HOW ARE COMPETITIVE MOUNTAIN BIKERS TRAINING:

AN ASSESSMENT OF FREQUENCIES, MODALITIES,

AND DURATIONS

by

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ABSTRACT

The popularity of mountain biking has increased steadily over the past 10 years, and the number of competitive mountain bikers increases on a yearly basis. High physical conditioning is essential in performing well within the sport. As important as the training component is, very little is known as to how competitive mountain biker's train in an effort to enhance performance. Physiological parameters associated with success within the sport of mountain biking have been identified, as well as training suggestions for performance enhancement. However, these training suggestions targeted towards mountain bikers are not data driven. For the purposes of the present study, frequencies, durations, and modalities of exercise training among competitive mountain bikers were assessed, as well as recovery. A clear theoretical model was created to provide insight into how competitive mountain bikers are training. This model guided the present investigation and helped determine whether or not competitive mountain bikers are incorporating training techniques specifically targeted towards improving the physiological characteristics associated with success within the sport of mountain biking. Forty competitive riders completed a one-time in-depth online survey designed for the purposes of this study. The development of the present survey was driven by exercise training modalities known to increase the performance parameters associated with successful mountain bike riding. Participants represented all regions of the United States and were recruited through university sponsored sports club teams and NCAA intercollegiate teams.

Competitive riders affiliated with local and national racing chapters were also contacted as potential participants. Results from the present study suggest that riders are participating in training modalities shown to increase physiological markers associated with successful mountain bike riding. Additionally, a majority of riders are adhering to the recommendations of workout frequency, as well as the recommended duration of these workout sessions. Findings from the current study also suggest that riders spend a majority of their exercise training on the trail.

DEDICATION

First and foremost, I would like to dedicate this dissertation to my family, who supported me throughout this process. To my mom, Shirley, I would like to say I love you. You have always picked me up when I have been knocked down. Thank you. I would like to thank my in-laws, Randy and Nancy, for all of your support, especially after the Tornado hit our house. I would have never been able to propose my dissertation without you being in Tuscaloosa to help us. I would especially like to thank my wife, Randi, for her support, understanding, and help while I completed the requirements for this degree. I can honestly say my love for you has grown stronger while living here in Tuscaloosa. I would like to thank my brother, Scott, who has been with me from the beginning. I love you little brother.

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LIST OF ABBREVIATIONS AND SYMBOLS

α	Cronbach's index of internal consistency
α	Type I error rate
ATP	Adenosine triphosphate
$a\text{-}vO_2$	Ateriovenous oxygen difference
CO	Cardiac output
HIIE	High intensity intermittent exercise
HIIT	High intensity interval training
HR	Heart rate
HRmax	Maximal heart rate
kg	Kilogram
LT	Lactate threshold
M	Mean
MPO	Mean power output
mL	Milliliter
mmol	Millimolar
OBLA	Onset of blood lactate accumulation
PPO	Peak power output
PO	Power output
SD	Standard deviation

SV	Stroke volume
VO_2	Oxygen uptake
VO_2max	Maximal oxygen uptake
<	Less than

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Chapter 1

Introduction

Since the time of early man, humanity has sought to meet the demands of daily life through better physical fitness (Darwin, 1859). While the term training was coined in the age of the modern era, its concept dates back centuries. In a hunting and gathering society, greater levels of physical fitness were essential for survival. Food had to be tracked, captured, and killed; shelter had to be built to survive the elements; and combat with other societies was essential to ensure the survival of the fittest on our planet (Darwin, 1859; Haviland, Prins, Walwrath, & McBride, 2007).

With advancements in technology and agriculture, many of these demands are not seen in our present day society (Haviland et al., 2007); however, the objective of improving performance through physical conditioning is evident in our modern day sports. Individuals and athletes wanting to perform better undertake some type of physical conditioning training to excel in their chosen sport. The concept of excelling in sport is, in part, outperforming a competitor at a specific task. General physical conditioning has now given way to sport specific training, meaning that athletes perform training exercises specific for their chosen sport (Kraemer, Deschenes, & Fleck, 1988; Kraemer, Ratamess, & French, 2002).

Due to its high physical demand and reliance on multiple energy pathways, the sport of mountain biking provides an ideal avenue for examining sport specific training. Recent research has identified mainstays in mountain bike performance. These mainstays include peak power output (PPO) and mean power output (MPO) at the lactate threshold up to the onset of blood lactate accumulation (OBLA) (Gregory, Johns, Walls, 2007; Impellizzeri, Rampinini, et al., 2005; Lee, Martin, Anson, Grundy, Hahn, 2002; Prins, Terblance, Myburgh, 2007). PPO is defined as the maximum level of power generated during cycling and MPO is the average level of power sustained throughout the duration of high intensity exercise. (Prins et al., 2007). The lactate threshold (LT) refers to the highest value of oxygen uptake or exercise intensity obtained just before an increase of 1.0 mmol of blood lactate concentration above pre-exercising levels, while OBLA refers to a systematic increase of blood lactate concentration to 4.0 mmols (Brooks, Fahey, White, & Baldwin, 2000, pp. 199, 469 Figure 10.1; McArcle, Katch, & Katch, 2007, pp. 299-300).

Percentage of VO_2max at the occurrence of the lactate threshold has also been identified as a mainstay in mountain bike performance and provides another venue for examining sport specific training (Gregory et al., 2007; Impellizzeri, Rampinini, et al., 2005; Lee et al., 2002). VO_2max is defined as "the oxygen intake during an exercise intensity at which actual oxygen intake reaches a maximum beyond which no increase in effort can raise it" (Hill & Lupton, 1923, p. 136). Overall, it is the aforementioned physiological characteristics at the LT and the OBLA that appear to be significant contributors to successful performance within the sport of mountain biking.

Despite various PO and percentages of VO_{2max} at the occurrence of the LT and the OBLA being identified as predictors of success within mountain biking, research examining various training methods aimed at increasing these predictors of success among mountain bikers is, to the best of our knowledge, non-existent. While articles have been published in peer-reviewed journals offering training suggestions for mountain bikers, it is unfortunate that these articles lack the scientific basis of how competitive mountain bikers are currently training (Rhyan, 1998; Rhyan, 2005; Willis & Jones, 1999). As a result, it is possible that the types of training programs currently suggested may not be associated with how competitive mountain bikers are actually training.

Furthermore, within the data driven general exercise training literature, research has identified modalities shown to increase the aforementioned physiological parameters associated with performance in mountain biking and include: 1) resistance training, 2) endurance training, and 3) interval training (Jackson, Hickey, & Reiser, 2007; Mier, Turner, Ehsani, & Spina, 1997; Tabata, Nishimura, Kouzaki, Hiral, Ogita, Miyachi, & Yamamoto, 1996). Due to the association between the physiological parameters of the sport and adaptations resulting from exercise training, these training modalities (e.g., resistance, endurance, interval) served as the driving force behind the development of the survey implemented in the present study. Assessment of training among competitive mountain bikers will provide the necessary insight into how this population is training in an effort to increase their sport specific performance. Therefore, we seek to address these specific research questions.

Specific Aims/Study Questions:

1) Are competitive mountain bike riders implementing exercise training modalities that are shown to increase the physiological parameters associated with successful mountain bike performance?
2) What is the prevalence of various types of exercise training among competitive mountain bikers in their effort to improve performance?
3) How much time is spent using various modalities of exercise training to improve performance among competitive mountain bikers?

Chapter 2

Literature Review

There are several key considerations when examining the performance of competitive mountain bikers. These include the characteristics of the sport, the physiological responses associated with the sport of mountain biking, the specific types of training activities (e.g., resistance, endurance, interval) associated with increased performance, and recovery. This chapter will review these considerations in an effort to produce a clear theoretical model. This model will guide the present investigation and help determine whether or not competitive mountain bikers are incorporating training techniques, including recovery, specifically targeted towards improving the physiological characteristics associated with success within the sport of mountain biking. Finally, when discussing training modalities, a brief description of each modality will be provided, as well as the mechanisms that contribute to the physiological adaptations from these training methods.

Characteristics of the Sport of Mountain Biking

Mountain biking is characterized by intermittent bursts of power in an effort to navigate the off-road terrain (Gregory, Johns, Walls, 2007; Impellizzeri, Marcora, Rampinini, Mognoni, & Sassi, 2005; Lee, Martin, Anson, Grundy, Hahn, 2002; Prins, Terblance, Myburgh, 2007) and can include lengthy uphill cycling at power outputs greater than 500 watts and fast downhill descents over technical terrain (Impellizzeri, Rampinini, Sassi, Mognoni, Marcora, 2005). Within the sport of mountain biking exists several different disciplines, including *cross-country, super-D, downhill, and freeride.* Typical *cross-country* races demand the rider be efficient in cycling sprinting, climbing, descending, as well as navigating technical terrain. *Cross-country* races can last from one to three hours (Rhyan, 1998; Willis & Jones, 1999; Stapelfeldt, Schwirtz, Schumacher, & Hillebrecht, 2004).). Due to the demands presented to riders in a typical race, *cross-country* mountain biking incorporates elements of muscular strength, power, and endurance, as well as aerobic capacity.

Conversely, *downhill* mountain biking demands the navigation of technical terrain and steep descents at high speeds. *Downhill* mountain biking incorporates explosive and intermittent movements aimed at increasing speeds during downhill descents. Typical races can last from two to five minutes (Rhyan, 2005; Thomas & Atkins, 2006). By necessity, *downhill* mountain biking incorporates elements of muscular strength and power (Rhyan, 1998; Rhyan, 2005).

The discipline of *super-D* incorporates elements of both *cross-country* and *downhill* races (International Mountain Biking Association, 2010). While rides are typically shorter in duration when compared to *cross-country* events, *super-D* races last longer than traditional *downhill* races. *Super-D* races involve steep descents, large drop-offs, and jumps; however, these races also incorporate elements of extended uphill climbs. As a result, this discipline incorporates elements of muscular strength, power, and endurance.

Finally, *freeride* is a discipline associated solely with large drop-offs and jumps. Of all the disciplines discussed, *freeride* is in its infancy. Inherently, *freeride* incorporates explosive movements off jumps and drop-offs. The jumps used for *freeride* are often man-made but can include structures found in nature (International Mountain Biking Association, 2010). The nature of *freeride* incorporates elements of muscular strength and power.

To date, there have not been a large number of studies examining the dynamics of mountain biking; thus, it will not be possible to discuss all four of the aforementioned disciplines. Nonetheless, there are studies examining the physiological and race characteristics of *cross-country* and *downhill* riding. These two disciplines will be discussed in more detail next.

Physiological Responses Associated with the Sport of Mountain Biking

Heart rate during a typical cross-country race. Because of the strong correlation between heart rate (HR) and exercise intensity, several studies have used HR in relation to LT to characterize the intensity of a typical *cross-country* mountain bike race (Impellizzeri, Sassi, Rodriguez-Alonso, Mognoni, & Marcora, 2002; Stapelfeldt et al., 2004). For the purposes of these studies, "intensity zones" categorized the time spent at varying intensities during a *cross-country* race. Although these studies employed different methods for determining HR intensity zones in relation to the LT, % of VO_2max, and PO, the results clearly demonstrate that the time spent in intensity zones at and above the LT during a typical mountain bike race is approximately half or more of the total race time (Impellizzeri et al., 2002; Stapelfeldt et al., 2004). These findings suggest that mountain bike riders experience high intensity work rates during a typical race. Therefore, performance factors, such PO and VO_2, at the LT and the OBLA, are crucial for successful performance during a mountain bike race.

HR during a typical downhill race. Similarly, studies examining HR in relation to *downhill* mountain biking found that the average HR during the race was roughly 176 beats per minute (bpm) over 3-4 minutes, compared to *cross-country* riders at approximately 171 bpm over 90 minutes (Impellizzeri et al., 2002; Stapelfeldt et al., 2004). This value among *downhill* riders was approximately 90% of their maximum HR (HRmax) (Thomas & Atkins, 2006). However, HR values between cross-country and downhill riders were never compared to determine if this difference was significant. In comparison to *cross-country* races, *downhill* mountain bike riders do not encounter any uphill sections, where PO would be highest and concomitant with an elevation in HR. The authors suggest that the rapid activation of the sympathetic nervous system in response to the fast speeds traveled during the race may account for such an elevation in HR (Thomas, & Atkins, 2006). Due to this high level of sympathetic nervous system activation, it is important for riders to train under conditions that simulate typical race conditions, thus aiding in an increase in *downhill* performance.

More recently, researchers examined the intensity of *downhill* mountain biking by monitoring HR, salivary cortisol, and blood lactate responses during a downhill competition (Sperlich, Achtzehn, Buhr, Zinner, Zelle, & Holmberg, 2012). Intensity zones for the study were based on HR correspondence to PO. Low intensity was characterized by a HR below the onset of 2 mmols blood lactate concentration resulting from PO (P2). Moderate intensity was marked by heart rates between P2 and P4. P4 was categorized as the intensity of exercise (i.e., power output) that corresponded to 4 mmols of blood lactate concentration. Finally, high intensity was operationally defined as HR correspondence to a blood lactate concentration above 4 mmols. Results from the study showed that, during competition, *downhill* mountain bikers spend an average of 23 and 24 seconds in the low and moderate intensity zones. However, time spent in the high intensity zone averaged 151 seconds, or an average of 76% of the total race time. These results suggest that *downhill* mountain bikers spend a large amount of race time performing high intensity exercise.

However, as mentioned earlier, the rapid activation of the sympathetic nervous system must be considered as a contributing factor to the elevation in HR; although, it does appear that *downhill* riders will experience high intensity exercise during a typical race. Thus, participating in training modalities known to increase the aforementioned performance markers should increase *downhill* mountain bike performance (Sperlich et al., 2012).

