SEQUENCING OF HIGH INTENSITY EXERCISE BOUTS DURING A
SEVEN-DAY TAPER IN TRAINED CYCLISTS

A Thesis

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Nathanael V. Dunn

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SEQUENCING OF HIGH INTENSITY EXERCISE BOUTS DURING A
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Nathanael V. Dunn

Approved by:

___________________________, Committee Chair
Daryl Parker, Ph.D.

___________________________, Second Reader
Roberto Quintana, Ph.D.

___________________________
Date
Student: Nathanael V. Dunn

I certify that this student has met the requirements for format contained in the University format manual, and that this thesis is suitable for shelving in the Library and credit is to be awarded for the thesis.

__________________________, Graduate Coordinator
Michael Wright, Ph.D. Date

Department of Kinesiology
Abstract

of

SEQUENCING OF HIGH INTENSITY EXERCISE BOUTS DURING A
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Nathanael V. Dunn

Introduction: While a wealth of current literature exists to support the effectiveness of a training taper on athletic performance, no study has compared the sequencing of high intensity exercise bouts during the taper period. Purpose: To examine the effect of different sequences of high intensity exercise bouts on cycling time trial performance during a seven-day taper.
Methods: 10 well-trained male cyclists age 24-48 underwent a VO\(_2\)peak test to determine Wmax. Subjects were then counter-balanced to 1 of 2 groups following an opposite taper week order (Taper 1-2 or Taper 2-1). Each taper week was preceded by a seven-day training volume increase to 120% of a subject’s self-reported weekly training volume. Both taper weeks utilized a 50% reduction in training volume. Taper 1 consisted of a H|L|H|O|L|L|T sequence (H=High Intensity, L=Low Intensity, O=Day Off). Taper 2 consisted of a H|L|H|O|L|H|T sequence. All participants returned to the lab for a 288kJ time trial (T) on the first and seventh day of each taper. Analysis between the tapers used a two-way repeating measures ANOVA, with an \(\alpha\)-level of .05. Results: There was no main effect for time trial performance, HR response, or RPE vs. taper protocol. There was however a trend toward significance comparing pre and post time trial performance (\(p=0.11\)) as well as HR response (\(p=0.08\)) following both taper protocols. Conclusions: The different sequences of high intensity exercise bouts during a seven-day taper were not observed to
make a statistically significant difference in time trial performance during a 288kJ laboratory time trial.

_______________________, Committee Chair
Daryl Parker, Ph.D.

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Date
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1. INTRODUCTION

Professional and amateur athletes alike are constantly searching for innovative strategies to optimize athletic performance. Some training strategies are rooted in science, some on previous observation. One strategy demonstrated to be effective at improving performance across several athletic disciplines is the training taper (Houmard, 1991). A taper is a “reduction in the training load of athletes in the final days before important competition, with the aim of optimizing performance” (Bosquet, Montpetit, Arvisais, & Mujika, 2007). The primary objective of a taper is to maximize the physiological benefits of previous training while simultaneously reducing the fatigue resulting from training (Bosquet, et al., 2007; Mujika & Padilla, 2003). While taper protocols differ in their length and method of training volume reduction (Mujika, 1998), they have been shown to yield performance improvements ranging from 3-5% in activities as physically diverse as swimming, cycling, and running (Houmard & Johns, 1994; Houmard, Scott, Justice, & Chenier, 1994; Johns et al., 1992; Neary, Martin, & Quinney, 2003).

Closely related to performance improvements are positive physiological adaptations brought about by the training taper (Mujika, Padilla, Pyne, & Busso, 2004). These include an increase in VO$_2$ max (Neary, Bhambhani, & McKenzie, 2003), an increase in blood volume (Shepley et al., 1992), improved blood lactate kinetics (Mujika, et al., 2004), and an increase in muscle glycogen concentration (Neary, Bhambhani, et al., 2003). This physiology/performance relationship was clearly demonstrated in a study by Neary et al. (2003) examining cycling performance and the training taper through time trial measurements and muscle biopsies before and after the taper period (Neary, Martin, et al., 2003). Observing performance improvements in a 40-kilometer (km) time trial of 4.3%, Neary et al. (2003) was also able to observe a correlation between functional measures of endurance and metabolic changes at the single muscle cell.
These metabolic changes included increases in oxidative and contractile enzyme activity as well as structural changes to type II muscle fibers.

While results such as those observed by Neary et al. (2003) give clear evidence to the improved endurance performance and metabolic changes following a taper, the body of research offers conflicting methods on how to best execute a taper. While the central components of a taper are training volume reduction and maintenance of training intensity, the method of volume reduction and intensity dosage can differ widely. While some studies show endurance performance increasing following a taper using a step-reduction in training volume of 50% (Neary, Bhambhani, et al., 2003), others have employed a linear reduction in training volume coupled with a more conservative 20% reduction in volume (Houmard & Johns, 1994).

In a unique approach to comparing different tapers, Bannister et al. (1999) used a theoretical model to first design several distinctive tapers then followed up later with a criterion cycling and running test to examine each taper’s “real-world” effectiveness. In this study, Banister et al. (1999) observed that a fast-exponential taper resulted in a significantly greater improvement in cycling performance over a step taper (Banister, Carter, & Zarkadas, 1999).

