, muscle glycogen will be depleted, followed by measurable fatigue. Increasing pre-race muscle glycogen status will prolong the point at which fatigue occurs at a given intensity. This is especially true in longer endurance events, such as cycling road races that can last for several hours. In addition to simply delaying fatigue during submaximal exercise, higher levels of glycogen storage have been shown to enhance late-exercise performance. Higher levels of muscle glycogen through carbohydrate loading have been shown to enhance performance and mean power output in a 1-hour time-trial completed after two hours of submaximal exercise in cyclists (18). This is especially important in racing situations, such as road races, in which decisive efforts often occur towards the end of the race, often after several hours of racing. While the data are equivocal as to whether higher levels of muscle glycogen can enhance performance in bouts of exercise shorter than 90 minutes, starting with higher levels of muscle glycogen does extend the time to exhaustion during endurance exercise (13). While cyclists may benefit from higher levels of muscle glycogen from an opener workout, these benefits are most likely highest during road racing situations that last in excess of 90 minutes. Yet, cyclists often complete openers even before shorter race situations, such as criterium races that typically last between 30 minutes and 90 minutes. Whether glycogen stores are the main contributor to enhanced performance in these conditions is questionable, however starting with higher levels of glycogen before competitions supports enhanced performance through a higher rate of carbohydrate oxidation.

Warm Up Intensity and VO_2 Kinetics

While the protocol of a warm-up immediately prior to a race is inherently different than a workout completed the day before a race, studies that examine warm-up intensity, duration, and recovery after the warm-up do provide insight. This is a well-established area of study, but does not provide a clear consensus on what constitutes an "optimal" warm-up. An interesting aspect of warm-ups that has implications in relation to opener workouts is a change in VO_2 kinetics in response to different intensities of warm-up exercise (2). VO_2 kinetics relay the rates at which changes in oxygen utilization occur. Often examined are the primary VO_2 response, the maximum VO_2 reached for a given intensity, and the VO_2 slow component, the slow drift of VO_2 upwards at a given steady state.

A study by Burnley, et al. concluded that mean power output and the amplitude of the primary VO_2 response significantly increased in well-trained cyclists during a 7-minute performance trial after completion of both moderate and heavy exercise (warm-up) followed by a 10-minute rest period before the trial as compared to control (no prior exercise before 7min trial). Sprint exercise before the 7-minute performance trial slightly decreased mean power output, though not significantly, while also increasing the primary VO_2 response (7). Increasing the primary VO_2 amplitude at a given work intensity results in a higher degree of oxygen utilization, thereby delaying anaerobic energy usage and thus metabolic acidosis.

These findings are in contrast with research claiming that performance in a 4-minute max test was lowered by a high-intensity warm-up followed by either 6- or 20-minutes of rest before the trial as compared to a moderate-intensity warm-up followed by 6-minutes of rest before the trial (8). Extrapolation of these studies to a race situation due to their short time of performance testing as compared to a race situation that may last an hour or more is difficult. With this notion, the possibility of very high-intensity exercise prior to a race situation lowering subsequent performance must be kept in mind in designing an opener workout. Bailey, et al. found that high-intensity exercise tolerance was improved in cyclists by prior high-intensity exercise given adequate recovery (≥9 minutes) before the performance trial began as compared to control. Also, this study found a speeding of O_2 kinetics was due to a decrease in the VO_2 slow component amplitude (3). The VO_2 slow component is a slow rise in oxygen uptake seen at a given exercise intensity. A reduction in the VO_2 slow component might increase exercise performance by delaying the attainment of maximal VO_2 and/or speeding overall VO_2 kinetics to allow for quicker acquisition of a high level of oxygen uptake thus reducing anaerobic deficit. Burnley, et al. report that priming exercise above "gas exchange threshold" and below "critical power," (a performance measure somewhat correlated with Maximal Lactate Steady State), improved "W'," (the work that can be performed at a given work rate) as well as time to exhaustion at several work rates (6, 17). An increase in VO_2 amplitude and decrease in VO_2 slow component trajectory and amplitude was also measured in this study (6). While a reduction in the slow component of VO_2 could be a factor contributing to enhanced performance, the likelihood of this resulting from an opener workout 24-hours in advance of the primary workout/race is unknown. However, a lasting change in VO_2 kinetics could partially account for the increase in performance as a result of an opener workout.