PO at LT among cross-country riders. As expected, PO would be highest during uphill sections or steep climbs. Conversely, PO would show a decrease during downhill sections (Gregory et al., 2007; Impellizzeri, Marcora, et al., 2005; Stapelfeldt et al., 2004). When expressed in terms relative to body mass, PO at the occurrence of the LT and the OBLA is a significant contributor to successful mountain bike performance (Baron, 2001; Prins et al., 2007; Gregory et. al., 2007; Impellizzeri et al., 2002; Lee et al., 2002; Costa & Fernando, 2008). Riders that are able to sustain a higher work rate during intense exercise performance tend to outperform those who cannot (Baron, 2001; Impellizzeri, Marcora, et al., 2005; Gregory et al., 2007). Sustaining a higher work rate during a typical mountain bike race translates into more successful mountain bike performance. Furthermore, PO at the LT and the OBLA has also been shown to significantly correlate with performance time. (Gregory et al., 2007; Impellizzeri, Marcora, et al., 2005; Impellizzeri, Rampinini, et al., 2005; Stapelfeldt et al., 2004). In fact, Gregory et al. (2007), found a strong correlation ($r = -0.93$, $p < 0.01$) between PO relative to body mass and time trial speed among competitive mountain bikers.

Compared to road cyclists, mountain bikers had an 11% higher PO at the LT relative to body mass (Lee et. al., 2002). Conversely, other studies have shown that absolute and relative PO at LT was slightly greater among road cyclists compared to off-road cyclists, with a 16% greater PO relative to body mass among road cyclists (Wilber, Zawadzki, Kearney, Shannon, & Disalvo, 1997). While the results are mixed, these studies suggest that similar physiological characteristics do exist between elite road and off-road cyclists and measuring a rider's PO at the LT may be a prime indicator of success within the sport of mountain biking (Lee et al., 2002; Wilber et. al., 1997). Thus, an athlete wanting to increase performance should look to training modalities shown to increase PO.

PO during downhill competition. Finally, it is important to mention the only study examining the relationship between PO and *downhill* mountain biking performance (Thomas, & Atkins, 2006). These authors found that PO was not related to downhill mountain bike performance but rather pedal cadence during the race. Those with a higher cadence showed better performance. This is the only study examining this area, and as a result, the interpretation of the results is necessarily limited. Further studies will need to be conducted before any definitive answer can be provided regarding PO, as well as other physiological performance markers, and downhill mountain bike race performance.

However, PO at high levels of exercise intensity appears to contribute to success within the sport of mountain biking (Gregory et al., 2007; Impellizzeri et al., 2005; Prins et al., 2007) Therefore, it is imperative that riders seeking to improve performance participate in training modalities that improve MPO and PPO.

%VO_2max at LT among cross-country riders. Aerobic capacity has long been used as a performance marker within the sport of road cycling, and when compared to off-road cyclists, road cyclists, on average, have higher absolute aerobic capacity (Wilber et al., 1997). However, when VO_{2max} is expressed relative to body mass, the differences between off-road and road-cyclists are not significant (Wilber et al., 1997). In fact, Lee et al., (2002) found that when VO_2max was expressed relative to body mass, mountain bikers had higher values when compared to road-cyclists. Additionally, percent of VO_2max at an individual's relative LT explained 40% of the variance in relation to mountain bike racing performance (Impellizzeri, Marcora, et al., 2005; Impellizzeri, Rampinini, et al., 2005). While VO_2max is important, these findings suggest that that there are other factors that contribute to successful performance within mountain biking; as mentioned earlier, these factors include increased PO production at the LT and the OBLA, as well as PPO production (Impellizzeri, Marcora, et al., 2005; Impellizzeri, Rampinini, et al., 2005).

Nonetheless, VO_2 at the LT contributes to the performance of mountain biking. In fact, research suggests a strong correlation ($r= -0.80$, $p < 0.05$) between VO_2max and time trial speed among mountain bikers (Gregory et al., 2007). Moreover, VO_2max expressed relative to body mass has been shown to significantly correlate ($r = -0.68$, $p < 0.05$) with a mountain bike rider's final race time ranking (Impellizzeri, Rampinini, et al., 2005). As a result of a trained state, an individual can exercise at a higher percentage of VO_2max before the OBLA. The reduction in lactate levels at a given work rate is a result of reduced lactate production and increased lactate clearance, thus contributing to an increase in aerobic performance (Brooks et al, 2000, pp. 85, 89; McArdle et al., 2007, p. 168).

While aerobic capacity contributes to successful performance, the degree of its effect is not clearly understood (Gregory et al., 2007; Impellizzeri, Marcora, et al., 2005; Impellizzeri, Rampinini, et al., 2005; Lee et al., 2002). Therefore, it is important for mountain bike riders to participate in training techniques that have been shown to increase aerobic capacity. Based on the aforementioned studies, it is logical to conclude that if a rider has a higher aerobic capacity, then he/she should be able to maintain a higher work rate for a given level of strain on the cardiorespiratory system, which could result in better mountain bike performance.

VO_2max among downhill riders. When compared to *cross-country* riders, *downhill* mountain bike riders have slightly lower values for VO_2max. Reported values among professional Italian *cross-country* riders averaged 75.2 mL/kg/min[1] (Impellizzeri, Marcora, et al., 2005; Impellizzeri, Rampinini, et al., 2005) and among Austrian riders, values for VO_2max averaged 68.4 mL/kg/min[1] (Baron et al., 2001). Sperlich et al., (2012) found that values for VO2max among *downhill* riders averaged 59.5 mL/kg/min[1]. While the demands of *downhill* racing require a high aerobic capacity, these demands are not likely as high as those needed for success in *cross-country* events. Research has yet to determine the relationship between *downhill* mountain bike riding and VO_2max. Still, these results suggest that downhill riders need to incorporate training regimens known to maintain or increase aerobic capacity.

Training Modalities Shown to Increase VO_2max, PO, and the LT

Resistance training.

Characteristics of resistance training and current recommendations.

Resistance training is characterized by muscular contractions performed against a specific load or force (ie. resistance), such as a dumbbell, barbell, or weight stack (Kraemer, Deschenes, & Fleck, 1988; Kraemar & Ratamess, 2004). This type of training relies heavily on the creatine phosphate and anaerobic glycolysis pathways for energy metabolism to meet the demands of exercise (Brooks et al., 2000, p. 440 Table 20-2; McArdle et al., 2007, p. 548) Over the last decade, resistance training has become a popular training modality for athletes wanting to improve sports performance, and the challenge in program design involves trying to meet or exceed the demands of physical competition during a typical workout session (Kraemer et al., 1988). According to Kraemer, Ratamas, and French (2002), a resistance-training program should consist of three basic principles; progressive overload, specificity, and variation. Progressive overload involves a gradual increase of stress placed on an individual during resistance training. Specificity reflects the demands and movements of a chosen sport that are implemented into a workout regimen. Finally, variation is necessary in order to prevent chronic adaptation to identical consecutive workouts. An athlete must vary factors such as workout mode, duration; thus, the body is forced to adapt to the new demands, which can result in improved performance markers (Kraemer et al., 2002).

While neuromuscular adaptations, such as an increase in strength, can be experienced within the first few weeks of resistance training, it is recommended that athletes resistance train for a minimum of 6-8 weeks, 2-3 times per week, to increase physiological parameters associated with sport performance (Kraemer et al., 1988; Bishop, Jenkins, MacKinnon, McEniery, & Carey, 1999; Jackson, Hickey, & Reiser, 2007; Levin, McGuigan, & Laurson, 2009). Because of the demands placed on the body's physiological systems, recovery is an important consideration for program design and will be discussed in more detail later.

Effects of resistance training on PO. Power is defined as work divided by time, (Knuttgen, & Kraemer, 1987) and muscular power is a function of speed of movement and muscular strength (Deshenes & Kraemer, 2002). An increase in strength will increase PO by increasing the velocity and force by which a muscle contracts (Jensen & Fisher, 1979; Kraemer et al., 2002; Patton & Hopkins, 2005; Stone et al., 1991; Stone et. al., 1980; Stone and Garhammer, 1982). Resistance training has long been credited for significantly increasing muscular strength (Hickson, Dvorak, Gorostiaga, Kurowski, & Foster, 1988; Kraemer et al., 1988; Kraemer et al., 2002; Marcinik, Potts, Schabach, Will, Dawson, & Hurley, 1991; Stone, Fleck, Triplett, & Kraemer, 1991). Muscular strength is characterized by the maximal amount of force that a muscle group or muscle can generate at a specific velocity (Harris & Dudley, 2000). Increases in strength as a result of resistance training include, but are not limited to, increases in Type I and Type II muscle fiber size, which contributes to an increased cross-sectional area of muscle fibers, and more efficient neuromuscular fiber recruitment. (Bishop et al., 1999; Gonyea & Sale, 1982; Kraemer et al., 1988; Kraemer et al., 2002; Stone et al., 1991; Thorstensson, 1976).

Type I muscle fibers are resistant to fatigue and primarily use aerobic metabolism to provide energy. Conversely, Type II muscle fibers are responsible for short, powerful contractions, but are easily fatigued after recruitment and rely heavily on creatine phosphate and anaerobic metabolism of glucose to sustain energy for exercise (Harris & Dudley, 2000). By increasing the size of muscle fibers through resistance training, also called hypertrophy, an individual will able to generate more power and velocity during a specific movement. If the movement is sport specific, then the results should produce enhanced performance within the range of motion of said movement (Brooks et al., 2000, pp. 424, 431-432; Harris & Dudley, 2000). Furthermore, by increasing cross-sectional area of muscle fibers, both Type I and II, an individual is able to generate more force during a specific movement. As a result of resistance training, muscle fibers increase in size and create a larger cross-sectional area of muscle. The maximum amount of force that can be generated by a muscle is directly related to cross-sectional area. Larger muscles have a greater potential for applying force (Baechle, Earle, & Wathen, 2000; Harris & Dudley, 2000; McArdle et al., 2007, p. 515).

Additionally, enhanced neuromuscular fiber recruitment is a consequence of resistance training and involves the body's ability to more efficiently recruit Type I muscle fibers and Type II muscle fibers. This effect is based on the size principle, which states that motor units are recruited for activation according to their firing rates and recruitment thresholds. Motor units that are high in the recruitment order, meaning they have a higher recruitment threshold before firing, are used primarily in high velocity and power movements (i.e., Type II muscle fibers), whereas those with a lower recruitment threshold are used for slow, sustained contractions (i.e., Type I muscle fibers). The training adaptation occurs when an individual is able to recruit more motor units to perform a specific task (Brooks et al., 2000, pp. 407, 438; Baechle, Earle, & Wathen, 2000; Harris & Dudley, 2000; McArdle et al., 2007, p. 540).

In sum, an increase in power would allow an athlete to perform at higher absolute and relative workloads (Stone & O'Byrant, 1987), and a stronger individual will typically produce greater sustained PO, thereby increasing sport performance considerably (Crieland & Pirnay, 1981; Jackson et al., 2007; Patton & Hopkins, 2005; Stone et al., 1980).

Effects of resistance training on VO_2max. Several studies have demonstrated that, although increases in strength resulted from resistance training, there was no change in VO_2max (Bishop et al., 1999; Levin et al., 2009). These results suggest that traditional resistance training may not increase aerobic performance (Bishop et al., 1999; Levin et al., 2009). Although improvements in VO_2max may not directly result from resistance training, there are other cardiovascular benefits that may contribute to improving aerobic capacity (Baechle et al., 2000). For example, resistance training has been shown to improve the ability of the heart to pump blood by a phenomenon known as cardiac hypertrophy. As a result of resistance training, the thickness of the ventricle's muscular wall increases, allowing a more efficient and forceful contraction of the heart. A more efficient and forceful contraction of the heart leads to greater blood flow to working muscle. Coupled with any improvements in VO_2max from other training modalities, the aerobic capacity of the athlete can be enhanced by participating in resistance training (Baechle et al., 2000; McArdle et al., 2007, pp. 481, 548-549; Paton & Hopkins, 2005).

Finally, circuit resistance training has been shown to moderately increase aerobic capacity. This effect may be due to the high repetitions and short rest periods that characterize circuit training (Stone et al., 1991; Wright et al., 1983); however, if an athlete desires to increase aerobic performance, it may be more advantageous to implement other training modalities known to increase VO_2max, such as steady state endurance training or high intensity interval training (HIIT).

Effects of resistance training on LT. Investigations into the effects of resistance training on LT has provided mixed results (Bishop et al., 1999; Jackson et al., 2007; Marcinik et al., 1991). For example, studies implementing a low-volume resistance program designed to increase muscular strength demonstrated no effect on LT (Bishop et al., 1999). Conversely, studies incorporating high volume resistance training with short rest periods between exercises found significant increases in LT (Jackson et al., 2007; Marcinik et al., 1991; Schantz, 1982; Tesch, Thorsson, Kaiser, 1984). It was speculated that an increase in LT was associated with improved lactate clearance resulting from increased capillarization in the muscle. Overall, it appears that the principle of specificity, as discussed earlier, relates to improvements in performance at the LT. If an individual wants to increase his/her LT, it is important to design and implement a resistance-training program that will require sustained work at and above the LT. For example, if the objective of a resistance-training program is to increase the LT, then exercise and rest durations must be conducive to increasing LT. As demonstrated in previous studies, high volume workloads with short rest periods (i.e., 15-30 seconds) in between will contribute to an increase in blood lactate accumulation; thus increasing the LT over time for a given workload (Jackson et al., 2007; Marcinik et al., 1991; Schantz, 1982; Tesch, Thorsson, Kaiser, 1984).

Endurance training.

Characteristics of endurance training and current recommendations.

Endurance training is characterized by repeated bouts of steady state exercise performed over an extended period of time (Jones and Carter, 2000; Wenger & Bell, 1986) and can be defined as "the capacity to sustain a given velocity or power output for the longest possible time" (Jones and Carter, 2000, p. 373). Performance of aerobic based exercise relies heavily on the aerobic resynthesis of adenosine-tri-phosphate (ATP) (Brooks et al., 2000, p. 93) and results in adaptations of the cardiovascular, pulmonary, and neuromuscular systems. The magnitude of training adaptations is dependent on several key factors, including the intensity, frequency, and duration of the performed exercise bouts (Brooks et al., 2000, pp. 331, 459; McArdle et al., 2007, pp. 493-494). These adaptations increase the delivery of oxygen from atmospheric air to working muscle, which shifts the time at which a certain intensity of movement can be sustained. This results in improved endurance performance (Brooks et al., 2000, p. 332 Table 16-2; Jones and Carter, 2000; McArdle et al., 2007, p. 493 Figure 21.20). Modalities of endurance training can include running, swimming, and cycling and selection of modality should be dictated by the chosen sport in which an athlete participates (Pierce, Weltman, Seip, & Snead, 1990). Research suggests that a minimum of 4-8 weeks of endurance training is needed to increase physiological markers associated with endurance performance. Sessions should take place 2-4 times per week and last between 30-120 minutes in duration (MacRae, Dennis, Bosch, & Noakes, 1992; Hickson, Hagberg, & Holloszy, 1981); however, cardiovascular adaptations have been seen in as few as 10 days (Mier, Turner, Ehsani, & Spina, 1997). As with resistance training, recovery is also an important factor when considering the frequency, duration, and intensity of endurance training exercise and will be discussed in more detail later in this chapter.