The wide range of taper methods and athletic disciplines used to assess performance further complicate the taper literature. Taper studies have been performed on kayakers (Garcia-Pallares, Sanchez-Medina, Perez, Izquierdo-Gabarren, & Izquierdo, 2010), triathletes (Banister, et al., 1999), runners (Mujika et al., 2002), swimmers (Houmard & Johns, 1994), and cyclists (Neary, McKenzie, & Bhambhani, 2005). These studies often employ a wide range of taper duration, type, and training intensity dosage. In Garcia-Pallres et al. (2002) study examining world-class kayakers training intensity was increased during the 4-week taper period, including 2 strength training sessions a week, utilizing intensities as high as 90-95% of 1 repetition maximums coupled with endurance training at paddling speeds as high as 105%VO₂max. In the
Banister et al. (1999) study examining triathletes, training intensity was prescribed by using a mathematical formula equal to 70% of Δ HR ratio (HR exercising - HR Resting/HR Max - HR Resting). Mujika et al. (2002) examined runners, using “high intensity” training during the taper characterized by running speeds greater than 100% of the final individual speed attained during a maximal blood lactate steady state test. The methods used to quantify high intensity training have been shown to be as diverse as the sports represented in the taper literature.

A common technique to resolve conflicting findings in research is the meta-analysis. Bosquet et al. (2007) utilized this technique to examine the taper and found the most effective taper framework was one lasting two weeks during which training volume was exponentially reduced 41-60% while training frequency and intensity were maintained. Since the overall objective of the taper is to reduce fatigue through training volume reduction while maintaining the physiological adaptations of previous training, maintaining training intensity throughout the taper has been identified as one of the keys to an effective taper strategy (Mujika, 2010). While the essential taper ingredient of intensity is widely recognized, the best way to maintain intensity throughout the duration of a taper can be confusing to athletes and coaches alike.

No sport seems to suffer from more confusion surrounding the best way in which to execute a training taper than cycling (Bosquet, et al., 2007). While lay publications agree on the need for some sort of taper with a component of high intensity exercise (Allen & Coggan, 2010; Barry, Barry, & Sovndal, 2006; Burke, 2002; Friel, 2009; Wenzel, 2003), the sequencing of these high intensity exercise bouts seems up for debate, especially in the final day before a race or time trial. In the cycling culture these short but intense efforts the day prior to a competition are known as “openers”. Ask any competitive cyclist or cycling coach about the value of “openers” the day prior to a race and their responses will likely be varied and contradictory. While some professional coaches advocate executing a day of active recovery on the bike, typically performed
by training for 45-90 minutes at an intensity equal to 40% of an athlete's VO$_2$peak (Barry, et al., 2006; Burke, 2002; Wenzel, 2003) others advocate the execution of “openers” (110% VO$_2$peak) performed to mimic the demands of the following day of racing (Allen & Coggan, 2010; Friel, 2009). Neither perspective has the backing of any peer-reviewed research, but has probably been the result of years of trial and error observation.

While current research has examined length, training reduction volume, and maintenance of training intensity during the taper, no research to date has directly compared different sequences of high intensity exercise bouts during the taper period, more specifically high intensity exercise bouts or “openers” the day prior to a performance test. Research aimed at answering the question of whether or not “openers” are effective could go a long way in clarifying the confusion surrounding the cycling taper as well as provide insight into how the human body is impacted by prior bouts of high intensity exercise.

1.1 Problem

High intensity exercise coupled with a substantial (41-60%) decrease in training volume is key during a training taper to maintain the physiological adaptations earned through intense training (Mujika, 2010). While this much is known, the potential impact of different sequences of high intensity exercise during a taper is unknown.

1.2 Purpose

It is the purpose of this study to compare the sequencing of high intensity exercise bouts during a seven-day taper and observe the potential impact this sequencing might have on cycling time trial performance, HR response, and RPE.

1.3 Significance of Thesis

The performance enhancing effects of a training taper have been widely researched. The importance of high-intensity exercise during this taper period has also been well established. In
the sport of cycling, the question remains as to the effectiveness of “openers” during the taper period. This study seeks to answer the question of whether or not there is a performance difference between a taper that includes a day of “openers” and a taper that does not.

1.4 Definition of Terms

Training Taper – A reduction in training volume typically spanning one to two weeks during which an athlete attempts to maintain fitness while shedding the fatigue of intense training.

VO₂peak – The point at which oxygen consumption plateaus, typically during a graded exercise test.

Cycling Ergometer – A stationary bicycle that displays power output in watts and total work performed in kilojoules.

288kJ Time Trial – A timed effort on a cycling ergometer that is considered finished upon the completion of 288kJ of work, approximately 10 kilometers.

Active Recovery – Describes an exercise intensity prescribed for the purpose of maximizing recovery rather than eliciting a positive training stimulus.

GXT – Graded Exercise Test such as a VO₂peak test. Intensity is increased on a “graded” scale until volitional fatigue is reached upon which the test is ended.

Wmax – The maximum workload achieved over the duration of a stage during a GXT. Expressed in watts.

“Opener” – Common vernacular used to describe a short but intense series of high intensity intervals, typically executed one day prior to a cycling race or time trial.

1.5 Hypothesis

A. There will be no significant difference in time to completion for a 288kJ time trial between Taper 1 and Taper 2 (p≤.05)
B. There will be no significant difference in mean RPE during a 288kj time trial between Taper 1 and Taper 2 (p≤.05)

C. There will be no significant difference in mean HR response during a 288kj time trial between Taper 1 and Taper 2 (p≤.05)
2. REVIEW OF LITERATURE

2.1 Introduction

The taper is a training strategy by which training load is reduced leading up to a competitive event with the intent of minimizing residual fatigue while simultaneously maintaining the positive physiological adaptations of a period of previous intensive training (Mujika, et al., 2004). While differences between specific tapering strategies exist across athletic disciplines and between individual athletes, the performance gains elicited have been confirmed anecdotally and empirically (Bosquet, et al., 2007; Mujika, et al., 2004). As coaches, athletes, and sports scientists attempt to maximize the smallest of performance gains, tapering strategies have become an increasingly important facet of a comprehensive training strategy (Mujika & Padilla, 2003).