Tapering Strategies

Another important area of research related to optimizing race performance is tapering strategies. Most research in this area involves the use of longitudinal studies or simulations. Trinity, et al. (22), followed seven female competitive collegiate swimmers over the course of two seasons looking at maximal mechanical power (P_{max}), torque at power maximum (T), velocity at power maximum, and swim performance during the 2004 and 2005 seasons. The 2004 season had a taper leading up to the national championship meet characterized by a low volume of high-intensity training (at or above race pace) (LIT) while the 2005 season had a taper characterized by a high volume of high-intensity training (HIT). The HIT followed a progressive and linear reduction in high-intensity training and volume over the seven-week taper period while LIT followed a large reduction in high intensity training. Results from each taper period showed that HIT maintained swim performance, P_{max}, and T at the national championship meet, while LIT led to significantly lower swim performance (22). Shepley et al., found that middle distance runners not only performed better but had a variety of positive physiological adaptations (increased O_2 consumption, red blood cell count, and citrate synthase activity) to a taper that consisted of high-intensity, but low-volume work, as compared to a low-intensity taper and a rest-only taper. Each subject randomly underwent three 7-day taper conditions in a repeated measures crossover design before completing a treadmill run to exhaustion at their best 1500m pace of that year. Subjects rested on the first or sixth day of all taper pardigms. Testing was completed on the seventh day. The high intensity taper condition (HIT) consisted of 5 days of 500m sprints at 115-120% of VO_{2max} of reducing volume each day (five sprints the first day, four the second, etc.). The low intensity taper condition (LIT) consisted of five days of running at 57-50% of VO_{2max} with a 20% reduction in volume each day (10km the first day, 8km for the second day, etc). The rest only condition taper (ROT) did no running over the six-day period. HIT greatly increased time to fatigue over LIT and ROT. HIT, ROT, and LIT experienced a change in glycogen concentration of 15%, 8%, and 0% respectively. Citrate synthase and total blood volume decreased in ROT, increased in HIT, and did not change during LIT (20). These results indicate that HIT taper preserves performance, possibly through attenuated loss of aerobic/anaerobic training adaptations. While low-intensity taper paradigms may preserve some aspects of training over rest-only tapers, it appears tapers with high-intensity built in actually improve performance. While the taper period leading up to an opener workout may be nothing more than a day of rest 48 hours before a race, perhaps this slight increase in intensity immediately leading into an event preserves training adaptations. In line with this, Thomas, et al. (21), modeled the potential performance benefit of an increase in training intensity in the final three days of a theoretical "2-phase" taper compared to a traditional "optimal" linear taper. Their results suggested that an increase of 20-30% in training load in the final three days before an event resulted in a modest increase in maximal performance (21). While a computer simulation may not perfectly translate to real world performance, one may postulate where the crossover between such a model and the novel concept of an opener workout exists.

Conclusion

Coaches and cyclists alike agree that the inclusion of opener workouts within a training schedule is beneficial. While scientific rationale for the inclusion of these workouts exist, a clear investigation of the purported benefits in the scientific literature has yet to be conducted. An absence of scientific reasoning for these workouts in coaching manuals is evident, though scientifically minded coaches might very well be aware of the possible benefits. With the lengths that cyclists often go to in order to enhance race day performance, such a staple as the opener workout deserves further in-depth examination.