Effects of endurance training on VO_2max. Research strongly supports endurance training as a method for increasing VO2max, thus resulting in improved performance during aerobic-based sport activities (Brooks et al., 2000, p. 332; Dennis et al., 1992; Hickson et al., 1981; Mier, et al., 1997; Pierce et al., 1990; Spina, Ogawa, Martin, Coggan, Holloszy, & Ehsani, 1992). Typically, VO_2max reflects an athlete's maximal rate of aerobic energy expenditure, which has traditionally been associated with success in endurance-based sports events (Costill, Thomason, & Roberts, 1973; Saltin, & Astrand, 1967). In part, VO_2max is determined by maximal cardiac output (CO), which is the delivery of oxygenated blood to working muscle, and the arteriovenous oxygen difference (a-vO_2) (Brooks et al., 2000, p. 329; McArdle et al., 2007, pp. 484-485). The a-vO_2 difference reflects the amount of O_2 that is extracted from arterial blood by the muscle cell (Paterson, Shephard, Cunningham, Jones, & Andrew, 1979). The muscle cell's ability to extract O_2 from blood is a direct result of an increase in capillary density and mitochondria volume, which increases mitochondrial enzymatic activity within the cell (Shepard, 1992; Spina, 1999). The increase in CO during maximal exercise has been attributed to an increase in maximal stroke volume (SV). SV is the volume of blood pumped out of the heart per contraction (Brooks et al., 2000, p. 334; Mier et al., 1997). The increase in SV results primarily from a combination of adaptations. As a result of endurance training, exercising HR at a given intensity is lowered and plasma volume is increased. Greater plasma volume results in greater total blood volume, flow, and venous return for a given intensity. In turn, a lower HR at submaximal exercise, coupled with an increase in blood volume, allows more time for blood to enter the heart via increased venous return before contraction (Brooks et al., 2000, p. 334; Mier, et al., 1997; Wilmore, Costill, & Kenney, 2008, pp. 165-167). This additional time before contraction allows the heart to respond through what is known as the Frank-Starling Mechanism. This mechanism dictates that when the heart expands as a result of increased ventricular filling, the force of contraction will be greater. The more blood pumped from the heart per contraction results in more blood circulation throughout the body (i.e., CO) (McArdle et al., 2007, p. 484; Wilmore et al., 2008, p. 167).

Furthermore, endurance training leads to a larger interior of the heart's left ventricle (McArdle et al., 2007, p. 481; Wilmore et al., 2008, p. 224). This increase will also contribute to an increase in SV by allowing a greater volume of blood to enter the heart during diastole (Brooks et al., 2000, p. 334; Wilmore et al., 2008, p. 224). The combination of decreased exercising HR and increased SV for a given absolute intensity results in a greater efficiency of the heart to meet the metabolic demands of intense exercise. Coupled together, changes in CO (CO = HR x SV) and a-vO_2 produce a greater amount of oxygenated blood being pumped from the heart and extracted by working muscles for energy metabolism. The increase in maximal CO may be the greatest cardiovascular adaptation to endurance training (McArdle et al., 2007, p. 484).

Following endurance training, exercising muscle may actually require less blood flow for the same submaximal exercise due to the increase in the a-vO_2 difference. Due to changes in HR and SV, CO may also slightly decline during submaximal exercise as a result of endurance training. The slight change in CO is reflective of an increase in a-vO_2, meaning the working muscle has now become more efficient at extracting O_2 for energy metabolism (Brooks et al., 2000, p. 334; McArdle et al., 2007, p. 485). An athlete with a greater VO_2max will be able to sustain bouts of exercise at a given absolute intensity at a lower percentage of VO_2max, meaning they can sustain exercise longer before reaching physiological exhaustion (Shepard, 1992; Spina, 1999). This, in turn, can contribute to increases in performance.

Effects of endurance training on LT and PO. LT has also been shown to increase as a result of endurance training, which will improve PO. However, for this adaptation to take place, an individual must train at or slightly above the existing LT (Acavedo & Goldfarb,1989; Carter, Jones, & Doust, 1999; Henritze, Weltman, Schurrer, & Barlow, 1985; Keith, Jacobs, & McLellan, 1992; Sjodin, Jacobs, & Svedenhag, 1982; Weltman, Seip, Snead, Weltman, Haskvitz, Evans, Veldhuis, & Rogol, 1992); otherwise, increases in the LT will not occur (Carter et al., 1999; Henritze et al., 1985; Weltman et al., 1992). The biggest performance benefit from an increased LT comes from the ability to sustain higher work rates for a longer period of time. For example, after 2 weeks of endurance training, blood lactate concentration at 95% of VO_2max was significantly lower when compared to pre-training values (Hickson et. al., 1981; Holden, MacRae, Dennis, Bosch, & Noakes, 1992). Furthermore, endurance training appears to improve the rate of lactate clearance, as well as delays the OBLA (MacRae et al., 1992; Holden et. al., 1992). Muscle cells also become more efficient in metabolizing lactate as a precursor for fuel substrate, which also contributes to the increase in LT (Brooks et al., 2000, p. 56; McArdle et al., 2007, p. 151). The increase in LT plays a vital role in the effects of endurance training on PO production. In order for PO, at a given high, submaximal intensity, to increase as a result of endurance training, the LT must be increased (Jones & Carter, 2000). Once this threshold is increased, individuals can sustain a higher absolute PO for a longer period of time before energy stores are depleted and physiological exhaustion occurs (Jones & Carter, 2000).

In sum, endurance-training effects include the delay in the OBLA, as well as increases in the muscle cell's ability to clear lactate. Improved clearance is a result of the improved efficiency of the muscle cell to utilize lactate in the process of energy substrate metabolism (Carter et al., 1999; MacRae et al., 1992; Weltman et al., 1992). The increased rate of clearance, as well as the delayed OBLA, will allow an athlete to sustain a higher absolute work rate without accumulation of lactate in the blood. This, in turn, will increase endurance performance (Jones & Carter, 2000; Keith et al., 1992). It is important to mention once more that these adaptations will only occur if the intensity of endurance training is at or above the current lactate LT (Acavedo & Goldfarb, 1989; Carter et al., 1999; Henritze et al., 1985; Hickson et al., 1991; Holden et al., 1992; Jones & Carter, 2000; Keith et al., 1992; MacRae et al., 1992; Sjodin et al., 1982; Weltman et al., 1992).

High intensity interval training.

Characteristics of HIIT and current recommendations. HIIT is characterized by bouts of brief, vigorous exercise separated by short rest periods. Depending on the training goal, bout and rest periods both can vary in length of time (McArdle, 2007, p. 498). These bouts and periods of rest are then repeated in cycles (Tabata, Irisawa, Kouzaki, Nishimura, Ogita, & Miyachi, 1997; Tabata, Nishimura, Kouzaki, Hiral, Ogita, Miyachi, Yamamoto, 1996). When designing an interval training protocol, several key factors must be considered. The intensity of exercise, which is usually based on a percentage of HRmax, VO_2max, or PPO, the duration of the overall exercise session, and the number of cycles all must be given consideration. The research seems to support 6-8 work:rest cycles per session of HIIT, with 2-3 sessions per week (Hawley, Myburgh, Noakes, & Dennis, 1997; Lindsay, Hawley, Myburgh, Schomer, Noakes, & Dennis, 1996; Laurson, Shing, Peake, Coombes, & Jenkins, 2002; Tabata et. al., 1997).

Effects of HIIT on PO. Although the literature examining the impact of HIIT on physiological parameters related to sport performance is somewhat scarce, studies have demonstrated that HIIT significantly increases MPO and PPO (Burgomaster, Gaiga & Docherty, 1995; Gibala, Little, Van Essen, Wilkin, Burogmaster, Safdar, Raha, & Tarnopolsky, 2006; Heigenhauser, & Gibala, 2006; Hawley et al., 1997; Laursen, Blanchard, & Jenkins, 2002; Laurson et al., 2002; Lindsay et al., 1996; MacDougall, Hicks, MacDonald, McKelvie, Green, & Smith, 1998; Tabata et al., 1997; Westgarth-Taylor, Hawley, Rikard, Myburgh, & Noakes, 1997). The greatest increases in MPO and PPO result from 2-4 weeks of interval training with 2-3 sessions of HIIT per week (Hawley et al., 1997; Lindsay et al., 1996; Tabata, 1996), after which non-significant, slight improvements in PO and VO_2max were observed. Individuals participating in HIIT significantly increased MPO and PPO by 15-20 watts (Burgomaster et. al., 2006; Gibala et al., 2006; Hawley et al., 1997), and the time spent sustaining higher MPO and PPO also increased as a result of HIIT (Gibala et al., 2006; MacDougall, et al., 1998).

It appears that the nature of HIIT is responsible for the increases observed in MPO and PPO (Gaiga et al., 1995; Tabata et al., 1997). Inherently, HIIT requires an individual to train at intensities at or greater than his/her individual LT, which contributes to the increases in PO (Tabata et al., 1996; Tabata et al., 1997). Training at or above the LT will begin to shift the LT in such a way that an individual can sustain greater MPO and PPO before the appearance of lactate exceeds its removal rates. Thus, they are able to generate greater PO and maintain them for longer periods, which can contribute to an increase in sport performance (Brooks et al., 2000, pp. 134, 199-Figure 10-1).

Effects of HIIT on VO_2max. While studies have observed an increase in VO_2max with HIIT, the mechanisms behind this increase are not clearly understood (Giaga & Docherty, 1995; Laurson, Blanchard et al., 2002; Laurson, Shing, et al., 2002; MacDougall et al., 1998; Tabata et al., 1996). Regardless, increases have been observed comparable to, and sometimes exceeding, those associated with traditional endurance training (Giaga et al., 1995; Laurson, Shing, et al., 2002; Tabata et al., 1996). One possible explanation for the increase in VO_2max is the increase in oxidative enzyme activity within the muscle cell during exercise performance (MacDougall et al., 1998). As the progression of HIIT continues, the body must become more reliant on oxidative cellular respiration to continue exercise. As oxidative demands increase over time, the aerobic capacity of the muscle cell will also increase. This would mean that more O_2 is being extracted from the blood by working muscle, which would contribute to the efficiency of O_2 extraction (Brooks et al., 2000, pp. 93-94; McArdle et al., 2007, pp. 359, 362; Rowell, 1993).

Consequently, there other factors which may contribute to an increase in VO_2max and include possible training effects on HR, SV, and CO. Considering the physiological demands placed on the heart during high intensity exercise, it would seem logical to conclude the effects of HIIT on VO_2max are similar to those of endurance training (McArdle 2007, pp. 499-500; Mier et al., 1997; Tabata et al., 1996; Tabata et al., 1997). Overall, an athlete with a greater $VO2_{max}$ will be able to sustain a higher absolute workload at a lower percentage of VO2max, meaning he/she can sustain exercise longer at a given level of physiological strain. This, in turn, can contribute to increased performance.

Effects of HIIT on LT. The design of a HIIT protocol will determine the training effects on the LT. For example, if the work to rest ratio were 10 seconds work to 30 seconds rest, then the creatine phosphate pathway would be predominant. As a result, there would be a low level of lactate accumulation, which would be cleared (Brooks et al., 2000, pp. 85-87, 462; McArdle, 2007, p. 498; Tabata et al., 1996; Tabata et al., 1996). However, if the work to rest ratio were 5 minutes of work to 1 minute of rest, then there would be a considerable accumulation of lactate which would take time to clear (Hawley et al., 1997; Lindsay et al., 1996). In turn, repeated exposure to the accumulation of lactate would cause the body to adapt by increasing the rate of clearance and shifting the LT to a higher intensity (Brooks et al., 2000, p. 462; McArdle, 2007, p. 499).

In summary, the training effect of HIIT on the LT is a function of duration, frequency, and most importantly, intensity (McArdle et al., 2007, p. 498). These factors will dictate the energy system primarily responsible for substrate metabolism, and in turn, the degree to which lactate will accumulate and be cleared during exercise (Brooks et al., 2000, pp. 199-200, 210; Hawley et al,, 1997; Lindsay et al., 1996; McArdle et al., 2007, p. 498; Tabata et al., 1996). If a greater amount of lactate is accumulated, but the rate of clearance is limited, tolerance of lactate may transition into an increase in the LT over time (Brooks et al., 2000, p. 462). Continued training would also affect the LT by delaying the accumulation of lactate, which is done by increasing the removal rate of lactate for any given workload (Brooks et al., 2000, p. 210; McArdle et al., 2007, p. 167). This effect will allow for greater work rates during HIIT. In relation to mountain bike performance, an athlete with a higher LT will be able to generate and sustain a higher PO during a race.

Recovery

Recovery Between Sessions of High Intensity Intermittent Exercise. While various types of recovery have been identified in the literature, training recovery has received little attention. Due to the scarcity of scientific literature, it will be more advantageous to discuss each study independently, as each study took a different approach in regard to exercise modality and amount of recovery between sessions of high intensity intermittent exercise (HIIE). HIIE is a similar training modality to HIIT in that both involve intermittent bouts of high intensity exercise; however, with HIIE, the work:rest ratio is not necessarily fixed, as it is with HIIT. As a result of the similarities between the two, suggestions for recovery from HIIE may be applicable to HIIT. Training recovery is defined as recovery between sessions of high intensity intermittent exercise (Bishop, Jones, Woods, 2008). In a study examining training recovery, researchers found that 70% of participants in a high-intensity resistance training protocol were recovered near baseline values 48 hours post exercise. Furthermore, only 80% were fully recovered after 72 hours (McLester, Bishop, Smith, Wyers, Dale, Kozusko, Richardson, Nevett, Lomax, 2003), suggesting that individual genetic factors may play a role in recovery between sessions of HIIE (Bishop et al., 2008). Likewise, Jones and colleagues found that 70% of participants in a high-intensity resistance protocol returned to baseline performance values after 48 hours of recovery and 80% returned to baseline values after 96 hours of recovery (Jones, Bishop, Richardson, Smith, 2006).