2.2 Components of a Taper

Tapering is traditionally achieved through altering a combination of several different training components; volume, frequency, and intensity (Wenger & Bell, 1986). Apart from these components, tapers can differ in the pattern by which they reduce training load leading up to an event. Load reduction can be achieved through a linear, exponential (slow), exponential (fast), or step reduction in training volume (Mujika & Padilla, 2003).

Not surprisingly the inter-athlete variability and seemingly complicated nature of tapering has resulted in a rather ambiguous training phase during which Mujika states, “coaches are…insecure about the most suitable training strategies for each individual athlete, as they have most often relied almost exclusively on a trial-and-error approach” (Mujika & Padilla, 2003). Despite confusion amongst coaches and athletes as to the optimal tapering strategy, research clearly demonstrates positive physiological adaptations during the taper period (Mujika, et al., 2004).
2.3 Physiological Adaptations

Perhaps the most quantifiable physiological adaptation during the taper period is an increase in VO$_2$\textsubscript{max} (Dressendorfer, Petersen, Lovshin, & Keen, 2002; Dressendorfer et al., 2002; Jeukendrup, Hesselink, Snyder, Kuipers, & Keizer, 1992; Margaritis, Palazzetti, Rousseau, Richard, & Favier, 2003; Neary, Bhamhansi, et al., 2003; Neary, Martin, et al., 2003). More specifically VO$_2$\textsubscript{max} enhancements of 6.0% were reported in cyclists during a 7 day taper during which training volume was reduced by 50% (Neary, Bhamhansi, et al., 2003). While some studies showed performance improvements without an increase in VO$_2$\textsubscript{max} (Muji, et al., 2004), measuring an improvement in maximal oxygen uptake has long been used as a determinant of human performance (Saltin & Astrand, 1967). While the physiological changes that impact VO$_2$\textsubscript{max} are varied and work in an integrated fashion (Mujika, et al., 2004), many of the specific physiological adaptations that contribute to an increase in VO$_2$\textsubscript{max} are known.

Research has shown that during the taper period there is an increase in blood plasma (Mujika, et al., 2002), red blood cell production (Mujika, Padilla, Geyssant, & Chatard, 1998; Shepley, et al., 1992), blood volume (Shepley, et al., 1992), oxygen extraction (Neary, et al., 2005), and ventilatory function (Neary, Martin, et al., 2003; Shepley, et al., 1992). Collectively the taper induces “improved or stable VO$_2$\textsubscript{max} and performance gains…particularly where training intensity has been maintained” (Mujika, et al., 2004). While the taper has been shown to produce measureable improvements in VO$_2$\textsubscript{max}, its impact on substrate utilization and RER has shown mixed results. While one study found a slight change in RER (alluding to more fat utilization during exercise) following a 4 and 8 day taper (Neary, Martin, Reid, Burnham, & Quinney, 1992), other studies have shown no change in rates of fat oxidation (Neary, Bhamhansi, et al., 2003; Rietjens, Keizer, Kuipers, & Saris, 2001).
While the impact of the taper on substrate utilization has produced conflicting results, the taper’s impact on blood lactate kinetics is more solidly understood. In his 2004 review of taper studies, Mujika found a total of 8 studies demonstrating improvements in peak blood lactate (Mujika, et al., 2004). Also shown was a reduction in blood lactate at submaximal exercise intensities (Neufer, Costill, Fielding, Flynn, & Kirwan, 1987). Improvements in blood lactate kinetics were likely a component in the performance gains Jeukendrup observed while studying the effect of the taper on male competitive cyclists. Following a period of intense training and taper, Jeukendrup found a 7.2% improvement in an 8.5km outdoor time trial and a 10.3% increase in peak power output (Jeukendrup, et al., 1992).

Like peak blood lactate, muscle glycogen concentration has also been shown to increase during the taper (Neary, Martin, et al., 2003; Neary, et al., 1992). In Neary’s 2003 study examining the effects of a taper on endurance cycling he found the amplitude of glycogen supercompensation was associated with the amplitude of improvement in the 40k time trial used as a performance metric (Neary, Martin, et al., 2003). Since glycogen supercompensation is largely dependent on prior glycogen depletion it stands to reason that maintaining intensity throughout the taper period plays a vital role in the body’s ability to store excess glycogen.

Hormonal changes are also apparent during the taper period. Resting cortisol and Human Growth Hormone levels have been shown to decline, (Costill et al., 1991; Steinacker et al., 2000) while ILFG (Insulin Like Growth Factor) levels increase (Koziris et al., 1999).

Neuromuscular changes are another area of the taper with well documented performance improvements. Of the 12 studies Mujika examined in his 2004 review paper on taper studies, 9 reported increases in strength and/or power (Mujika, et al., 2004).
2.4 Psychological Changes

Since physiological changes do not likely account for all the performance benefits of the taper (Mujika, et al., 2004), it is important to examine what psychological changes have been observed following a taper. In Berger’s 1999 study examining mood and cycling performance it was found that a two-week taper induced positive changes in the mood state of cyclists (Berger et al., 1999). Perhaps even more crucial to an improved mood state was the finding that the ratio of HR/RPE was reduced in cyclists following a taper period (Martin, Scifres, Zimmerman, & Wilkinson, 1994; Neary, Bhambhani, et al., 2003).

2.6 Key to an Effective Taper

As the research looking into the physiological rationale behind improved performance following a taper has been understood for some time, our understanding of the specific type of taper that produces the best chance for performance improvement is following suit. In his 2007 meta-analysis of 27 different papers examining the performance taper, Bosquet et al. (2007) concluded that the greatest potential for performance gains come from following a 12 day taper with an exponential 41-60% reduction in volume, while maintaining frequency and intensity of training (Bosquet, et al., 2007). As the first study of it’s kind to compare performance data on swimming, running, and cycling taper studies, Bosquet et al. (2007) was able to provide a measure of clarification amidst the inconsistency of taper protocols and performance measures.