This study examined the effect of a high-intensity interval (HII) bout or "opener," completed 12-24hr prior to a 40km time trial in an attempt to mimic the effect of an opener workout on race performance. The study used a crossover, repeated measures design in which cyclists completed one 40km time trial for familiarization (FAM) to gain a baseline average power (p) followed by two 40km time trials. After the FAM trial the subsequent trials were randomly assigned to perform or not perform an opener intervention. Half the participants completed the second trial with openers and the third without (with "easy spin"), while the other half of the group completed the second trial without openers (with easy spin) and the third with openers. Inclusion of a rest-only condition did not occur as this has been shown to decrease performance in studies on tapering (20). HII consisted of one-hour cycling (fifteen-minute warm up at 63% FAMp, three one-minute efforts at 150% FAMp separated by five-minutes at 63% FAMp, three thirty-second efforts at maximum separated by five-minutes at 63%, and fifteen and one-half minute cool down at 63% FAMp). Such a design allowed for a close approximation of race performance while randomizing the experimental design to account for a learning effect. I hypothesized that HII would decrease time to completion and increase average power output over the duration of the time-trial in trained cyclists as compared to a time-trial completed with a low intensity effort (LIE) the day before. I also hypothesized a greater utilization of muscle glycogen during the time trials; measured indirectly by respiratory exchange ratio (RER), a factor that may lead to enhanced performance.

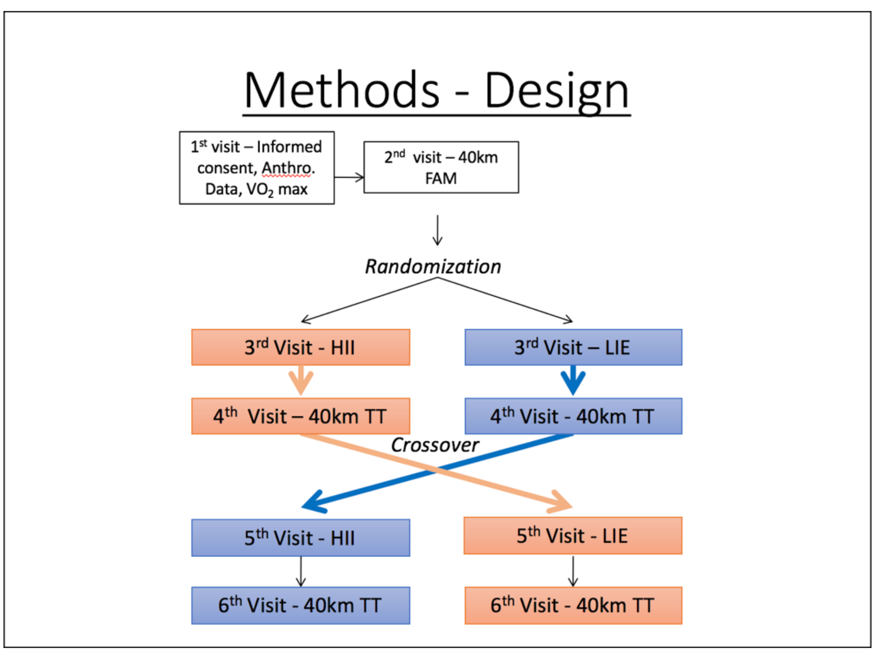
Chapter 3: Methods

Subjects

Nine competitive cyclists (ages 20-50, 7 M and 2 FM) from the local community were recruited; eight (6 M and 2 FM) completed all phases of the study. Subjects all met training requirements: ≥4days/wk and/or ≥10hr/wk cycling for ≥1 year. Additionally, subjects all had a background of bicycle racing ≥1year. Subjects filled out a questionnaire to ensure no pre-existing medical conditions, injuries, or sickness put the subjects at risk (appendix A). All subjects provided informed consent as approved by the Appalachian State University Institutional Review Board, #16-0313.