In 2003, Luebbers and colleagues examined the effects of recovery after participation in either a 4-week or 7-week high-intensity plyometric training program. After four weeks of recovery that was characterized by no plyometric training, results showed that participants in both groups significantly increased vertical jump height and power (Luebbers, Potteiger, Hulver, Thyfault, Carper, Lockwood, 2003). While the recovery period was extensive, these findings demonstrate the need for adequate recovery following HIIE. Similarly, Lane & Wenger (2004) examined the impact of various recovery modalities (e.g., active recovery, cold compression, massage) on performance during intermittent bouts of high-intensity cycling separated by 24 hours of recovery. All treatment groups were able to perform at baseline values following the recovery period, but the control group performed below baseline values. Aside from specific recovery treatments, 24 hours may not be enough time to allow for recovery between bouts of high-intensity exercise (Lane & Wenger, 2004).

Finally, in a study conducted by Bishop & Jenkins (1995), researchers found that the level of recovery between bouts of HIIE did not differ when separated by 3 and 24 hours of recovery. However, it is important to note that full recovery was not suggested, only recovery separated by 3 and 24 hours. As a result, it is difficult to ascertain whether or not participants' recovery rates would have been different 48 and 72 hours post exercise (Bishop & Jenkins, 1995).

Although not examined in the literature, recovery between sessions of HIIT must be considered when designing an interval training protocol. Training recovery is an important factor when considering sport performance. If an athlete is in an overtrainined state due to a lack of recovery, performance will be adversely affected. As a result, it is important for individuals participating in high intensity exercise to include adequate recovery between sessions of exercise. (Kraemar & Ratamess, 2004).

Conclusion

While the research regarding mountain biking performance is rather scarce in number, the existing studies provide insights regarding the mainstays of performance. Factors that correspond to mountain bike riding performance include PPO, as well as PO and percentage of VO2max at the LT and the OBLA. With the identification of these physiological performance markers, it is important that riders incorporate training modalities into their workout routines that are known to enhance these performance markers. Research suggests that the exercise training modalities known to increase the aforementioned physiological parameters of successful riding include resistance training, endurance training, and HIIT. A rider must also take into account the frequency, duration, and modalities of training in order to maximize the gains needed for successful performance, while also incorporating adequate recovery in order to minimize the risk of injury. The following study is an assessment of the modalities, frequencies, and durations of sport specific training programs among competitive mountain bikers, as well as recovery between sessions of HIIT.

Chapter 3

Methods

Study Design

The approach for this study was an anonymous, convenience sample survey using a one-time in-depth online questionnaire to assess exercise-training methods among competitive mountain bikers.

Participant Recruitment

Participants for this study were a nationwide convenience sample and were recruited by contacting groups whose members are competitive mountain bikers. Sources for participant recruitment included a nationwide search on public websites and resources in the public domain. For example, university or college sponsored teams were identified from races schedules found at www.usacycling.org. This site has information on university sport's club teams, as well as NCAA intercollegiate teams. Teams from these race schedules were identified as competitive. These teams had team page links through their university or college sports team homepages. For these teams, many had multiple contacts. For example, there may be a contact for the team president or captain, as well as the vice-president or co-captain. In these instances, both contacts were used as a potential source for participant recruitment. Other competitive professional mountain bikers were identified through an internet search on a major search engine. Many of these riders have their personal webpages displaying contact information. This information was used to contact these riders as potential candidates for completing the present survey. Finally, competitive members of the Birmingham Urban Mountain Pedalers (B.U.M.P) were contacted as potential participants. This organization represents mountain biking in the

Southeast for the state of Alabama. It is part of a larger governing body known as the International Mountain Biking Association (IMBA). A total of 63 contacts were identified for potential participant recruitment.

Based on observations from the aforementioned webpages, it was estimated that the potential pool of participants was 315 members. Each team had approximately 5 members. This value, multiplied by the 63 identified contacts, provided the estimate pool of participants. However, due to the nature of the present study, that number is not precisely known. Sixteen coaches and 47 athletes were contacted to fill out the survey. Two versions of the recruitment letter were created: one was written for the athletes and the other for team coaches. This letter was sent via e-mail a total of four times during a 4-month period, and it was requested that these contacts forward the survey along to their riders and teammates. Overall, at total of 254 e-mails were sent to these 63 contacts during the 4-month period. The e-mail recruitment letters can be found in Appendix 1. Those who chose to complete the survey remained anonymous. Riders from these clubs and teams represented all regions of the United States, including the Pacific Northwest, West Coast, East Coast, Desert Southwest, Northeast, and the Southeast.

Survey

A nationwide online survey using the Vovici online survey system was developed. Vovici is a Verint company and is one of the leading providers of online survey management software. Vovici and the Verint Company provide service for more than 50% of Fortune 500 companies. The online survey was sent via e-mail through a weblink. Participants then clicked on the link to begin the survey. Depending on the athlete's responses, the survey took between 5-20 minutes to compete. Please see Appendix 2 for a complete version of the survey. The survey assessed several types of training, including resistance training with weights, high intensity interval exercise, and endurance exercise. Additionally, time spent using these types of exercise was assessed, as well as bike training on a mountain trail. Major responses were questions that were seen by everyone that completed the survey. These were yes and no questions. Depending on the answer to the major responses, the rider would move into more detailed questioning regarding the specificities of that type of training. For example, a major response question was as follows, "In an effort to improve performance, do you resistance train?" If the participant answered yes, then more detailed questions were asked regarding resistance training. If they answered no, the survey moved onto the next modality of training.

Survey Design

Due to the association between the aforementioned performance parameters within the sport and the training modalities associated with the physiological adaptations of these parameters, the exercise training modalities (e.g., resistance, endurance, and interval) served as the driving force behind the development of the present survey. The body of scientific literature examining the physiological training adaptations to the presently selected exercise training modalities supports each question written for this survey.

Additionally, the Delphi Method was used for the development of the present survey. A focus group was used with individuals from B.U.M.P. During the meeting, questions were presented to the group in an effort to determine the nature of training that these riders preferred. These responses were then used in the development of each survey question. Once a rough draft of the survey was constructed, it was then pre-tested among competitive mountain bikers from B.U.M.P. and then, based on feedback, was revised before being sent out for national distribution.

Survey Response Rate

Response rates from a survey of this nature have been shown to vary considerably. Researchers have observed response rates from internet-based surveys ranging from 20-53% (Sax, Gilmartin, & Bryant, 2003; Sheehan, 2001;Truell, Bartlett, & Alexander, 2002). Among first generation respondents, 63 individuals were contacted and 40 completed the survey, providing a 64% response rate. First generation respondents were considered the direct contacts identified via the internet websearch and included all individuals to which the recruitment letter (See Appendix 1) was sent directly from the principle investigator of this study. Among the second-generation respondents, potentially 315 individuals were contacted. Second generation respondents were considered all individuals to whom the recruitment letter (See Appendix 1) was forwarded via e-mail from the first generation respondents. Based on the number of respondents (n = 40), the estimated response rate among the second-generation respondents was 13%. These values are on par with the current recommendations from the literature (Sax et al., 2003; Sheehan, 2001; Truell et al., 2002).

Statistical Analyses

Many of the questions in the survey (See Appendix 2) were open-ended, allowing respondents to enter numeric values for time spent using various types of training. “Yes” and “no” questions assessed whether or not participants engage in the aforementioned types of exercise training. After obtaining all answers, this information was collated and evaluated by the principle investigator. The data collected from the online survey was organized into three types of training: 1) resistance training, 2) endurance training, and 3) interval training. For analysis purposes, mean durations of workouts, total weeks spent training, and number of workouts per week were calculated. Additionally, frequency was calculated into percentages for the analysis. For example, the total number of riders assessed (n = 40) was divided by various frequencies. Frequencies included participation in assessed modalities of training, as well as other descriptives of the rider's workout sessions.

A Cronbach's alpha (α) test of internal consistency was conducted to determine the reliability of the present survey. Major responses were used to determine the reliability of the present survey, as those were answered by all respondents.

Finally, non-parametric binomial statistical analyses were conducted to determine significant differences between the percentage of riders participating in selected exercise modalities during the *in-season* versus the *off-season*. The type I error rate was set at an alpha value of .05.

Chapter 4

Results

Sample Characteristics

For the present study, 27 male and 13 female competitive mountain bikers completed the online survey. The mean age of the participants was 25.75 years (*SD* = 9.12) (Table 4.1). Riders competed in an average of 15.33 races per year (*SD* = 9.36). The number of years spent in competitive racing averaged 4.79 years (*SD* = 4.39) (Table 4.1). Participants were given the option of selecting all disciplines they competed in during the previous year (Table 4.2). Ninety-three percent of riders reported competing in *cross-country* racing, 38% reported competing in *Super-D*, 28% reported competing in *downhill* racing, and 20% reported participating in *Freeride* competitions (Table 4.3). Of the 40 participants, 43% of riders competed on a sponsored local or national team, 40% of the riders competed as part of a collegiate sports club team, 28% competed on a National Collegiate Athletic Association (NCAA) team, and 23% competed as a sponsored individual (Table 4.4).

Table 4.1

Sample characteristics of competitive mountain bikers (N = 40)

Sample Characteristics	**Mean**	**Standard Deviation**
Age	25.75	9.12
Years as a competitive mountain biker	04.78	4.39
Competitive races per year	15.33	9.36
Total months of the in-season	06.75	2.92
Total months of the off-season	04.63	2.99

Table 4.2

Number and percentage of riders who chose one or more disciplines

Number of riders	*Percentage*	*Cross-Country*	*Downhill*	*Freeride*	*Super D*
19	47.5	**X**	----	----	----
10	25.0	**X**	----	----	**X**
3	7.5	**X**	**X**	**X**	----
3	7.5	**X**	**X**	**X**	**X**
1	2.5	**X**	**X**	----	**X**
1	2.5	**X**	**X**	----	----
1	2.5	----	**X**	----	----
1	2.5	----	**X**	**X**	----
1	2.5	----	**X**	**X**	**X**

Table 4.3

Percentage of selected disciplines among competitive mountain bikers (N = 40)

Discipline	**Frequency**	**Percentage**
Cross Country	37	92.50
Downhill	11	27.50
Freeride	8	20.00
Super D	15	37.50

Table 4.4

Competitive affiliation among competitive mountain bikers (N = 40)

Rider Affiliation	**Frequency**	**Percentage**
Sponsored Team	17	42.50
University or College Sport Club	16	40.00
NCAA Intercollegiate Team	11	27.50
Independent	9	22.50
Other	2	05.00
Professional	1	02.50

Cronbach's Alpha

Major responses were examined to determine the reliability of the present survey. The alpha value for reliability was .82 ($\alpha = .82$), suggesting a high level of internal consistency among survey items (Nunnally, 1978), indicating a measure of reliability for this survey. While this reliable instrument does not guarantee validity, it would be much less so if it were determined to be unreliable.

In-Season Training

In an effort to assess whether or not riders are implementing exercise-training modalities during the *in-season,* which have been shown to increase mountain bike performance, we evaluated responses to survey question items 10, 21, and 29. These questions are as follows: 10) Do you resistance train during the *in-season* to increase your mountain biking performance? (Resistance training is defined as the specialized method of conditioning that involves the progressive use of resistance to increase one's ability to exert or resist force and can include the use of dumbbells, barbells, machines, kettlebells, or body weight), 21) In an effort to increase your mountain bike performance, do you participate in traditional aerobic/endurance training, excluding interval training? (Aerobic/endurance exercise is characterized by extended exercise durations incorporating large muscle groups. Examples of aerobic exercise include but are not limited to cycling, running, swimming, cross-country skiing), and 29) In an effort to increase your mountain bike performance, do you participate in interval/intermittent training during your *in-season*? (Interval/intermittent exercise is characterized by bouts of brief, moderate to high-intensity, interval type exercise. Bouts are separated by recovery periods (e.g., 1-8 minutes) during the exercise session and then repeated in cycles). Responses to these items are presented in Table 4.5. Furthermore, in order to assess the prevalence of the types of exercise training among competitive mountain bikers during the *in-season*, we examined the responses to survey question items 12, 14-20, 23, 25, 27, 31, 34, and 36 (Appendix 2), and these responses are also presented in Table 4.5. Finally, to determine how much time is spent during the *in-season* using the selected exercise training modalities, we assessed rider responses to survey question items 11, 13, 22, 24, 26, 28, 30, 35, and 37 (Appendix 2). Responses to these items are presented in Tables 4.6 and 4.7.

Table 4.5

Selected exercises and training modalities for performance enhancement during the in-season

In-Season	Frequency	Percentage
Resistance training (RT) (N = 22)		55.00
Upper body parts selected for weekly workout sessions of those that RT		
Chest	17	77.27
Back	18	81.82
Shoulders	20	90.90
Core	20	90.90
Biceps	15	68.18
Triceps	15	68.18
Lower body parts selected for weekly workout sessions of those that RT		
Quadriceps	20	90.90
Hamstrings	20	90.90
Calves	15	68.18
Resistance Training Tempo		
High Explosive Tempo Resistance Training	9	40.90
Slow Tempo Resistance Training	13	59.09
Endurance Training (N = 39)		97.50
Trail Riding	39	100.00
Cycle Ergometer	11	28.20
Interval Training (N = 34)		85.00
Trail Riding	23	67.64
Cycle Ergometer	9	26.47

Table 4.6

In-season average workout sessions per week and minutes per session. Data are means (SD), N = 40.