Regardless of the specific type of taper used, the key to maintaining the physiological adaptations achieved through training is to maintain training intensity through the taper (Mujika, 2010; Mujika, et al., 2004). Since the overall objective during the taper period is to minimize the presence of fatigue while maintaining a high degree of athletic performance, one must take caution to insure that detraining does not take place with the reduction in training load brought about by the taper. Several studies have outlined the physiological impact of detraining (Coyle,
Hemmert, & Coggan, 1986; Garcia-Pallares, et al., 2010; Hickson, Foster, Pollock, Galassi, & Rich, 1985; Mujika & Padilla, 2000a, 2000b). These impacts include a reduction in VO$_2$max (Coyle et al., 1984), decrease in blood volume (Coyle, et al., 1986; Houmard et al., 1992), decrease in stroke volume (Coyle, et al., 1986), decrease in cardiac output (Coyle, et al., 1984), and a decrease in enzymatic activity (Shepley, et al., 1992). As stated earlier, the key to avoiding these effects of detraining is a maintenance of training intensity throughout the taper period (Bosquet, et al., 2007).

2.6 Circular Thinking

While the Bosquet et al. (2007) meta-analysis concluded the superiority of a 12-day taper during which training volume is decreased while training intensity is maintained a disclaimer was also made in regards to the 27 studies used in the analysis. “In a context where no one wants to take the chance of a sub-standard performance, it is likely that researchers are studying tapering strategies that have been proved to be successful, either scientifically or empirically, thus leading to a circular thinking” (Bosquet, et al., 2007). Bosquet goes on to make the case for an examination of more innovative tapering strategies to more fully understand the adaptive response that takes place following a taper.

2.7 Innovative Strategies

One such innovative tapering strategy was examined by Thomas et al. during which computer modeling was used to determine the effect of a training load increase during the final 3 days of a taper (Thomas, Mujika, & Busso, 2009). This study was novel in that it was the first of its kind to introduce a 2-phase taper with a training load increase in the second phase allowing “additional training adaptations without compromising the removal of fatigue” (Thomas, et al., 2009). This study highlighted a possible benefit from increasing training load during the final 3 days before a competition, a departure from historical tapering strategies that reduce training
volume while maintaining training intensity leading up to a competitive event (Bosquet, et al., 2007).

2.8 Summary

While numerous studies exist to support the performance benefits of a training taper (Bosquet, et al., 2007) in conjunction with a maintenance of training intensity (Mujika, 2010), the author knows of no studies to date that have directly compared tapers with different sequences of high intensity exercise bouts or “openers” during the final days leading up to a performance time trial.

In the sport of competitive cycling a great deal of confusion exists as to the optimal placement of high intensity exercise bouts before a time trial or race. While some coaches advocate the sequencing of high intensity exercise to occur 72 hours before a race (Barry, et al., 2006; Burke, 2002; Wenzel, 2003), others advocate a bout of high intensity exercise no later than 24 hours prior to a race (Allen & Coggan, 2010; Friel, 2009). The lack of empirical data supporting either of these approaches as well as the need to examine more novel tapering strategies (Bosquet, et al., 2007) raises the question as to whether or not the sequencing of high-intensity exercise bouts or “openers” during the taper have a significant impact on athletic performance.
3. METHODS

3.1 Subjects

10 competitive, male cyclists training 9.3 ± 2.83hrs/week, age 38.8 ± 8.61yrs, weight 75.38 ± 9.6kg, height 178.2 ± 8.21cm, and BMI 23.8 ± 1.75 from the greater Sacramento area were recruited for this study performed at the exercise physiology laboratory at California State University Sacramento. Thirteen male subjects (from an initial subject recruitment pool of 19) met research inclusion criteria and completed an initial GXT and familiarization protocol. One subject failed to complete the prescribed training volume increase during the first week of the protocol and was asked to “restart” his training sequence. This subject subsequently sustained an unrelated injury and withdrew from the study. Another subject sustained a rib injury and chose to withdraw from the study. A third subject was involved in an automobile accident that excluded him from participating in the remainder of the study. Ten male subjects completed the initial GXT and 4 week training and taper sequence as well as all laboratory time trials.

3.2 Design

In order to directly compare two different sequences of high intensity exercise during a 7-day taper, all ten subjects were systematically counter-balanced into one of two taper protocols throughout the four week training and testing period. Each subject completed both 7-day taper protocols, preceded by a week of training overload, totaling 4 weeks of training. Half of the subjects completed a Taper 1/Taper 2 sequence and the other half a Taper 2/Taper 1 sequence. A time trial on the first and last day of each taper was used to assess performance at the beginning (day 1) and end (day 7) of each taper week.
3.3 Procedures

All participants signed “Consent to Participate” forms detailing the inherent risk involved in strenuous exercise. Included in the consent form was a general outline of a GXT that served as an introduction to the laboratory visits to come. All design elements of this research were approved through the institutional review board (IRB) at California State University Sacramento.

Prior to an initial laboratory visit, participants completed a medical and training questionnaire to assess health status and eligibility for participation. Following a medical questionnaire screening, an initial laboratory visit was scheduled during which baseline blood pressure, resting heart rate, and BMI calculations were taken to confirm health status in conjunction with each participant’s medical questionnaire. During this visit each subject’s weekly training volume was recorded (9.3 ± 2.83hrs/week).