Design

Subjects reported to the lab on six separate occasions. During the first visit, subjects filled out all necessary forms, had anthropometric data recorded, and underwent a VO_{2max} test. The second visit consisted of a 40km time trial, which acted as a familiarization trial (FAM) for subsequent performance trials and allowed for the establishment of a baseline 40km TT average power to be used for performance trial power (p) determinations. The third and fifth visits consisted of either the opener workout (HII) or an easy spin workout (LIE - easy 1hr spin at 35% of FAMp). The fourth and sixth visits consisted of the actual performance trials (40km time trials). Subjects were tested in a random crossover, repeated measures design in which each subject received both an experimental treatment (HII) and control treatment (LIE). Performance measures included time to completion, mean power output, and expired gas values during each 40km time trial. Subjects were required to abstain from exercise 48hr prior to each 40km time trial. The experimental treatment consisted of an HII workout completed 12-24hr prior to a 40km time trial. HII consisted of one hour cycling (fifteen-minute warm up at 63% FAMp, three one minute efforts at 150% FAMp separated by five minutes at 63% FAMp, three thirty second efforts at maximum separated by five minutes at 63%, and fifteen and one half minute cool down at 63% FAMp). The control trial consisted of the subject reporting to the lab 12-24hr prior to the 40km time trial in the same manner as the experimental condition, however LIE was completed. LIE consisted of one hour cycling at 35% of first 40km TT power. Subjects were provided a carbohydrate beverage (Gatorade), 1.2g/kg, 12-24hr prior to the 40km time trial upon completion of the HII and LIE sessions to insure adequate carbohydrate availability. Subjects were instructed to maintain their normal training schedule leading into all three time trials. Subjects were instructed to maintain a similar diet 48hr prior to both sessions, preferably favoring high carbohydrate consumption. Subjects were given a food list containing a sample menu of high-carbohydrate food items. Subjects were asked to abstain from eating for three hours prior to all laboratory visits. Subjects were asked to complete a food log for the two days before and the morning of the 40k time trial.



VO_{2max} Testing

All subjects underwent a VO_{2max} test to exhaustion on their first day reporting to the laboratory. During VO_{2max} testing, expired gases were collected and analyzed with a breath-by-breath metabolic analyzer system (Quark CPE2, Cosmed, Rome, Italy). Subjects completed the test on an electronically braked ergometer (LC6, Monark, Vansbro, Sweden). Subjects were allowed to use their own clipless pedal system and the ergometer was adjusted to match the bike fit of the subject's personal bike. The VO_{2max} test included a 4min warm-up at 100W. After the warm-up, workload increased 50W every 2.5min until subjects reached exhaustion. Termination of the test was volitional exhaustion or once the subject could no longer maintain 60rpm at the designated workload. VO_{2max} was defined as the highest 30 second average VO_2 achieved. Attainment of VO_{2max} was validated by the subject having at least three of the following: RER≥1.10, an RPE of ≥17 (on a 6-20 rating scale), heart rate of ±10 beats/min of age-predicted max heart rate (220-age), lactate concentration of ≥8mmol/l.

40km Time Trial

The subjects completed a familiarization 40km time trial to account for any learning effect and establish baseline average 40km TT power. The subjects then completed two subsequent 40km time trials 24hr after either the experimental (HII) or the control (LIE) condition. Subjects were instructed to complete all time trials as quickly as possible. Subjects rode at a self-selected pace and cadence. The only feedback given was distance left to completion. All 40km time trials involved the analysis of VO_2 data to assess VO_2 kinetics using the above-mentioned breath-by-breath system. Data for respired gas concentrations was sampled every 10min for 2min. All 40km time trials took place on a Wattbike Pro

(Woodway; Waukesha, WI, USA). Data for pace, power, and total time to completion was recorded by this device.

Blood Lactate Concentration

Blood lactate concentration was measured with a portable lactate analyzer (Nova Biomedical; Waltham, MA, USA). Blood samples were taken by fingerstick. Lactate measurements were performed during VO_{2max} testing. Lactate concentrations were taken at the end of each stage during VO_{2max} testing.

Statistical Analysis

All statistical analyses were performed using SPSS, Version 25 (IBM, Armonk, New York). All data are expressed as mean ± SE. The between trial total 40km time and average power data were analyzed using two-tailed paired t-tests, with significance set at $p \leq 0.05$. The time, VO_2, RER, and RPE data were analyzed for changes over distance between conditions using a 2 (condition) × 8 (time) repeated-measures ANOVA, within-subject design, with significance set at $p \leq 0.05$.

Chapter 4: Results

4.1. Subject characteristics, training, and study completion

All subjects were trained and competitive cyclists. All subjects followed a consistent training schedule and dietary intake throughout the training study. Eight subjects successfully completed all phases of the study.