In-Season	***Number of Riders***	***Workout Sessions/Week***	***Minutes/Workout***
Resistance Training	22	3.00 (1.19)	052.05 (34.35)
Upper Body Resistance Training	20	2.75 (1.16)	----
Lower Body Resistance Training	20	3.45 (1.76)	----
Endurance Training	39	4.26 (1.65)	103.85 (66.63)
Trail Riding	39	2.51 (1.44)	104.05 (46.32)
Cycle Ergometer	11	1.73 (0.79)	051.45 (23.13)
Interval Training	34	1.85 (0.86)	----
Trail Riding	23	1.43 (0.73)	051.86 (29.02)
Cycle Ergometer	9	1.67 (0.50)	056.78 (27.05)

Table 4.7

In-season mean values for total weeks resistance, endurance, and interval training. Mean values for upper and lower body exercises selected per resistance workout session, as well as interval work:rest ratio and days between sessions of interval training are represented, N = 40

In-Season	**Number of Riders**	**Mean Values (SD)**
Total Weeks Resistance Training	21	23.10 (18.00)
Upper Body Exercises/Workout Session	20	06.25 (02.33)
Lower Body Exercises/Workout Session	20	05.85 (03.13)
Total Weeks Endurance Training	39	28.55 (16.98)
Total Weeks Interval Training	32	19.28 (13.62)
Interval Training Work Ratio	24	01.67 (00.96)
Interval Training Rest Ratio	24	01.77 (01.91)
Days Between Sessions of Interval Training	34	03.13 (02.03)

Resistance training during the in-season. Fifty-five percent (n = 22) of respondents reported participating in resistance training as a training modality during the *in-season*. The average number of workout sessions per week devoted to resistance training was 3.00 days (*SD* = 1.19) per week. Table 4.5 presents the percentages of riders selecting upper and lower body exercises during their resistance training workout sessions. Table 4.7 shows the average number of exercises selected for upper and lower body workouts. The mean numbers of upper body and lower body workouts per week were 2.75 (*SD* = 1.16) and 3.45 (*SD* = 1.76) workout sessions per week, respectively. Additionally, 40.90% of the riders reported performing resistance exercises in a high-explosive lifting tempo, whereas 59.09% reported performing resistance-training exercises at a slow lifting tempo. Of the total months *in-season* (*M* = 6.75; *SD* = 2.92), riders spent an average of 23.10 weeks (*SD* = 18.00) implementing resistance training into their weekly workout sessions. The average duration of weekly individual resistance training workout sessions was reported at 52.05 minutes (*SD* = 34.35) per session.

Endurance training during the in-season. The proportion of respondents participating in endurance training during the *in-season* was 97.50% (n=39). Riders reported an average of 4.26 sessions (*SD* = 1.65) of endurance training per week, and the average number of weekly endurance sessions spent trail riding was 2.51 sessions (*SD* = 1.44) per week. Reported aerobic workout sessions per week on a stationary cycle ergometer were reported as 1.73 sessions (*SD* = .79) per week. Overall, 100.oo% of those participating in aerobic endurance training selected trail riding as a modality for aerobic exercise, whereas 28.20% (n = 11) reported using a stationary cycle ergometer in conjunction with trail riding. Riders reported implementing aerobic endurance training over an average of 28.55 weeks (*SD* = 16.98) during the approximate 7-month *in-season*. Individual sessions of endurance training lasted an average of 103.85 minutes (*SD* = 66.63) per session. Sessions of endurance exercise performed on a cycle ergometer were reported to last an average of 51.45 minutes (*SD* =23.13) per session, whereas the mean duration for sessions of trail riding endurance exercise was reported to last 104.05 minutes (*SD* = 46.32) per session.

High intensity interval training during the in-season. The percentage of respondents participating in high intensity interval training during the *in-season* was 85.00% (n = 34), with an average of 1.85 days (*SD* = .86) per week devoted to HIIT. The average number of HIIT workout sessions on a cycle ergometer was 1.67 sessions (*SD* = .50) per week. Riders reported an average of 1.43 (*SD* = .73) HIIT workout sessions per week on an off-road trail. However, a greater number of riders reported trail riding as the modality for HIIT, 67.64% (n=23). Among riders participating in interval training, 26.47% (n = 9) reported using a cycle ergometer to perform their HIIT sessions. The number of weeks spent during the *in-season* incorporating HIIT into weekly workout sessions averaged 19.28 weeks (*SD* = 13.62). Riders reported spending a mean of 56.78 minutes (*SD* = 27.05) of HIIT on a cycle ergometer per workout session and a mean of 51.86 minutes (*SD* = 29.02) per workout session of HIIT trail riding. The average reported work to rest ratio for interval training was .94:1. Riders reported taking an average of 3.13 days (*SD* = 2.03) of rest between workout sessions of HIIT.

Off-Season Training

In an effort to assess whether or not riders are implementing exercise training modalities during the *off-season* that are shown to increase mountain bike performance, we evaluated responses to survey question items 39, 50, and 58. These questions are as follows: 10) Do you resistance train during the *off-season* to increase your mountain biking performance? (Resistance training is defined as the specialized method of conditioning that involves the progressive use of resistance to increase one's ability to exert or resist force and can include the use of dumbbells, barbells, machines, kettlebells, or body weight), 21) In an effort to increase your mountain bike performance, do you participate in traditional aerobic/endurance training, excluding interval training? (Aerobic/endurance exercise is characterized by extended exercise durations incorporating large muscle groups. Examples of aerobic exercise include but are not limited to cycling, running, swimming, cross-country skiing), and 29) In an effort to increase your mountain bike performance, do you participate in interval/intermittent training during your *off-season*? (Interval/intermittent exercise is characterized by bouts of brief, moderate to high-intensity, interval type exercise. Bouts are separated by recovery periods (e.g., 1-8 minutes) during the exercise session and then repeated in cycles). Responses to these items are presented in Table 4.8. Additionally, in order to assess the prevalence of the types of exercise training among competitive mountain bikers during the *off-season*, we examined the responses to survey question items 41, 43-49, 52, 54, 56, 60, 63, and 65 (Appendix 2), and these responses are presented in Table 4.8. Lastly, to determine how much time is spent during the *in-season* using the selected exercise training modalities, we assessed rider responses to survey question items 40, 42, 51, 53, 55, 57, 59, 64, and 66 (Appendix 2). Responses to these items are presented in Tables 4.9 and 4.10.

Table 4.8

Selected exercises and training modalities for performance enhancement during the off-season, N = 40

Off-Season	**Frequency**	**Percentage**
Resistance training (RT) (N = 21)		52.50
Upper body parts selected for weekly workout sessions of those that RT		
Chest	15	71.43
Back	16	76.19
Shoulders	17	80.95
Core	20	95.24
Biceps	14	66.67
Triceps	16	76.19
Lower body parts selected for weekly workout sessions of those that RT		
Quadriceps	20	95.24
Hamstrings	20	95.24
Calves	17	80.95
Resistance Training Tempo		
High Explosive Tempo Resistance Training	10	47.62
Slow Tempo Resistance Training	11	52.38
Endurance Training (N = 33)		82.50
Trail Riding	28	84.85
Cycle Ergometer	15	45.45
Interval Training (N = 12)		30.00
Trail Riding	4	33.33
Cycle Ergometer	9	75.00

Table 4.9

Off-season average workout sessions per week and minutes per session. Data are mean (SD), N = 40.

Off-Season	***Number of Riders***	***Workout Sessions/Week***	***Mean Minutes/Workout***
Resistance Training	21	2.76 (1.09)	52.14 (29.26)
Upper Body Resistance Training	20	3.15 (2.06)	----
Lower Body Resistance Training	20	2.85 (1.46)	----
Endurance Training	32	4.13 (1.66)	85.19 (42.65)
Trail Riding	28	2.54 (1.55)	97.50 (41.26)
Cycle Ergometer	15	1.93 (1.16)	65.31 (27.89)
Interval Training	12	1.67 (0.65)	----
Trail Riding	4	1.50 (1.00)	60.00 (00.00)
Cycle Ergometer	9	1.78 (0.67)	53.75 (19.04)

Table 4.10

Off-season mean values for total weeks resistance, endurance, and interval training. Mean values for upper and lower body exercises selected per resistance workout session, as well as interval work:rest ratio and days between sessions of interval training are represented, N = 40

Off-Season	**Number of Riders**	**Mean Values (SD)**
Total Weeks Resistance Training	21	17.14 (11.64)
Upper Body Exercises/Workout Session	20	05.40 (01.87)
Lower Body Exercises/Workout Session	20	05.25 (03.19)
Total Weeks Endurance Training	31	22.65 (15.19)
Total Weeks Interval Training	12	11.92 (08.31)
Interval Training Work Ratio	12	01.90 (01.10)
Interval Training Rest Ratio	12	01.30 (00.48)
Days Between Sessions of Interval Training	12	03.25 (02.00)

Resistance training during the off-season. Fifty-two and a half percent (n = 21) of respondents reported participating in resistance training as a training modality during the *off-season*. The average number of workout sessions per week devoted to resistance training was 2.76 days (*SD* = 1.09) per week. Table 4.8 presents the percentages of riders selecting upper and lower body exercises for their resistance training workout sessions. Table 4.10 shows the average number of exercises selected for upper and lower body workouts. The mean number of upper body and lower body training sessions per week was 3.15 (*SD* = 2.06) and 2.85 (*SD* = 1.46). Additionally, 47.62% of the riders reported performing resistance exercises in a high-explosive lifting tempo, whereas 52.38% reported performing resistance-training exercises at a slow lifting tempo. Of the total months *off-season* (*M* = 4.63, *SD* = 2.99), riders spent an average of 17.14 weeks (*SD* = 11.64) resistance training. The average duration of weekly individual resistance training workout sessions was reported at 52.14 minutes (*SD*= 29.26) per session.

Endurance training during the off-season. The proportion of respondents participating in endurance training during the *off-season* was 82.50% (n=33). Riders reported an average of 4.13 sessions (*SD* = 1.66) of endurance training per week, and the average number of weekly endurance sessions spent trail riding was 2.54 sessions (*SD* = 1.55) per week. Aerobic workout sessions reported per week on a stationary cycle ergometer were 1.93 sessions (*SD* = 1.16) . Overall, 84.85% (n = 28) of those participating in aerobic endurance training selected trail riding as a modality for aerobic exercise, whereas 45.45% (n = 15) reported using a stationary cycle ergometer. Riders reported implementing aerobic endurance training over an average of 22.65 weeks (*SD* = 15.19) during the approximate 5-month *off-season.* Individual sessions of endurance training lasted an average of 85.19 minutes (*SD* = 42.65) per session. Sessions of endurance exercise performed on a cycle ergometer were reported to last an average of 65.31 minutes (*SD* =

27.89) per session, whereas the mean duration for sessions of trail riding endurance exercise was reported to last 97.50 minutes (*SD* = 41.26) per session.

High intensity interval training during the off-season. The percentage of respondents participating in high intensity interval training during the *off-season* was 30% (n = 12), with an average of 1.67 days (*SD* = .65) per week devoted to HIIT. The average number of HIIT workout sessions was slightly greater on a cycle ergometer, 1.78 (*SD* = .67). Riders reported an average of 1.50 (*SD* = 1.00) HIIT workout sessions per week on an off-road trail. Among riders participating in interval training (n = 12), 30.76% (n=4) reported trail riding as the modality for HIIT, whereas 75.00% (n=9) of riders reported using a stationary cycle ergometer to perform their HIIT sessions. The number of weeks spent during the *off-season* incorporating HIIT into weekly workout sessions averaged 11.92 weeks (*SD* = 8.31). Riders reported spending a mean of 60.00 minutes (*SD* = .00) of HIIT on a cycle ergometer per workout session and a mean of 53.75 minutes (*SD* = 19.04) of HIIT trail riding per workout session. The average reported work to rest ratio for interval training was 1.46:1. Finally, riders reported taking an average of 3.25 days (*SD* = 2.00) of rest between workout sessions of HIIT.

Differences in Percentages of *In-Season* versus *Off-Season Training*

In an effort to determine differences in percentage of rider participation in selected exercise modalities during the *in-season* and *off-season*, non-parametric binomial statistical analyses were conducted. Results demonstrated that, statistically, there was no difference between the percentages of riders that participate in resistance training during the *in-season* versus the *off-season* (Z = 0.09, p = .463). Percentages between *in-season* and *off-season* participation in resistance training are presented in Figure 4.1. Conversely, a higher percentage of riders participate in endurance training during the *in-season* compared to the *off-season* (Z = 2.58, p = .005*). Percentages between *in-season* and *off-season* participation in endurance training are presented in Figure 4.2. Likewise, a higher percentage of riders participate in high intensity interval training during the *in-season* compared to the *off-season* (Z = 3.10, p < .001*). Percentages for interval training participation between the *in-season* and *off-season* are presented in Figure 4.3.