3.3.1 GXT

Following final risk assessments, participants underwent a basic familiarization protocol as well as a GXT to determine VO$_2$peak and maximal aerobic power (Wmax). During the familiarization protocol participants were given a Polar heart rate strap to wear, then introduced to the cycling ergometer, a Lode Excalibur electromagnetically braked ergometer (Netherlands). This introduction included a basic fitting to the ergometer during which seat height, handle bar height, and handle bar distance were adjusted to best fit each participant. These measurements were noted and used to replicate position on the ergometer for all future trials. After fitment to the ergometer, participants were introduced to the two-way breathing valve (Hans-Rudold, Kansas City, MO), headgear, nose-clip, and flexible plastic breathing hose. This breathing hose was then connected to the pneumotach through which expired gas could be analyzed by the ParvoMedics Trueone 2400 metabolic measurement system (Sandy, Utah).
After instrument familiarization participants were given instructions on the GXT. The GXT used a staged protocol beginning at 75W followed by a 35W increase every 1 minute. Expired gas analysis measuring VO$_2$, VCO$_2$, and VE was performed by the ParvoMedics metabolic cart at 30 second sampling intervals. Participants exercised to the point of volitional fatigue. VO$_2$peak (54.43 ± 4.99ml/kg/min) and Wmax (390.3 ± 38.93W) was determined and recorded for each participant. Expired gas analysis data was saved and stored immediately on a laboratory computer as well as backed up on the lead researchers personal computer. Signs and symptoms prior, during, and after exercise were carefully observed in order to insure a high level of participant safety.

At a later starting date, each subject was instructed to execute two unique 7-day tapers each preceded by one week of training at 120% their normal training volume. Each performance taper involved a training volume reduction of 50%. Subjects were counter-balanced to the order of each taper and performed a pre-test on day one and a post-test on day seven of each taper.

3.3.2 Performance Time Trial

The testing protocol consisted of a warm up of 10 minutes at 100W followed by a 288kJ time trial during which participants were instructed to ride at a self-selected cadence in an effort to produce the shortest time to complete 288kJ (approximately 10km) of work. The Lode cycling ergometer was placed in Linear mode during which each participant rode with a linear factor equal to 70% of their Wmax divided by the square root of 90 (a typical cycling cadence). This linear factor (0.03 ±0.0034) calculation is represented by the following equation (0.7xWmax/8100). Performance (approximate distance to completion) feedback during the time trial was given at approximately 1km markers throughout the duration of the test.
3.3.3 Taper Protocols

Sequences of high intensity exercise bouts during each taper were as follows. “H” (High Intensity), “L” (Low Intensity), “O” (Day Off) and “T” (Test)

- Taper 1: T|L|H|O|L|L|T
- Taper 2: T|L|H|O|L|H|T

“High intensity” (H) training days consisted of the following workout protocol: 20-minute warm up at Borg RPE 10 followed by a set of three, one minute bouts at Borg RPE 18 (5 minute rest intervals between bouts at Borg RPE 10) followed by a set of three bouts of thirty second intervals at RPE 18 (5 minute rest intervals between bouts at Borg RPE 10) followed by a cool down of 5 ½ minutes at Borg RPE 10, for a total duration of 60 minutes. “Low Intensity” (L) training days consisted of a 60-minute protocol of cycling at Borg RPE 10 pedaling between 90-100 rpm. “Day Off” consisted of a day without training.

3.3.4 Monitoring Training

During each pre-taper and 7-day taper period, participants were required to confirm their training volume and workout compliance through an online training log accessible by both participant and researcher. This online training log was used to schedule each day of training during the four-week training period as well as validate the training compliance of each participant. Subjects were required to record their daily training volume during each overload week, as well as specific workout confirmation during each taper week.

3.4 Data Analysis

After study completion, time to completion, HR response, and RPE measures were analyzed between the tapers using a two-way repeating measures ANOVA, with an α-level of .05. In order to calculate mean training volume, daily training volumes were collected from each
subject’s online training journal. These values were averaged across each overload and taper week during the four week training period.
4. RESULTS

4.1 Introduction

Ten male subjects completed the initial GXT, 4-week training/taper sequence and four 288 kJ laboratory time trials. To introduce a sufficient training overload leading into each taper week, subjects underwent a training increase of 120% their typical training volume. Each subsequent taper week involved a training volume reduction of 50%. Participants were asked to record their actual training volume for each day throughout the study to verify compliance with the prescribed training volume increase during the overload and volume decrease during the taper week. Actual training volumes can be seen in Table 1.

4.2 Training Analysis

Listed in Table 1 is the training data for all 10 participants. Data represented includes (starting with the third column moving left to right) self-reported weekly training volume at the onset of study, 120% (overload week) of self-reported training volume, 50% prescribed taper, actual training volume for overload week 1, actual taper volume for taper 1, actual training volume for overload week 2, and actual taper volume for taper 2.

Mean prescribed vs. mean actual was as follows. 120% prescribed overload vs. Overload 1 actual was 5.4% different, vs. Overload 2 actual was 8.4%. 50% prescribed taper vs. Taper 1 actual was 2.7%, vs. Taper 2 actual was -7%. These relatively small differences in prescribed vs. actual suggest good participant compliance throughout the 4 weeks of overload and taper sequences.
Table 1. Individual subject training data

<table>
<thead>
<tr>
<th>N</th>
<th>Age (years)</th>
<th>Self-Reported Volume (hr/wk)</th>
<th>120% Prescribed Overload</th>
<th>50% Prescribed Taper</th>
<th>Overload 1 Actual</th>
<th>Taper 1 Actual</th>
<th>Overload 2 Actual</th>
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Figure 1. Mean training volume for all ten subjects demonstrating self-reported, prescribed, and actual volumes throughout the four week training period.
4.3 288kJ Performance Time Trials

All ten subjects completed one pre-test and one post-test 288kJ performance time trial for each taper protocol, totaling 4 time trials. Time trials were conducted on day one and day seven of each taper week. Mean time trial performance and HR response can be seen in figures 2 and 3 respectively.