Table 1. Subject characteristics: N (male/female) = 8 (6/2)

Variable	**Mean ± SE**
Age (y)	29.6 ± 4.50
Body mass (kg)	62.3± 2.21
Height (cm)	171 ± 3.30
VO_2max (L/min)	3.57 ± 0.15
VO_2max (mL/kg/min)	57.4 ± 1.08
HR_{max} (BPM)	182 ± 6.30
VO_2max Final RPE	18.8 ± 0.41
Peak La (mmol/L) during VO2max	12.1 ± 0.88

Data are means ± SE.

Overall Time and Power for 40km Time Trials

There was no significant difference in time to completion between the 40km time trial with HII and the 40km time trial with LIE the day before ($p = 0.545$), Table 2. There was no significant difference in average power over the 40km time trials ($p = 0.374$), Table 2.

Table 2. Overall Times to Completion and Average Powers

Condition	Time to Completion (min)	Average Power (watts)
Baseline	63.9 ± 4.00	213 ± 36.3
LIE	62.9 ± 4.09	222 ± 38.6
HII	63.2 ± 3.51	219 ± 36.3

Data are Mean ± SE.

Time over the course of 40km Time Trials

No significant difference was found between times to complete every 5th km of each 40km time trial between conditions ($p = 0.362$), Figure 1. The pacing of each the 40km time trial in each condition was almost identical.

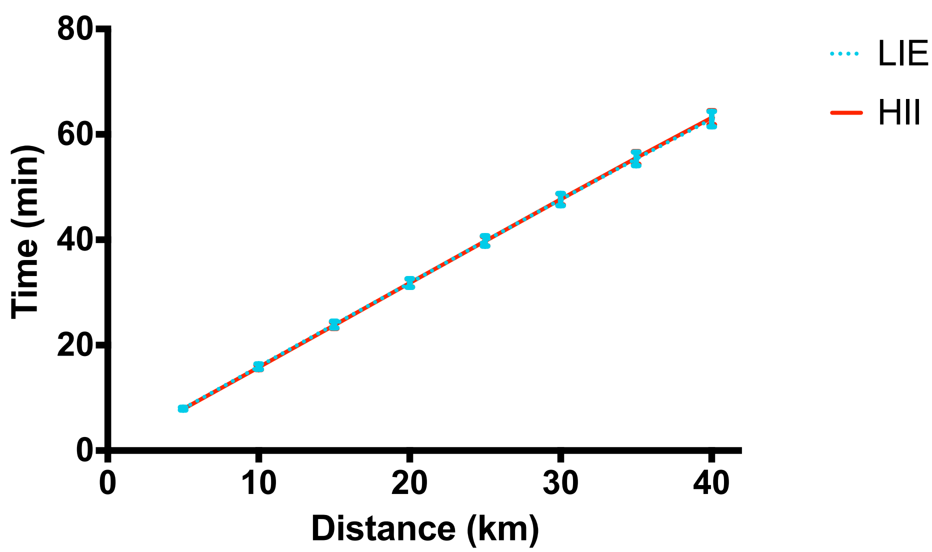


Figure 1. Average time taken to reach each 5km interval of total 40km distance. No significant difference found between conditions ($p = 0.362$). Data are Mean ± SE. Data was analyzed using a two-way ANOVA for repeated measures (condition x distance) with significance set at $p \leq 0.05$.

VO_2 over the course of 40km Time Trials

No significant difference in VO_2 values was measured across the distance of the time trial, sampled every 5th km ($p = 0.775$), between conditions, Figure 2.