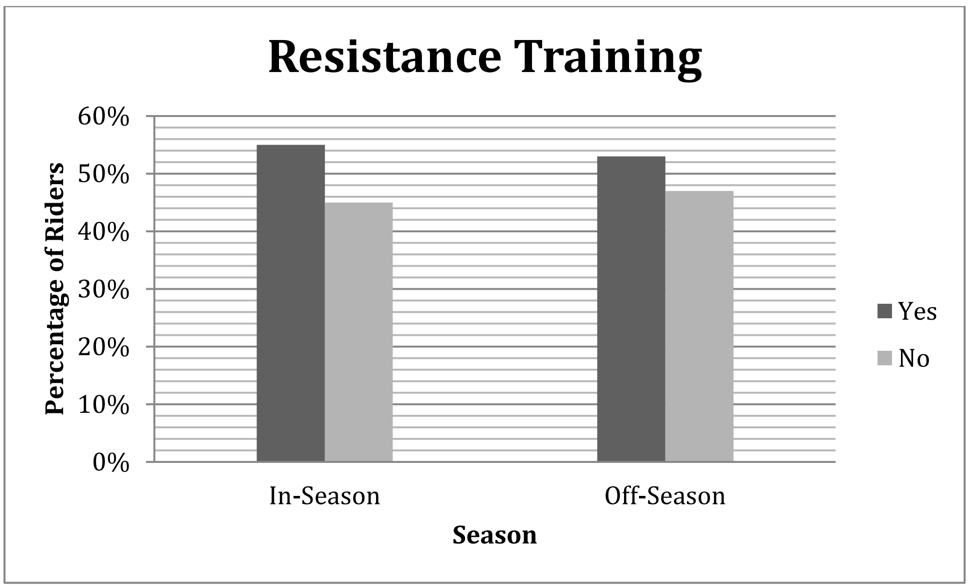

Figure 4.1. *Percentage of riders participating in resistance training during the in-season versus the off-season. (Z = 0.09, p = .463)*

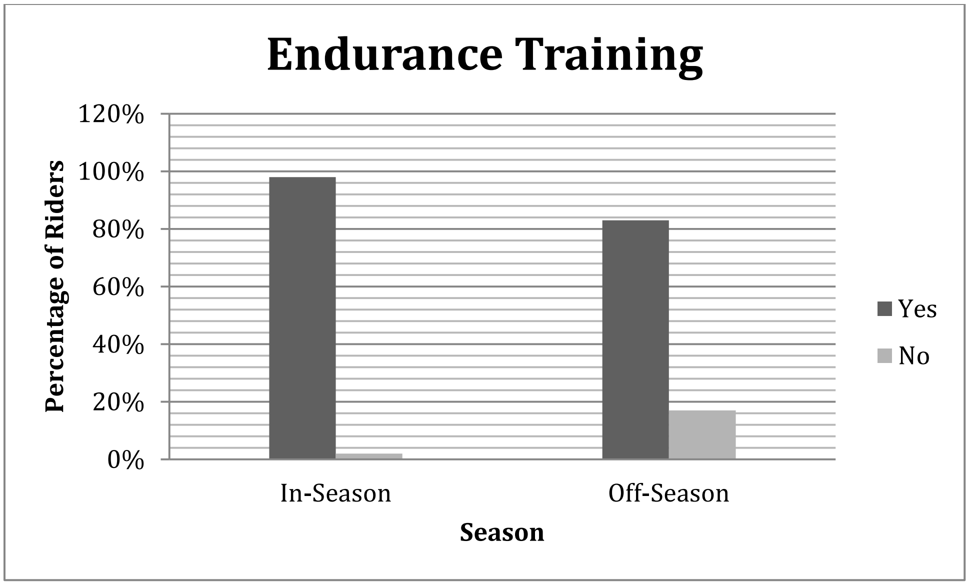

Figure 4.2. *Percentage of riders participating in endurance training during the in-season versus the off-season. (Z = 2.58, p = .005*)*
**indicates a significant difference*

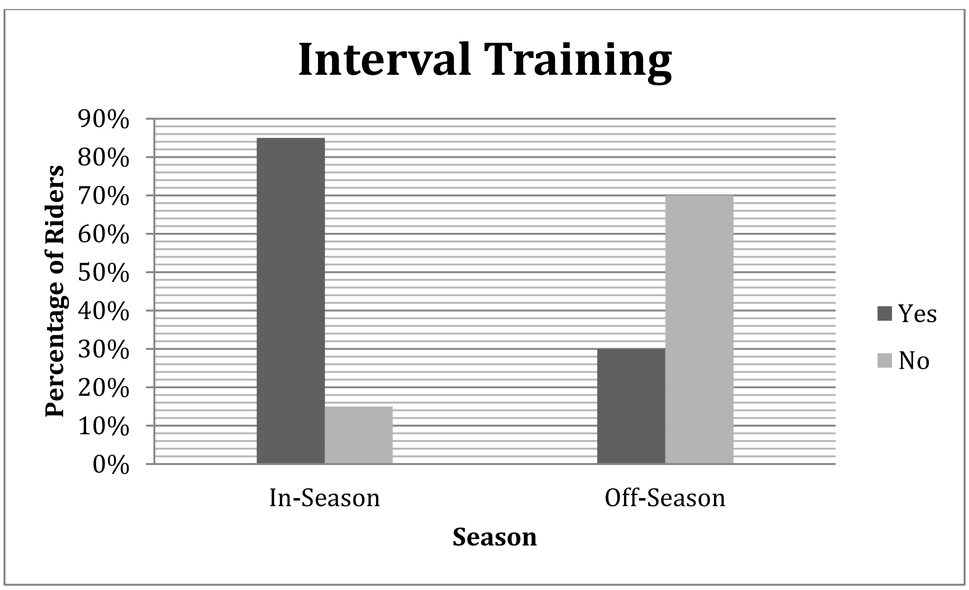

Figure 4.3. *Percentage of riders participating in high intensity interval training during the in-season versus the off-season. (Z = 3.10, p = < .001*)*
**indicates a significant difference*

Training Information

Sources of training information for respondents were examined. Fifty-eight percent (n=40) or riders reported using training programs given to them by their coaches. The other sources for training information are reported in Table 4.11.

Table 4.11

Sources of training information among competitive mountain bikers

Training Information (N=40)	Frequency	Percentage
Coach	23	57.50
Other	9	22.50
Books	2	5.00
Friends/Teammates	1	2.50
Other Racers	1	2.50
Certified Coach	1	2.50
Myself	2	5.00
Trainer	1	2.50
Online Sources	3	7.50
General Fitness Magazines	2	5.00
Peer-Reviewed Literature	2	5.00
Mountain Bike Magazines	1	2.50

Chapter 5

Discussion

To the best of my knowledge, this study is the first to examine the frequencies, durations, and modalities of exercise training among competitive mountain bikers. Overall, results suggest that endurance training is the most popular modality of exercise training, regardless of the season percentage. It was also shown that riders participate in endurance training for the duration of the entire percentage *in-season* and percentage *off-season*. This finding was comparable to the total numbers of weeks spent resistance training, which was close to the entire percentage *in-season* and percentage *off-season*. Approximately one half of the riders assessed implemented resistance exercises into their training programs, making it the least popular form of performance training during the *in-season.* During the *off-season*, however, resistance training was the second most popular method of exercise training. Interval training was shown to be the second most popular form of exercise training during the *in-season* but was the least popular form of training throughout the *off-season.* For both endurance training and HIIT, trail riding was the most popular method of exercise training within these two modalities. Trail riding offers the rider a training environment almost identical to an actual competition, as well as training on the type of equipment they will use in competition. Therefore, it is not surprising that riders would prefer to train on the trail.

As discussed in the review of literature, performance parameters associated with successful mountain bike riding have been identified and primarily include PO and % VO_2max at the LT and the OBLA (Gregory, Johns, Walls, 2007; Impellizzeri, Marcora, et al., 2005; Impellizzeri, Rampinini, et al., 2005; Lee, Martin, Anson, Grundy, Hahn, 2002; Prins, Terblance, Myburgh, 2007). Based on the results from the present study, it would appear that, indeed, mountain bike riders are participating in the modalities of exercise training known to increase these parameters, which should result in improved mountain bike riding. Moreover, results also suggest that riders are participating in the frequencies and durations of exercise training recommended to enhance mountain bike performance (Fuhrmann, 2002; Niederpruem, 2002; Rhyan, 1998; Rhyan, 2005; Willis et al., 1999). The following discussion will focus on the various nuances of the training modalities assessed by this survey. Because endurance training was shown to be the most popular modality, it will be discussed first, followed by interval training and resistance training.

Endurance Training

Results from the present study suggest that endurance training is the most frequent and popular modality of training among competitive mountain bikers for both the *in-season* and *off-season*. Among respondents, 97.50% reported participating in endurance training during the *in-season*, while 82.50% reported endurance training during the *off-season*. Based on the perception that mountain biking is an aerobically based event, these results may not seem surprising; however, VO2max has been shown to only explain 40% of the variance in mountain bike performance (Impellizzeri, Marcora, et al., 2005; Impellizzeri, Rampinini, et al., 2005). Moreover, the total weeks (M = 28.55; SD = 16.98) spent during the *in-season* endurance training was comparable to the total weeks (M = 22.65; SD = 15.19) of endurance training reported during the *off-season*. Results suggest that a majority of riders are participating in endurance training year round. As mentioned, the sport of mountain bike is perceived as predominately incorporating aerobic energy pathways (Baron, 2001; Impellizzeri, Marcora, et al., 2005; Impellizzeri, Rampinini, et al., 2005). Therefore, in an effort to increase performance, riders may feel the need to participate in endurance training during the entire year.

When considering frequency and duration for endurance training, current recommendations suggest, depending on intensity, 30-120 minute sessions, 2-4 times per week (McArdle et. al., 2007; Potteiger, 2000). Overall, it appears the riders are meeting the recommended prescription of exercise for enhanced aerobic performance. During the *in-season,* riders reported participating in endurance training sessions an average of 4.26 times per week, with each session lasting approximately 103.85 minutes. Upon examination of these aerobic training sessions, riders spent an average of 2.51 days per week trail riding, as opposed to an average of 1.73 sessions per week on a cycle ergometer. Interestingly, endurance-training sessions on a trail lasted approximately 104.05 minutes, whereas time per session on a cycle ergometer averaged 51.45 minutes. More time spent trail riding could translate into specificity of training. Riders may prefer to train in conditions very similar to those they would encounter during a race. Furthermore, 100.00% of the riders surveyed chose trail riding as a modality for endurance training and only 28.20% of the riders chose a cycle ergometer to complement their endurance training. These results may also suggest that riders prefer to train on equipment specific to that which they will use during competition. There is also the possibility that riders simply like riding their bikes on a trail, and as a result, workouts may lend themselves to being longer in duration.

Results from the *off-season* were shown to be very similar to results from the *in-season*. Riders averaged 4.13 sessions per week of endurance training, with the average session lasting approximately 85.19 minutes. Moreover, trail riding remained the modality of choice for 84.85% of the riders. Riders spent an average of 2.5 sessions per week endurance training on a trail and these sessions averaged 97.50 minutes per session. Riders who also chose to train on a cycle ergometer reported fewer weekly sessions, as well as a reduced duration of sessions. The average sessions per week on a cycle ergometer were reported at 1.93, and time spent endurance training on a cycle ergometer averaged 65.31 minutes per session. As mentioned, trail riding may prove a more advantageous method of endurance training for competitive mountain bikers. When trail riding, a rider must balance and navigate the bike through rough, technical terrain. As a result of the isometric muscle contractions needed to perform these tasks, trail riding may also incorporate elements of upper body muscular endurance (Baron, 2001; Gregory et al., 2007, Harris & Dudley, 2000; Impellizzeri, Marcora, et al., 2005; Impellizzeri, Rampinini, et al., 2005; Lee et al., 2002; Prins et al., 2007), an advantage that may not be gained by riders who train on a stationary cycle.

Overall, results suggest competitive mountain bikers are meeting the general recommendations for frequency of endurance training sessions per week and duration per session. These recommendations have been shown to improve physiological parameters associated with successful sport performance. (Potteiger, 2000; Wathen et al., 2000). Based on the results from this study, it would seem logical to conclude that riders are spending adequate time endurance training in an effort to increase performance.

Interval Training

High intensity interval exercise offers an advantage as a training modality for athletes looking to enhance sport performance. Specifically, it allows athletes to perform greater workloads over a shorter period of time when compared to longer, continuous workout sessions (Niederpruem, 2002). Research has shown HITT to significantly increase aerobic parameters, including VO_2max (Gaiga & Docherty, 1995; Laurson, Shing, et al., 2002; MacDougall et al., 1998; Tabata et al., 1996;). Additionally, HIIT has been shown to significantly increase MPO and PPO, as well as short distance time trial performance (Burgomaster et al., 2006; Gaiga & Docherty, 1995; Gibala et al., 2006; Hawley et al., 1997; Laurson, Blanchard, et al., 2002; Laurson, Shing, et al., 2002; Lindsay et al., 1996; MacDougall et al., 1998; Westgarth-Taylor et al., 1997). Results from these studies suggest that HIIT may utilize anaerobic and aerobic energy pathways during exercise. Benefits from HIIT have been observed in as little as 3-4 weeks, with 2-3 sessions of HIIT per week (Hawley et al., 1997; Lindsay et al., 1996; Niederpruem, 2002; Tabata et al., 1996)

Results from the present study show that 85.00% of the riders reported participating in HIIT during the *in-season*, whereas 30.00% reported HIIT during the *off-season*. A greater number of total weeks (M = 19.28; SD = 13.62) HIIT were reported during the *in-season*, when compared to weeks (M = 11.92; SD = 8.31) during the *off-season.* These results suggest that not only do fewer riders participate in HIIT during the *off-season*, they also appear to be spending less time doing so. When interpreting these findings, the nature of HIIT must be considered. By nature, HIIT is very intense, with exercising workloads typically at or above an individual's LT. Some riders may consider the o*ff-season* a time of recovery from an intense race season, so they avoid HIIT. Another possibility could be, due to the distinct performance benefits associated with HIIT, more riders may feel they have a competitive edge during the *in-season* by performing HIIT (Gaiga & Docherty, 1995; Laurson, Shing, et al., 2002; MacDougall et al., 1998; Tabata et al., 1996).

In regard to frequency of sessions per week, riders appear to be following the recommended suggestions of 2-3 sessions of HIIT per week (Hawley et al., 1997; Lindsay et al., 1996; Niederpruem, 2002; Tabata et al., 1996). Results suggest that, during the *in-season*, riders perform an average of 1.85 sessions of HIIT per week. Of these weekly sessions, more riders (67.64%) preferred trail riding as the modality of HIIT. During the *off-season*, riders reported an average of 1.67 weekly sessions of HIIT. However, 69.23% of the riders preferred to perform these sessions on a cycle ergometer. The nature of interval training may offer some insight into these findings. As mentioned in the previous section regarding endurance training, more riders may prefer trail riding as a mode for exercise training during the *in-season*. Trail riding simulates real race conditions, as well as riders are training on the exact type of equipment they will use during the race (i.e., mountain bike). However, during the *off-season*, this specificity may not be needed. To maximize the benefits from HIIT, workloads must be consistent (Burgomaster et al., 2006; Giaga & Docherty, 1995; Gibala, et al., 2006; Hawley et al., 1997; Laurson, Blanchard et al., 2002; Laurson, Shing, et al., 2002; Lindsay et al., 1996; MacDougall et al., 1998; Westgarth-Taylor et al., 1997), which is often difficult to control on a trail. A stationary cycle ergometer offers the advantage of controlling the exact workload at which exercise is being performed, which can ensure work rates are at or above the LT.

When determining the duration of weekly HIIT sessions, the time spent interval training should be dependent on the goals of the training program (Brooks et al., 2000; Niederpruem, 2002). For both the *in-season* and *off-season*, results demonstrated that the duration of weekly HIIT sessions exceeded 50.00 minutes, suggesting the interval sessions may be oriented more towards training for aerobic capacity. Shorter interval durations would suggest training to increase anaerobic capacity. (Tabata et al., 1996; Tabata et al., 1997; Niederpruem, 2002). For examples, studies examining the effects of HIIT on anaerobic capacity implemented HIIT sessions lasting 6-8 minutes (Tabata et al., 1996; Tabata et al., 1997).