4.4 Effect of Taper on Performance

To determine the effect of the two taper strategies on performance, time to complete 288 kJ of work on the cycle ergometer was used as a performance variable. There was no significant difference in performance following the taper, however there was a trend for an improvement in performance following the taper period (p=0.11). There was also no main effect for a change in performance between the two taper strategies (p=0.79). Finally no significant interaction effect was observed between the pre-post and taper strategy factors (p=0.54), suggesting that the sequencing of the high intensity bouts of exercise were not important to the magnitude of the effect of the taper. The results for performance following the taper period can be viewed in Figure 2.
4.5 Effect of Taper on HR Response

To determine the effect of the two taper strategies on HR response, average HR during the 288 kJ time trial was used as a measure of stress tolerance. There was no significant main effect in HR response following the taper, however there was a trend for an increase in average HR following the taper period (p=0.08). There was also no main effect for a HR response during the 288 kJ time trial between the two taper strategies (p=0.32). Finally no significant interaction effect was observed between the pre-post and taper strategy factors (p=0.36), suggesting that the sequencing of the high intensity bouts of exercise were not important to the magnitude of the effect of the taper. The results for HR response following the taper period can be viewed in Figure 3.
4.6 Effect of Taper on RPE

To determine the effect of the two taper strategies on RPE, average RPE during the 288 kJ time trial was used as a measure of perceived effort. There was no significant difference in RPE following the taper (p=0.30). There was also no main effect for RPE during the 288 kJ time trial between the two taper strategies (p=0.54). Finally no significant interaction effect was observed between the pre-post and taper strategy factors (p=0.24), suggesting that the sequencing of the high intensity bouts of exercise were not important to the magnitude of the effect of the taper.
5. DISCUSSION

5.1 Introduction

Competitive athletes and coaches are endlessly looking for innovative methods to improve performance. Improvements as small as 0.4% can sometimes make the difference between achieving a spot on the podium or falling out of contention (Pyne, Trewin, & Hopkins, 2004). The training taper is one area of athletic performance where research supports the potential for performance gains as great as 5.4% (Neary, Bhambhani, et al., 2003). When the margin of victory between first and third place can be less than half a percent, a training taper has the potential to be an important component of athletic success.

While the performance and physiological benefits of a training taper have been observed in previous research (Houmard, 1991; Mujika, et al., 2004), there still exists a level of uncertainty for athletes and coaches as to the best way to integrate one of the most important elements of a successful taper, intense exercise (Mujika, 2010). This uncertainty regarding training intensity in the final days before a competition is highlighted within the date over “openers” in the sport of competitive cycling. Openers are short but intense intervals performed at near maximal levels in order to mimic the demands of a race or time trial the following day. The “opener” debate centers around whether or not one should engage in a session of extremely light exercise or “openers” in the final day leading up to an important competition. This study examined the question of whether a training taper that contained “openers” the day prior to a performance test would yield different results than a taper that replaced this day of “openers” with a day of light, active recovery exercise.

5.2 Discussion of Findings

While no main effect of taper vs. time to completion, HR response, or RPE was observed between the two taper protocols, there was a trend toward statistical significance when examining
the pre and post time to completion (3.7% mean difference) and HR response (2.7% mean difference) following each taper protocol. This trend supports previous literature observing performance improvements in middle distance runners in the 800m run of 1.27% following a taper as short as six days (Mujika, et al., 2002) as well as a suppressed HR response of 1.05% following a period of intense training (Jeukendrup, et al., 1992). Although previous research using a 7-day taper did not demonstrate a decrease in post taper RPE, both Neary et al. (2003) and Martin et al. (1994) were able to show a decrease in the HR/RPE ratio by 3.2% and 4.5% respectively (Martin, et al., 1994; Neary, Bhambhani, et al., 2003). Although Neary et al. (2003) observed a decrease of 4.5% in HR/RPE ratio, our study utilized a significantly shorter time trial (10k) and may be the reason we did not observe a statistically significant decrease in HR/RPE ratio.

While statistical significance was not observed in this study, our trend toward significance when examining the pre and post time to completion (3.7% mean difference) and HR response (2.7% mean difference) provided insight into the possibility of real differences between the two taper protocols. When examined independently, a 5% improvement in time trial performance was observed following Taper 1 while a 2.4% improvement was observed following Taper 2. The performance improvement of Taper 1 was consistent with the 5.4% improvement in the Neary et al. (2003) cycling study examining different stepwise taper protocols. Our results compared favorably to Neary et al. (2003) who also utilized a 50% stepwise, 7-day taper in conjunction with a cycling time trial (20k) performance test. These similarities in study design and results provide support for the trend toward significance we observed following the taper period.

When comparing the percent improvement in time trial performance of Taper 1 vs. Taper 2 (5% vs. 2.4%), the findings of this study indicate that sequencing may make a possible
difference in time trial performance following a 7-day taper. This difference between the two taper protocols seems to suggest that a day of active recovery is superior to a day of “openers” during the 6th day of a 7-day taper. These results suggest that time trial performance could be improved by sequencing a day of active recovery rather than executing “openers” in preparation for a race or time trial. These findings provide the potential for clarity in the debate over the effectiveness of “openers” as well as a rationale for future research examining the possibility of statistically significant differences in time trial performance as a result of different sequences of high intensity exercise during a 7-day taper.

The results of this study beg the question; does sequencing of high intensity exercise in the final day of a taper (openers), make a difference in performance? When viewed through the lens of statistical significance the answer to that question seems to be that openers have no impact on time trial performance. While no interaction was shown between the two taper protocols for any of the three variables (time trial performance, HR response, or RPE), one confounding variable could have had an impact on our ability to observe statistically significant results.