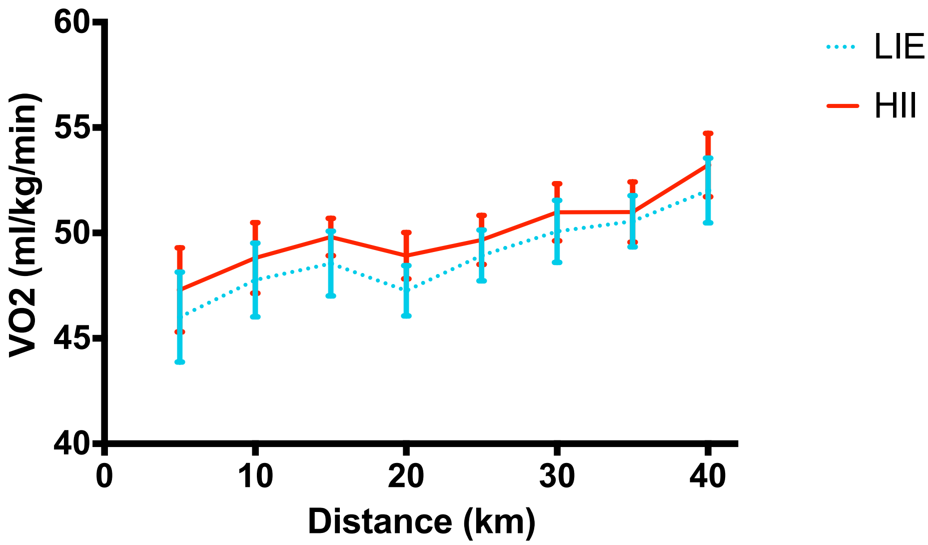


Figure 2. Average VO_2 at each 5km interval of total 40km distance. No significant difference was measured between conditions ($p = 0.775$). Data are Mean ± SE. Data was analyzed using a two-way ANOVA for repeated measures (condition x distance) with significance set at $p \leq 0.05$.

RER over the course of 40km Time Trials

There was no significant difference between RER values at every 5th km between conditions for each time trial ($p = 0.281$), Figure 3.

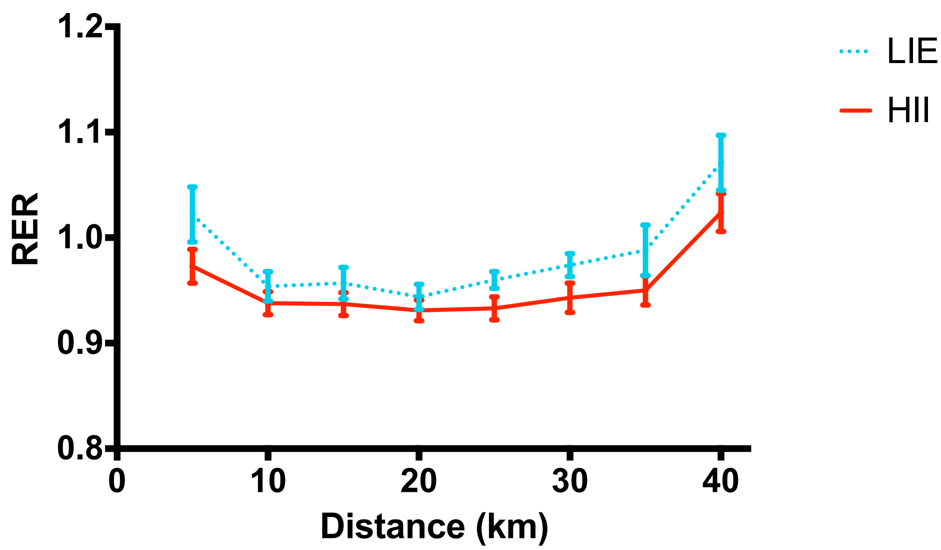


Figure 3. Average RER at each 5km interval of total 40km distance. No significant difference found between conditions ($p = 0.281$). Data are Mean ± SE. Data was analyzed using a two-way ANOVA for repeated measures (condition x distance) with significance set at $p \leq 0.05$.

RPE over the course of 40km Time Trials

There was no significant difference between RPE at every 5th km between conditions for each time trial ($p = 0.508$), Figure 4.