During the *in-season*, riders also reported a .94:1 work/rest ratio, meaning that the time spent exercising is closely matched to the time spent in recovery between bouts of HIIT during the workout session. However, during the *off-season*, riders reported using a 1.46:1 work/rest ratio, suggesting that the time exercising exceeded the time of recovery between bouts of HIIT during the workout session. Considering all the performance factors related to the sport of mountain biking (Impellizzeri et al., 2002; Rhyan, 1998; Stapelfeldt et al., 2004; Willis et al., 1999), it would be advantageous for riders to incorporate varying work/rest ratios into HIIT cycles in an effort to increase both aerobic and anaerobic performance markers. For example, a 3:1 work to rest ratio could be 30 seconds of work and 10 seconds of active recovery. This ratio would begin to tax anaerobic energy pathways. However, to tax the aerobic energy pathways, the same 3:1 work to rest ratio could be implemented, but the time spent exercising would be 3 minutes to 1 minute of active recovery.

Finally, recovery between sessions of HIIT should be considered. However, the literature examining recovery between sessions of high intensity exercise is very limited. (Bishop et al., 1995; Jones et al., 2006; Lane et al., 2004; McLester et al., 2003), and, to the best of my knowledge, there are no studies examining recovery between sessions of HIIT. While there are no specific recommendations for the amount of recovery between sessions of HIIT, applications from studies examining recovery between sessions of high intensity resistance training could be useful. Approximately 3 days of recovery was adequate time for 80% of participants to be close to or fully recovered from sessions of high intensity resistance exercise (Jones et al, 2006; McLester et al, 2003). Riders reported allowing 3.13 days between *in-season* sessions of HIIT for recovery and 3.23 days of recovery between sessions of HIIT during the *off-season*. If the literature from recovery of HIIE is applied to HIIT (Jones et al, 2006; McLester et al, 2003), these results suggest that riders are taking enough time off between sessions of HIIT to allow for adequate recovery.

Resistance training

During the *in-season,* resistance training was shown to be the least popular modality of exercise training. Results from the present study indicate that only 55.00% of the riders incorporate resistance training into their workout sessions during the *in-season*. During the *off-season*, 52.50% of the riders reported participating in resistance training, making it the second most popular modality of training among riders in the *off-season*. When compared to the aforementioned modalities of exercise training, the percentage of riders participating in resistance training seems to be more consistent, suggesting that riders who resistance train during the *in-season*, may continue this training during the o*ff-season*. The same conclusion cannot be made regarding endurance and interval training. Overall, it appears that riders are resistance training close to the entire year. It is possible that riders who resistance train feel they perform better, and therefore, continue to train in this manner throughout the year.

Currently, the suggestion for frequency of resistance training sessions is at least 3 times per week (Fuhrmann, 2002; Rhyan, 1998; Rhyan, 2005; Willis et al., 1999). During the *in-season,* riders reported an average of 3.00 workout sessions per week devoted to resistance training. During the *off-season,* this frequency dropped slightly to 2.76 sessions per week resistance training. Overall, it would appear that riders are adhering to the recommended frequency of workouts sessions per week associated with increases in sport performance. Additionally, according to Kraemer et al., (2002), a resistance-training program should include a variety of resistance training exercises targeted towards the upper and lower body. Results from the present study suggest that riders adhere to this recommendation by incorporating a variety of upper and lower body exercises into their resistance training programs during the *in-season* and *off-season*. For *both seasons*, more than 70.00% of riders included resistance exercises targeting the major muscles of the upper body. Riders reported selecting an average of 6.00 upper body exercises per workout session. Similarly, over 90.00% of riders reported implementing resistance exercises focused on the major muscles of the lower body, with an average of 5.00 exercises selected per workout session. Not only does the percentage of participation in resistance training remain consistent throughout the year, results suggest there is a large amount of consistency among upper and lower body training between *both seasons*. As mentioned earlier, the technical terrain encountered during an off-road competition incorporates elements of upper and lower body muscular strength, endurance, and power (Fuhrmann, 2002; Rhyan, 1998; Rhyan, 2005; Willis, et al., 1999). Therefore, performing resistance training as part of a mountain bike workout regimen would enhance performance while riding.

In terms of how these resistance-training exercises were performed, results from the present study demonstrated that 40.90% of riders incorporate a high-explosive tempo during the *in-season*. This increased to 47.62% during the *off-season*. High-explosive resistance training exercises focus on the speed and velocity of the exercise movement. This type of training has been shown to increase power production as a result of increasing a muscle's capacity to produce increased force at a high velocity (Jensen & Fisher, 1979; Kraemer et al, 2002; Patton & Hopkins, 2005; Stone et al., 1991; Stone et. al., 1980; Stone and Garhammer, 1982). In support of a high-explosive lifting tempo, research has shown that replacing a segment of a rider's endurance training program with high-explosive resistance training significantly increased power production, as well as prevented the decreases in high-intensity short-term performance associated with endurance training (Bastiaans, Van Diemen, Veneberg, & Jeukendrup, 2001; Paton & Hopkins, 2005). Research has demonstrated increases in velocity of exercise movement are associated with gains in strength (Jensen & Fisher, 1979; Kraemer, Ratamas, & French, 2002; Paton & Hopkins, 2005; Stone, Fleck, Triplett, and Kraemer, 1991; Stone et. al., 1980; Stone and Garhammer, 1982) and increases in strength are associated with resistance training (Baechle et al., 2000; Kraemer et al., 1988; Kraemer et al., 2002). As a result, riders performing high-explosive movements may increase PO during competition, thus improving riding performance.

Conversely, 59.09% of riders reported performing resistance-training exercises at a slow-tempo during the *in-season*. During the *off-season*, 52.38% reported performing slow tempo resistance exercises. A slow lifting tempo is characterized by performing exercise movements in a slow and controlled manner. This type of lifting tempo increases the time upon which force is being exerted, suggesting training oriented towards the development of strength, and, depending on the number of repetitions performed for each resistance exercise, possibly muscular endurance (Baechle et al., 2000). However, without determining the intensity of the workloads, it is difficult to ascertain whether or not a slow tempo performance of exercise is focused more on the development of muscular strength or endurance. More importantly, Jackson et al. (2007) found that when mountain bike riders participated in a resistance training program oriented towards either high volume or high intensity, significant increases in strength were experienced. It is important to note that these findings only held true when the principle of progressive overload was applied (Jackson et al., 2007).

Resistance training increases strength, which, in turn, increases a muscle's ability to generate force. These increases potentially contribute to a greater velocity of movement, and a greater velocity of movement may lead to greater power production during sport performance (Crieland & Pirnay, 1981; Jackson et al., 2007; Paton & Hopkins, 2005; Stone et al., 1980; Wilmore et al., 2008). It is possible that the riders in this study who participate in resistance training may have a competitive edge over those who do not. This conclusion coincides with research demonstrating PO as a performance indicator in successful mountain bike riding (Baron, 2001; Gregory et al., 2007; Impellizzeri, Marcora, et al., 2005; Impellizzeri, Rampinini, et al., 2005).

Practical Applications

The popularity of mountain biking has increased steadily over the past 10 years, and the number of competitive mountain bikers increases on a yearly basis (International Mountain Biking Association; 2010). High physical conditioning is essential in performing well within the sport. As important as the training component is, very little was known as to how competitive mountain biker's train in an effort to enhance performance. Each discipline within the sport requires varying physical demands, and training should be specific to those demands. By having a better understanding of how and how often riders are training, program design can become more specific to meet the demands of riding. It appears that trail riding is the most popular modality of riding for endurance and interval training. If trail riding is an activity riders enjoy as part of the sport, then program design should focus on training techniques that can be implemented outside on a trail.

In an exercise laboratory, resistance and intensity can be increased by the push of a button or the turn of a knob, but on a trail, these factors are either increased by the gear ratio of the bike or the incline of the terrain. As mentioned earlier, the intensity of a workload must be consistent in order to optimize the physiological adaptations. Educating riders on how to maintain consistent intensity of exercise while riding on a trail may be crucial if they are going to get the maximum benefits from training. For example, it may be important to educate riders on the selection of proper gear ratios that will maintain intensity of exercise regardless of the terrain. During a race or competition, a rider selects a gear ratio that makes it easier to navigate the terrain; however, from a training perspective, the reciprocal holds true. Riders should select gears that make the terrain more difficult to maneuver, thus providing a greater stimulus for physiological adaptations. The greatest application of the aforementioned results lies in creating sport specific training programs for trail riding.

Conclusion

For the purposes of the present study, frequencies, durations, and modalities of exercise training among competitive mountain bikers were assessed. Results suggest that riders are participating in training modalities shown to increase physiological markers associated with successful mountain bike riding. Additionally, a majority of riders are adhering to the recommendations of workout frequency, as well as the recommended duration of these workout sessions. For a rider to be successful on the trail, it is important that training focuses on increasing both aerobic and anaerobic capacities. Creating sport specific training programs for the trail should implement a method of training riders enjoy but be balanced with optimizing training adaptations.

Limitations and Future Considerations

The main limitation of the present study is the lack of assessment for the intensity of exercise performed. Without the assessment of intensity, it is difficult to determine whether riders are training at the intensity needed to gain the aforementioned training effects and if they are incorporating enough time for adequate recovery between sessions of exercise training. High-intensity exercise is considered vigorous in nature (McArdle et al., 2007; Harris & Dudley, 2000; Potteiger, 2000), and research has demonstrated that participants completing a survey regarding exercise tend to over-report vigorous exercise (Mader, Martin, Schutz, & Bernard, 2006; Rzewnicki, Auweele, & DeBourdeaudhuji, 2003). For the purposes of the present study, the assessment of intensity may not have produced meaningful results.

Therefore, future research should consider assessing the intensity of exercise among competitive mountain bikers. While the current study assessed the days of recovery between sessions of HIIT, it did not assess recovery between sessions of endurance and resistance training. Findings from this study suggest that a majority of riders are incorporating multiple modalities of training; therefore, examining recovery would provide insight as to whether or not riders are allowing enough time to recover from sessions of exercise training. If riders are not allowing enough time for recovery, overtraining is a distinct possibility, and overtraining has been associated with decreases in athletic performance (Brooks et al., 200; McArdle et al., 2007; Wilmore et al., 2008). Along with findings from the present study, future research in the aforementioned areas can create better insight into the application of training principles oriented towards meeting the physical demands of mountain biking, as well as ensuring an adequate state of recovery among riders.

Another limitation for the present study is the small sample size. As a result, it is difficult to generalize these findings to the estimated 315 potential competitive mountain bike riders in the United States. Additionally, the targeted population for the present study was a homogeneous group of competitive mountain bikers. Results from this study cannot be applied to recreational mountain bikers. Future research could examine if recreational riders participate in similar modalities of exercise in an effort to improve their mountain biking performance.

Finally, results from the present study showed that 57.50% of the riders surveyed listed their coach as the source for their training regimens. Future research should consider lines of study aimed at increasing training knowledge among coaches, as this knowledge will most likely be passed along to the riders.

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Appendix 1

Letters of Recruitment

Greetings:
We are writing to invite you and your teammates to take part in a study entitled "Assessing Various Types of Training Among Competitive Mountain Bikers." This study is being conducted by Shawn Mitchell at the University of Alabama's Department of Kinesiology. Your contact information was obtained on-line through your public race website. Please consider passing this along to your teammates. The link for the survey is https://vovici.com/wsb.dll/s/1300fg4dc01

For this study, we will be assessing the various types of exercise training competitive mountain bikers use in an effort to increase their riding performance. We are aware that certain training modalities can offer a competitive advantage. Therefore, at no time will the survey identify riders, and rider competitive rank will not be asked. Participation in this online survey is anonymous.

If you choose to participate in the study, you will be asked to take part in a single one-time 20-minute online survey. The survey will be administered through the Vovici online survey provider. During the survey, you will be asked to identify specific types of training you use during the off- and competitive- seasons, as well as how much time you spend using your selected types of training.

There will be no direct benefit to you as an athlete, but participation will help in the understanding of training methods among competitive mountain bikers. Our goal with this training assessment is to provide insight into current training modalities among competitive mountain bikers, as well as provide possible implications for new and innovative sport specific training targeted towards mountain bikers.

If you would like more information regarding this study, please call myself at 615-968-7091 or Dr. John Higginbotham at 205-348-0025. If you have questions regarding your rights as a person in a research study, please feel free to contact Tanta Myles, the Research Compliance Officer at the University of Alabama, at 205-348-8461 or toll free at 1-877-820-3066. Agreement to be contacted or a request for more information does not obligate you to participate in this study.

Again, the survey link is https://vovici.com/wsb.dll/s/1300fg4dc01

Thank you for your time, and have a great day.
Sincerely,

Shawn Mitchell, MA, MS, CSCS
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The University of Alabama
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smmitchell1@crimson.ua.edu

Greetings:
We are writing to invite your athletes to take part in a study entitled "Assessing Various Types of Training Among Competitive Mountain Bikers." This study is being conducted by Shawn Mitchell at the University of Alabama's Department of Kinesiology. Your contact information was obtained on-line through your public race website. We understand that you are a coach and have access to the population we are seeking for our study. Please consider passing this along to your athletes. The weblink for the survey is https://vovici.com/wsb.dll/s/1300fg4dc01

For this study, we will be assessing the various types of exercise training competitive mountain bikers use in an effort to increase their riding performance. We are aware that certain training modalities can offer a competitive advantage. Therefore, at no time will the survey identify riders, and rider's competitive rank will not be asked. Participation in this online survey is anonymous.

If your athletes choose to participate in the study, they will be asked to take part in a single one-time 20-minute online survey. The survey will be administered through the Vovici online survey provider. During the survey, they will be asked to identify specific types of training they use during the off- and competitive- seasons, as well as how much time they spend using their selected types of training.

There will be no direct benefit to your athletes, but participation will help in the understanding of training methods among competitive mountain bikers. Our goal with this training assessment is to provide insight into current training modalities among competitive mountain bikers, as well as provide possible implications for new and innovative sport specific training targeted towards mountain bikers.