While every effort was made to recruit a homogenous group of participants for this study, differences in pre-taper training volume (5-13hrs/week) could have had an impact on the individual response to each taper. Although it was the original intent of this study to narrow the training volume range of participants to no more than ± 3hrs/week, our overall recruitment numbers did not allow for this level of selectiveness. One possible outcome of this wide range in training volumes was that participants with relatively low training volumes were never introduced to a sufficient level of training overload to realize the benefits of a reduction in training volume. For these subjects a training taper might have been more detrimental to their performance due to a lack of training stimulus necessary to maintain previous training adaptations.
As Neary et al. (2003) hypothesized while examining 3 stepwise tapers of 30, 50, and 80%, it is possible that those entering a taper period with greater fatigue would benefit from a greater reduction of volume during the taper (Neary, Bhambhani, et al., 2003). Presumably those entering into a taper period with lower levels of fatigue might benefit from a lesser reduction in volume, even no reduction at all. For this reason, other studies have employed a longer overload period recognizing fatigue as a vital component to the magnitude of taper effect. Previous taper research outlines an overload period ranging in duration from 18 weeks (Mujika, et al., 2002) to a more typical 4 weeks (Thomas, et al., 2009). While our study was limited to a 1-week overload period, we were still able to observe signs of overtraining and the presence of fatigue through a suppressed HR response at the beginning of each taper. Nevertheless, a longer overload period might have set the stage to observe a greater increase in post-taper performance leading to statistical significance.

One limitation possibly preventing our ability to observe statistically significant improvements in performance following the taper was a relatively small sample size of 10 subjects. While our sample size compared favorably with several taper studies containing 11 (Banister, et al., 1999), 12 (Johns, et al., 1992), and 9 subjects (Mujika, et al., 2002), other studies employed sample sizes of over 20 (Houmard, et al., 1994; Neary, Martin, et al., 2003; Neary, et al., 1992). The possibility exists that with a larger sample size we could have observed statistically significant performance improvements, but as noted in chapter 3, our original sample size of 19 was reduced to 10 due to injury and dropout.

5.3 Suggestions for Future Research

In light of our study, future research examining the taper would be well served by following the general taper framework (12-day, 41-60% exponential volume decrease, intensity maintained) as outlined by Bosquet et al. (2007) while taking a more in-depth look at the
sequencing of high intensity exercise during a taper. It seems probable that statistical significance could be observed with a larger (20+) more homogenous sample of participants. With the potential for greater understanding of the body’s acute response to exercise following a taper, coupled with performance gains well covering the 0.4% margin that can often make the difference between 1st and 4th place in competitive sport (Pyne, et al., 2004), future research should be conducted further examining the optimal sequencing of high intensity exercise during a training taper.

5.4 Conclusion

As current research gives some measure of guidance regarding the core components of an effective training taper (Bosquet, et al., 2007), the specifics of how to execute a taper while managing bouts of high intensity exercise remain in dispute. In the sport of competitive cycling where the difference between winning and losing is often mere seconds, it is no surprise that athletes and coaches have become increasingly interested in small performance enhancements that when aggregated, can equal full percentage points of performance improvement.

Interestingly enough when these small improvements are examined through the lens of statistical significance they are often rendered “insignificant”. Such was the case in our study where Taper 1 time trial performance improved by 5%, double the 2.4% observed in Taper 2, but still failed to meet the standard of statistical significance (p=0.11). While statistical significance is an important standard for research, it inherently cannot provide definitive answers on the worthiness of every training intervention or strategy. While this study found no main effect between the two taper protocols for time trial performance, mean HR response, or mean RPE, it did find a trend toward significance of improved time trial performance following the taper period (p=0.11). This trend indicates the potential for real performance differences when comparing the
sequencing of intense exercise during a 7-day taper as well as the potential for an adequate training overload following a period of intense training as short as 7 days (p=0.08).
APPENDIX A

SAC STATE HUMAN PERFORMANCE RESEARCH LABORATORY

SUBJECT INFORMATION AND MEDICAL HISTORY

NAME:________________________________________________________

DATE_______________________________

ADDRESS:_____________________

PHONE:_____________________________ EMAIL:_____________________

OCCUPATION:_________________________________________________

GENDER: M__ F__ AGE________yrs DATE OF BIRTH_______________

TOTAL CHOLESTEROL________ mg/dL HDL_______ mg/dL LDL________ mg/dL

TG___________mg/dL

FASTING BLOOD GLUCOSE ________________mg/dL Other blood results:________________________

We will take the following 4 measurements (do not answer):

WEIGHT__________kg HEIGHT________cm BP____/____mmHg HR_______beats/min

MEDICAL HISTORY: (Please Circle your Answer/s)

Are you currently taking any medications: Yes or No:

If yes, please list:________________________________________________________

Please list all medical conditions (e.g. ulcers, arthritis, mono, hepatitis, HIV, musculoskeletal injury)?______________________________

Please list any hospitalizations and/or surgeries?