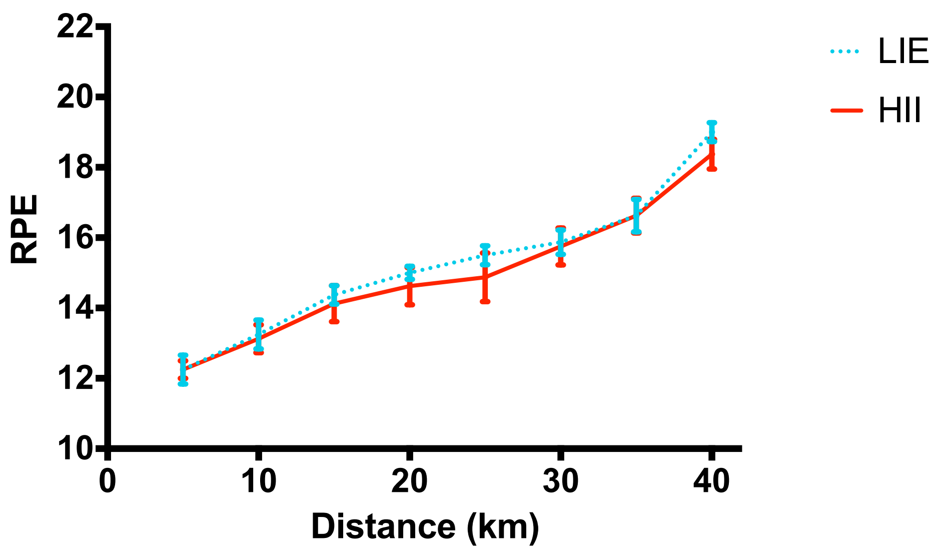


Figure 4. Average RPE at each 5km interval of total 40km distance. No significant difference found between conditions ($p = 0.508$). Data are Mean ± SE. Data was analyzed using a two-way ANOVA for repeated measures (condition x distance) with significance set at $p \leq 0.05$.

Chapter 5: Discussion

The hypothesis that an opener workout (HII) would decrease time trial time to completion and increase average power output over the duration of a 40km time trial in trained cyclists as compared to a time trial completed without a previous opener workout but with an easy spin (LIE) was rejected. Time to completion did not differ between conditions. This is in opposition to the practical experience of most cyclists and coaches. While a simulated flat 40km time trial is certainly different than stochastic race conditions one would still expect any efficacy of opener workouts to carry over to such a test. Additionally, it would be expected that cyclists would generally follow a similar structure of training and completion of HII even for a time trial. Average power, as expected given the time to completion, data did not differ between conditions. Once again, this is in contrast to current training and racing practice and in the cycling training literature (1,14,10).

In addition to total time to completion, the time to reach every 5th km of the 40km time trials with HII or with LIE was measured. The time to reach the standardized distant points did not differ between conditions. Once again, this is in contrast to current practice (1). While HII are more commonly completed for stochastic-natured races, they may occasionally be completed for time trials and one would expect HII to benefit the pacing strategy of the subjects. This was not the case in the present study; pacing did not differ between conditions.

Due to the nature of the testing, actual VO_2 primary amplitude and the slow component of VO_2 could not be measured from these tests as in other studies looking at VO_2 kinetics. Testing these require comparison of VO_2 response at a fixed workload (6). Completion of such a period at a fixed workload was not possible as the 40km time trials had to be completed in a self-paced, as quick as possible manner. Instead of VO_2 primary amplitude and slow component the trend of the VO_2 response over the duration of the 40km time trial was measured (6). The VO_2 response over the duration of the 40km time trials did not differ between trials. The data suggest that a lasting effect on VO_2 kinetics from the HII session 12-24 hours in advance did not occur under these testing conditions. In this study design, the work rate is not controlled in order to allow an “all-out” time trial by the subjects. In a controlled work-rate time trial HII may alter VO_2 kinetics.

RER did not differ between conditions over the course of the 40km time trials. This result is a reflection of pacing, total time, and power. RER was measured to indirectly determine if the opener workout had any effect on the utilization of fat or carbohydrate as a fuel source during each time trial. It is possible that HII would cause an enhanced storage of glycogen however it was not possible to measure this during this study (5). Upregulation of glycogen synthesis prior to a race situation could benefit racers in longer road race and stage race situations (4,9). Further studies should seek to measure muscle glycogen changes via muscle biopsy. Additionally, further studies might seek to test performance at over 90min as this seems to be the level at which higher levels of stored glycogen would benefit racing (4,9,12). It is possible that HII may not enhance actual performance in shorter trials, or alter substrate utilization, but instead cause a benefit through the ability to go hard longer, or later into a race due to extra glycogen storage.