If you would like more information regarding this study, please call myself at 615-968-7091 or Dr. John Higginbotham at 205-348-0025. If you have questions regarding your rights as a person in a research study, please feel free to contact Tanta Myles, the Research Compliance Officer at the University of Alabama, at 205-348-8461 or toll free at 1-877-820-3066. Agreement to be contacted or a request for more information does not obligate you to participate in this study.

Again, the survey link is https://vovici.com/wsb.dll/s/1300fg4dc01

Thank you for your time, and have a great day.
Sincerely,

Shawn Mitchell, MA, MS, CSCS
Doctoral Candidate
The University of Alabama
Department of Kinesiology
smmitchell1@crimson.ua.edu

Appendix 2

Survey Instrument

Mountain Bike Training Assessment

Letter of Consent

Shawn Mitchell, from the University of Alabama, is conducting a study called "Assessing Various Types of Training Among Competitive Mountain Bikers." He wishes to find out the types of training you use to improve your mountain bike riding and how much time you spend using the types of training you selected (IRB# EX-11-CM-096).

Taking part in this study involves completing a one-time web survey. The survey will be given through an online website. You will be given instructions that will guide you through the survey. The survey will take about 20 minutes to complete. This survey contains questions about the types of training you use to improve your mountain bike riding and how much time you spend using these types of training.

We will keep your answers completely anonymous. We will not ask any questions that will identify you as a rider. Your competitive rank will not be asked. Only members of the research team, Shawn Mitchell, Drs. Higginbotham and Richardson, and Ms. Randi Henderson, will have access to the data. The online survey is on a secured website. The data will be entered into a password protected computer. Only summary data will be presented at meetings or in publications.

The direct benefits to you as result of taking part in this study are limited. We hope to use all the information to help create sport specific training programs. It is also hoped that these programs can help mountain bikers train more effectively. These programs can also focus on factors that assist riding within the sport.

Risks to you for taking part in this study are low. The chief risk is that some of the questions may make you uneasy. You may skip any questions you do not want to answer.

If you have questions about this study, please contact Shawn Mitchell at 615-968-7091 or by email at smmitchell1@crimson.ua.edu. If you have questions about your rights as a research participant, contact the University Institutional Review Board at (205) 348-8461 or Tanta Myles, the Research Compliance Officer at the University of Alabama, at 205-348-8461 or toll free at 1-877-820-3066. After you participate in this study, you may choose to complete the UA IRB survey for research participants by contacting Shawn Mitchell for a copy, or you may e-mail us at participantoutreach@bama.ua.edu.

It is up to you if you want to take part in this study. You are free not to take part or stop taking part in this study at any time before you submit your answers.

If you understand the statements above, are at least 19 years old, and freely consent to be in this study, click on the "I Consent" button to begin.

Sincerely,
Shawn Mitchell, MA, MS, CSCS
Doctoral Candidate in Exercise Science
The University of Alabama
Department of Kinesiology

1) I have read this consent document. I understand its contents and freely consent to participate in this study under the conditions described.

☐ I Consent
☐ I Do Not Consent

2) **What is your gender?**

☐Female
☐Male

3) **What is your age?**

____

4) **What type of mountain biker are you?**

☐Recreational/Non-Competitive (someone who rides 1-3 times per week at a moderate intensity without the goal of high-level competitive results)
☐Competitive (riders pursuing a race schedule and seek to maximize their physiological development to reach higher competitive levels)

5) **Please choose the appropriate competitive level**

☐Intercollegiate Team (classified as a NCAA team through a university)
☐Sports Club (competitive team through a university)
☐Individual (not affiliated with a team but still pursue competitive racing schedule and somehow ranked against other riders)
☐Team (affiliated with a team outside a collegiate setting. For example, local team chapters or teams)
☐Other (please specify)

If you selected other, please specify ____

6) **How many years have you been a competitive mountain bike rider?**

____

7) **How many race/competitions do you typically participate in a year?**

____

8) **Please select all the disciplines of mountain biking in which you participate as a race competitor.**

☐Cross-Country (involves ascending and descending rides through technical terrain, with rides usually lasting 1-6 hours)
☐Downhill (solely focused on descendig trails as fast as possible, with rides typically lasting 4-6 minutes)
☐Freeride (involves large jumps and drops, often man made, and can take place on or off he trail)
☐Super D (best characterized as a downhill cross-country race. Combines elements of downhill racing with climbing and pedaling over technical terrain)

Please answer the following questions in regard to your <u>IN-SEASON.</u>

9) **How many months out of the 12 month year is your in-season/competition season?**

____

10) **Do you resistance train during the in-season to increase your mountain biking performance? (Resistance training is defined as the specialized method of conditioning that involves the progressive**

use of resistance to increase one's ability to exert or resist force and can include the use of dumbbells, barbells, machines, kettlebells, or bodyweight)

☐Yes
☐No

Please answer the following questions in regard to your <u>IN-SEASON.</u>

11) How many weeks do you typically resistance train?

____

12) How many workout sessions per week do you typically resistance train?

____

13) How many minutes per workout session do you typically resistance train?

____

14) How many workout sessions per week do you typically include upper body exercises?

____

15) How many upper-body exercises do you typically perform per workout session?

____

16) In a typical week, what upper body muscle groups do you predominantly train in your workout sessions?

☐Chest
☐Back
☐Shoulders
☐Core (For example, low back, obliques, and abdominals)
☐Biceps
☐Triceps

17) How many workout sessions per week do you typically include lower body exercises?

____

18) How many lower-body exercises do you typically perform per workout session?

____

19) In a typical week, what lower body muscle groups do you predominantly train in your workout sessions?

☐Quadriceps
☐Hamstrings
☐Calves

20) Overall, when resistance training, do you typically perform exercise movements at a slow tempo (e.g., concentrating on lifting the weight in a slow controlled manner) or a high-explosive tempo (e.g.,

focus is on speed and velocity)?

☐Slow tempo
☐High-explosive

Please answer the following questions in regard to your <u>IN-SEASON.</u>

21) In an effort to increase your mountain biking performance, do you participate in traditional aerobic/endurance training, excluding interval training. (Aerobic/Endurance exercise is characterized by extended exercise durations incorporating large muscle groups. Examples of aerobic exercise include but are not limited to 1) cycling, 2) running, 3) swimming, and 4) and cross-country skiing)

☐Yes
☐No

Please answer the following questions in regard to your <u>IN-SEASON.</u>

22) How many weeks do you typically aerobic/endurance train?

____

23) How many workout sessions per week do you typically perform aerobic/endurance exercise?

____

24) How many minutes per workout session do you typically perform aerobic/endurance exercise?

____

25) How many workouts per week do you typically trail ride for aerobic/endurance training purposes?

____

26) How many minutes per workout session do you typically trail ride for aerobic/endurance training purposes?

____

27) How many workouts per week do you typically ride a cycle ergometer (i.e., stationary bike) for aerobic/endurance training purposes?

____

28) How many minutes per workout session do you typically ride a cycle ergometer (i.e., stationary bike) for aerobic/endurance training purposes?

____

Please answer the following questions in regard to your <u>IN-SEASON.</u>

29) In an effort to increase your mountain biking performance, do you participate in interval/intermittent training during your in-season? (Interval/intermittent exercise is characterized

by bouts of brief, moderate to high-intensity, interval type exercise. Bouts are separated by recovery periods (e.g., 1-8 minutes) during the exercise session and then repeated in cycles.)

☐Yes
☐No

Please answer the following questions in regard to your <u>IN-SEASON.</u>

30) How many weeks do you typically interval train?

____

31) How many workout sessions per week do you typically perform interval/intermittent exercise?

____

32) Typically, when people perform interval exercise, they will then perform work at a vigorous level, followed by a short period of rest or work at a lower intensity level. Then repeat this cycle in an interval fashion. This is referred to as a work:rest ratio. For example, a 1:1 work:rest ratio would be 30 seconds of vigorous work, followed by 30 seconds of rest or work at a lower intensity level. A work:rest ratio of 1:2 would be 30 seconds of vigorous work, followed by 60 seconds of rest or work at a lower intensity level. For you, what is your typical work:rest ratio?

Work Duration _______________________
Rest Duration _______________________

33) When you perform interval training, how many days of rest do you take between sessions of interval exercise. For example, you may perform interval exercise on Monday and then wait again until Thursday to perform interval exercise. For you, what is your typical number of days of rest between sessions of interval exercise?

____

34) How many workout sessions per week do you typically perform interval exercise on a trail for training purposes?

____

35) How many minutes per workout session do you typically perform interval exercise on a trail for training purposes?

____

36) How many workout sessions per week do you typically perform interval exercise on a cycle ergometer (i.e., stationary bike) training purposes?

____

37) How many minutes per workout session do you typically perform interval exercise on a cycle ergometer (i.e., stationary bike) training purposes?

____

Please answer the following questions in regard to your <u>OFF-SEASON.</u>

38) How many months out of the 12 month year is your off-season/non-competition season?

____

39) Do you resistance train during the off-season to increase your mountain biking performance? (Resistance training is defined as the specialized method of conditioning that involves the progressive use of resistance to increase one's ability to exert or resist force and can include the use of dumbbells, barbells, machines, kettlebells, or bodyweight)

- ☐Yes
- ☐No

Please answer the following questions in regard to your <u>OFF-SEASON.</u>

40) How many weeks do you typically resistance train?

____

41) How many workout sessions per week do you typically resistance train?

____

42) How many minutes per workout session do you typically resistance train?

____

43) How many workout sessions per week do you typically include upper body exercises?

____

44) How many upper-body exercises do you typically perform per workout session?

____

45) In a typical week, what upper body muscle groups do you predominantly train in your workout sessions?

- ☐Chest
- ☐Back
- ☐Shoulders
- ☐Core (For example, low back, obliques, and abdominals)
- ☐Biceps
- ☐Triceps

46) How many workout sessions per week do you typically include lower body exercises?

____

47) How many lower-body exercises do you typically perform per workout session?

____

48) In a typical week, what lower body muscle groups do you predominantly train in your workout

sessions?

☐Quadriceps
☐Hamstrings
☐Calves

49) Overall, when resistance training, do you typically perform exercise movements at a slow tempo (e.g., concentrating on lifting the weight in a slow controlled manner) or a high-explosive tempo (e.g., focus is on speed and velocity)?

☐Slow tempo
☐High-explosive

Please answer the following questions in regard to your <u>OFF-SEASON.</u>

50) In an effort to increase your mountain biking performance, do you participate in traditional aerobic/endurance training, excluding interval training. (Aerobic/Endurance exercise is characterized by extended exercise durations incorporating large muscle groups. Examples of aerobic exercise include but are not limited to 1) cycling, 2) running, 3) swimming, and 4) and cross-country skiing)

☐Yes
☐No

Please answer the following questions in regard to your <u>OFF-SEASON.</u>

51) How many weeks do you typically aerobic/endurance train?

____

52) How many workout sessions per week do you typically perform aerobic/endurance exercise?

____

53) How many minutes per workout session do you typically perform aerobic/endurance exercise?

____

54) How many workouts per week do you typically trail ride for aerobic/endurance training purposes?

____

55) How many minutes per workout session do you typically trail ride for aerobic/endurance training purposes?

____

56) How many workouts per week do you typically ride a cycle ergometer (i.e., stationary bike) for aerobic/endurance training purposes?

____

57) How many minutes per workout session do you typically ride a cycle ergometer (i.e., stationary bike) for aerobic/endurance training purposes?

____

Please answer the following questions in regard to your <u>OFF-SEASON.</u>

58) In an effort to increase your mountain biking performance, do you participate in interval/intermittent training during your off-season? (Interval/intermittent exercise is characterized by bouts of brief, moderate to high-intensity, interval type exercise. Bouts are separated by recovery periods (e.g., 1-8 minutes) during the exercise session and then repeated in cycles.)

☐Yes
☐No

Please answer the following questions in regard to your <u>OFF-SEASON.</u>

59) How many weeks do you typically interval train?

____

60) How many workout sessions per week do you typically perform interval/intermittent exercise?

____

61) Typically, when people perform interval exercise, they will then perform work at a vigorous level, followed by a short period of rest or work at a lower intensity level. Then repeat this cycle in an interval fashion. This is referred to as a work:rest ratio. For example, a 1:1 work:rest ratio would be 30 seconds of vigorous work, followed by 30 seconds of rest or work at a lower intensity level. A work:rest ratio of 1:2 would be 30 seconds of vigorous work, followed by 60 seconds of rest or work at a lower intensity level. For you, what is your typical work:rest ratio?

Work Duration ____________________
Rest Duration ____________________

62) When you perform interval training, how many days of rest do you take between sessions of interval exercise. For example, you may perform interval exercise on Monday and then wait again until Thursday to perform interval exercise. For you, what is your typical number of days of rest between sessions of interval exercise?

____

63) How many workout sessions per week do you typically perform interval exercise on a trail for training purposes?

____

64) How many minutes per workout session do you typically perform interval exercise on a trail for training purposes?

____

65) How many workout sessions per week do you typically perform interval exercise on a cycle ergometer (i.e., stationary bike) training purposes?

____

66) How many minutes per workout session do you typically perform interval exercise on a cycle ergometer (i.e., stationary bike) training purposes?

____

67) Predominantly, where do you get your mountain bike training information?

☐Coach
☐Mountain Bike Magazines
☐General Fitness Magazines
☐Peer-reviewed scientific literature
☐Online sources
☐Other (please specify)

If you selected other, please specify ____

The survey is complete. Thank you for your participation.

Appendix 3

IRB Certificate

Office for Research

Institutional Review Board for the Protection of Human Subjects

THE UNIVERSITY OF
ALABAMA
RESEARCH

November 30, 201 !

Shawn Mitchell
Department of Kinesiology
College of Education
Box 870312

Re: IRB #: EX-11-CM-096, "Assessing Various Types of Training Amor g Competitive Mountain Bikers"

Dear Mr. Mitche l:

The University of Alabama Institutional Review Board has granted approval for your proposed research.

Your application has been given exempt approval according to 45 CFR part 46.101(b)(2) as outlined below:

(2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

This approval expires on November 29, 2012. If the study continues beyond that date, you must complete the appropriate portion of the Continuing Review Form. If you modify the application, please complete the Modification of an Approved Protocol Form. Changes in this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants. When the study closes, please complete the appropriate Closure form.

Should you need to submit any further correspondence regarding this application, please include the assigned IRB application number.

Good luck with your research.

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