Have you ever been diagnosed with a breathing problem such as asthma? Yes or No:

If yes, please explain:________________________________________________

Have you ever been diagnosed with a heart problem or condition? Yes or No:

If yes, please explain:________________________________________________

Do you have any of the following symptoms at rest or with low to moderate physical activity? Yes or No:

Lightheadedness Shortness of Breath Chest Pain Numbness

Fatigue Coughing Wheezing

Other____________

If yes, please explain:________________________________________________

Do you have any of following cardiovascular disease risk factors? Yes or No

Family History of Heart Attacks Hypertension High Cholesterol

Sedentary Lifestyle (refer to next page) Diabetes Current cigarette smoker
Obesity (Calculate BMI=______kg/m^2)
If yes, please explain:__________________________________________

Do you have an immediate family member with any of the following diseases? Yes or No
Diabetes Hypertension High Cholesterol Obesity
If yes, please explain:__________________________________________

Are there any other conditions that might affect your health/exercise ability? Yes or No:
If yes, please explain:__________________________________________

Training History
What USA Cycling road category or categories do you currently race in?________________________
How many mass road race starts have you completed in the last 12 calendar months? ______________
How many years have you been training competitively?_______________________________________
Over the last year, what has been your average weekly training volume?________________________
Over the last year, what percentage of your overall training has been at a high intensity, “somewhat hard”
or >70% of VO_2max?____________________________________________
Any recent significant injuries which have limited your training?_______________________________
__________________________________________________________

Do you currently own or have access to a power meter? If so, what type of power meter and head unit do
you have? ___________________________________________________________________________

Do you have regular access to a computer and Internet connection where you could upload your training data on
a bi-weekly basis? _______________________________________________________________________

Additional Information:
How have you ever performed a fitness or maximal exercise test? Yes or No:
If yes, what were the results of your tests? Protocol________________VO_2max__________________
Speed/Power_______________ Lactate Threshold________
Overall Interpretation:_______________________________________________________________

COMMENTS & OBSERVATIONS:_____________________________________________________________________

OVERALL RISK STRATIFICATION:_________________________________________________________________

EXERCISE & EXERCISE TEST RECOMMENDATIONS:_______________________________________________

APPROVED BY:_________________________Dr. Daryl Parker, Ph.D.
APPENDIX B

INFORMED CONSENT

Research investigator (California State University, Sacramento) Nathanael Dunn, B.S. and Dr. Daryl Parker, Ph.D. invite you to participate in a research study to better understand the sequencing of high intensity exercise bouts during a 7-day taper. We are interested in the effect of different sequences of high intensity exercise bouts on time trial performance following a 7-day taper. You were selected as a possible participant for this study because of your current health status, competitive cycling background, and your interest in participating in this research.

Explanation of the Treatments and Tests to Be Administered

If you decide to participate, you will be required to report to the Human Performance Research Laboratory (HPRL) on 5 separate occasions over the course of five weeks. Each visit will be approximately 1 hour in duration. The total time commitment to this study is approximately six hours. The procedures involved are explained as follows:

A. You will report to the HPRL to fill out a medical history questionnaire and have vital signs measured to determine whether you are suitable for enrollment in the study. Also during this time you will become familiar with the procedures and equipment that will be used. During this initial visit, if you are determined to be suitable for the study, you will perform a maximal graded exercise test (GXT) on a stationary cycling ergometer. This test is designed to be progressive and elicit maximal exercise capacity within 12-15 minutes of cycling. During this test your maximal oxygen consumption will be determined using expired gas analysis as well as your power production at VO$_2$peak.

B. In the week following your GXT (and subsequent weeks prior to each 7-day taper) your weekly training volume will be increased by 120%. Following this “pre-taper” training week you
will randomly be assigned to begin 1 of 2 different 7-day tapers. During each 7-day taper you will execute a specific sequence of high intensity and low intensity training days. On day one and day seven of each 7-day taper you will return to the laboratory to perform a 288kJ time trial. This two-week block of “training volume increase-followed by a 7-day taper” will be repeated two times in total, giving you the opportunity to perform both 7-day tapers. In summary you will be visiting the laboratory for an initial GXT, increasing your training volume by 120% in the week leading up to each taper, and returning to the lab on day 8, 14, 22, and 28 to perform a 250kJ time trial performance test.

C. The total time commitment for the study will be approximately six hours over five weeks.

**Risks From Procedures**

Exercise tests to the point of fatigue are associated with a risk of death (<0.01%) and complications with the heart (<0.1%) (i.e irregular heart rhythm, inadequate blood to the heart, and heart attack). The risk of incidents occurring is much less for individuals who are young, exercise regularly, and are in good health. Completion of the subject history and subject medical history questionnaire prior to beginning the study will help minimize the risks of any cardiac event. Also associated with an exercise test of this nature are leg and breathing discomfort (100%), as well as increases in body temperature (100%).

Any adverse reaction to the vigorous exercise you will perform in the laboratory will be monitored continuously during each trial by observing signs and symptoms of distress while exercising. Water will be provided to you during exercise to help control your core temperature. Upon cessation of each trial the investigator will monitor your physiological values until they have returned to normal. If any adverse reactions occur due to exercise testing, you will be referred to your personal physician or the CSUS Student Health Center if you are a student. In
the event of severe or acute signs and symptoms, researchers will follow CSUS Guidelines for Emergencies and when necessary Adult CPR/automated external defibrillator procedures.

Benefits of Participation

Potential benefits for participating in this study include the determination of your maximal oxygen consumption (VO\textsubscript{2} peak) during a GXT as well as learning which tapering strategy might be most effective for you. This information can be used to help you optimize your training and race preparation in the future.

Your Rights and Confidentiality

If you decide to participate, you are free to withdraw your consent and to stop participation at any time with no penalty to you. Any information which is obtained in connection with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. The data will be identified only with numeric codes, not the names of the participants.

Questions

If you have any questions please feel free to call Nathanael Dunn at XXX-XXX-XXXX anytime, or Dr. Daryl Parker at XXX-XXX-XXXX between 9-5.
Statement of Permission

You are making a decision whether to participate or not participate. Your signature indicates that you have decided to participate having read the information provided. Your signature also affirms that the medical history you have provided is complete and true to the best of your knowledge. You will be given a copy of this form to keep. You understand that you will not receive any compensation for participating in this study.

Date  ____________________________  Signature of Participant

Date  ____________________________  Signature of Investigator
References