Interestingly, the RPE response did not differ between trials. This was unexpected. The prior expectation that the psychologically influential nature of the subjects knowing the condition they were currently ‘racing’ under would have biased their reporting, specifically. It would be expected that racing cyclists would have reported a lower RPE after HII. This is not only because of almost universal usage and anecdotal evidence of the efficacy of HII to increase cycling performance, but also due to having been described as causing the cyclist's legs to become more supple and responsive during racing (1).

Overall, this study was underpowered with a power value of 0.05 (calculated using G*Power and significance was not found for any values (10). Future studies of similar design should seek to not only recruit more subjects but also potentially slightly alter the study design. While 40km time trials are the gold standard for in-lab performance testing, a stochastic race simulation that lasts 90min or more may be more appropriate to detect differences in performance despite the tradition of openers being utilized by short-distance (criterium/cyclocross) and long-distance (road) racers alike. There is evidence that during a longer taper (7d) resting as opposed to doing low-intensity or high-intensity workouts in fact decreases performance. (20). However, a rest-only condition should have been included in addition to the HII and LIE conditions in this study. Future studies should also include a moderate-intensity warm-up 6-minutes prior to each trial at a standardized power to allow for comparisons in effect on VO_2 kinetics and particularly the slow component of VO_2 (8). Unfortunately, direct measure of muscle glycogen was not measured in this study; rather carbohydrate utilization was inferred from RER. Although RER is a measure of overall carbohydrate utilization it is not a direct measure of muscle glycogen utilization. Future studies should directly measure muscle glycogen in muscle biopsies pre- and post-HII and LIE and pre- and post- each 40km time trial to measure glycogen storage and use. The lack of psychological influence on RPE in this study was of note. Future studies should employ psychological questionnaires to determine any effect of the opener workout on this aspect of training and racing.

Conclusions

This is the first study to examine the effect of an acute bout of HII and resultant exercise performance. The data presented here provide interesting insight into current training practices. Despite previous reports that high-intensity low-volume taper paradigms improve performance over a low-intensity taper, exercise performance, average power, VO_2, RER, and RPE did not differ in trained cyclists during 40km time trials completed 24hr after HII and LIE sessions.

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Appendix A: Pre-Participation Screening

Pre-Participation Screening: Performance Changes Due to High Intensity "Opener" Workout 24 Hours Prior to Race Simulation

Please fill out the following fields or provide answers to questions:

Birth date:__________________________

How long have you been training on a bicycle?

How long have you been racing bicycles?

Approximately, how many days per week do you ride a bicycle?

Approximately, how many hours per week, total, do you ride a bicycle?

Have you had a period of more than 4 weeks off the bike in the past 6 months?

Appendix B: Example of SPSS Syntax for Two-Way ANOVA of VO_2

```
GET
  FILE='/Users/alangarvick/Desktop/Thesis (8:29:16)/twowayanovavo2.sav'.
DATASET NAME DataSet2 WINDOW=FRONT.
GLM E5 E10 E15 E20 E25 E30 E35 E40 O5 O10 O15 O20 O25 O30 O35 O40
  /WSFACTOR=openerveasy 2 Polynomial VO2 8 Polynomial
  /METHOD=SSTYPE(3)
  /SAVE=SRESID
  /PLOT=PROFILE(VO2*openerveasy) TYPE=LINE ERRORBAR=NO MEANR
EFERENCE=NO YAXIS=AUTO
  /EMMEANS=TABLES(openerveasy) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(VO2) COMPARE ADJ(BONFERRONI)
  /EMMEANS=TABLES(openerveasy*VO2)
  /PRINT=DESCRIPTIVE ETASQ
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=openerveasy VO2 openerveasy*VO2.
```

Vita

Alan Garvick was born in New Bern, North Carolina to George and Peggy Garvick. He graduated from Appalachian State University in Boone, North Carolina in December 2014. He graduated with a B.S. in Exercise Science. The following fall he was admitted to Appalachian State University to pursue a M.S. degree. Alan is currently pursuing his M.S. at Appalachian State University in Exercise Science and is projected to graduate in December 2017.