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Exercise Intensity and Performance Aspects of Snow Biking through the Use of a Fat Bike

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EXERCISE INTENSITY AND PERFORMANCE ASPECTS OF SNOW BIKING THROUGH THE USE OF A FAT BIKE

By

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ABSTRACT

EXERCISE INTENSITY AND PERFORMANCE ASPECTS OF SNOW BIKING THROUGH THE USE OF A FAT BIKE

By

Kevin C. Phillips

The aim of this study was to quantify, describe, and compare the exercise intensity and performance aspects of riding a fat bike, in a time trial (TT) format, on a natural earthen trail (ET) vs. on a groomed snow trail (ST). Eleven subjects, nine males and two females, participated in this two part study. Heart rate (HR) was used to quantify exercise intensity, examining average heart rate (HR_{avg}), and peak heart rate (HR_{peak}). In addition, a global positioning system (GPS) watch was used to assess time to complete the trail, average speed ($speed_{avg}$), and max speed ($speed_{max}$). Immediately following completion of each ride, measures of post ride blood lactate (BL) concentrations were taken. Lastly, participants' reported their rating of perceived exertion (RPE). Results of this study showed that time to complete the trail was significantly ($P < 0.05$) shorter on the ET. $Speed_{avg}$ and $speed_{max}$ were significantly faster on the ET. Post ride BL concentrations were significantly higher after completion of the ET. However, no significant differences were noted between HR_{avg}, HR_{peak}, or RPE between field tests. This study shows that, although time to complete the trail was significantly shorter during the ET ride, and the participants' speeds were significantly slower on the ST, riding a fat bike on a ST can be completed at a very high exercise intensity. The HR response observed suggests potential for similar aerobic training adaptations with ST vs. ET riding.

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Lastly, I would like to thank the participants’ who gave their time to take part in this study. Without their participation, this study would not have been possible.

PREFACE

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CHAPTER I – Manuscript in Journal of Sports Sciences (JSS) Format

INTRODUCTION

Mountain biking is an outdoor, recreational, and competitive sport. It gained international recognition from the Union Cycliste Internationale in 1990 (Union Cycliste Internationale, 2014) and became an Olympic sport in 1996 (Olympic MTB, 2014). A variety of studies have examined the exercise intensity profile of the sport and showed that participants endure high physiological demands that are associated with beneficial effects on health related fitness.

The exercise intensity profile of the traditional form of mountain biking, cross-country (XC) style riding, has been examined under time trial (TT) and competition conditions by a number of authors (Gregory, Johns, & Walls, 2007; Impellizzeri, 2005; Impellizzeri, Rampinini, Sassi, Mognoni, & Marcora, 2005a; Impellizzeri, Sassi, Rodriguez-Alonso, Mognoni, & Marcora, 2002; Stapelfeldt, Schwirtz, Schumacher, & Hillebrecht, 2004). These studies used heart rate (HR) as a means of quantifying and describing the exercise intensity of high level XC mountain bike competitors. This discipline of riding has been consistently shown to be completed at a vigorous intensity of ≥ 90 % of maximum HR (HR_{max}).

The exercise intensity profile of downhill (DH) style riding, a sub-discipline of mountain biking, has also been examined. Although much shorter in duration than the XC competitions or TTs examined, DH mountain biking is also completed at a high exercise intensity of ≥ 80 % HR_{max} (Burr, Drury, Ivey, & Warburton, 2012; Chidley, MacGregor, Martin, Arthur, & Macdonald, 2014; Hurst et al., 2013; Sperlich et al., 2012). However, the authors noted that using HR to monitor exercise intensity during DH style riding may not be accurate due to activation of the sympathetic nervous system, due to nervousness and excitement, along with isometric contractions throughout the body, resulting in increased HRs not indicative of endurance or XC riding.

In recent years, fat bikes have become a popular option for mountain bikers. A fat bike is a mountain bike equipped with tires ranging from 9.3 – 10.1 cm wide, twice as wide as a traditional mountain bike tire (Barber, 2014). This allows them to be ridden at an inflation pressure as low as 27579 Pascal (4 PSI). The wide surface area, and low inflation pressure, of these tires allows for excellent handling of the bicycle while riding over sand, mud, and snow. It is difficult, if not impossible, for a traditional mountain bike to ride over such surfaces.

Snow biking in particular, has grown to become the most popular style of riding a fat bike, especially in areas that receive significant amounts of snow (Barber, 2014). For example, snow biking races are now held in the USA and community trail networks are grooming snow biking trails specifically for the use of fat bikes (Great Lakes Fatbike Series, 2014).

Despite this growing popularity, there is no published research on riding a fat bike on an earthen trail (ET) or snow trail (ST) to date. It seems pertinent to understand the exercise-intensity profile of this mountain biking sub-discipline. This information could prove useful to competitive mountain bikers looking to maintain or improve their physical fitness, as well as technical ability, during the winter months. Therefore, the aim of this study was to quantify, describe, and compare the exercise intensity and performance aspects of riding a fat bike, in a TT format, on an ET vs. on a groomed ST.

Importantly, the term snow bike and fat bike are sometimes used interchangeably. For this study, snow biking will describe the sport and fat bike will describe the bike used.

METHODS

A total of 11 mountain bike riders, nine males and two females, participated in this two part study. Participants with ≥ 2 years of mountain bike riding experience were sought for this study. This research was approved by the Institutional Review Board to use human subjects in research. Signed informed consent was obtained from all participants following both written and verbal explanation of procedures. Prior to participation, all volunteers were pre-screened for safe exercise participation using the Physical Activity Readiness Questionnaire (PAR-Q).

Each participant completed two baseline laboratory tests during this study. Each baseline test was completed within two weeks of the corresponding ET and ST field test in order to provide a physiological profile of the athlete and allow for comparisons between field and baseline tests. Participants' reported a mean age of 23.6 ± 2.5 years at the time of the first baseline test. Mean height of the participants' was 179.1 ± 8.9 cm and remained unchanged between baseline tests. Participants mass was 74.0 ± 9.1 kg vs 76.2 ± 9.9 kg, during the ET and ST baseline test, respectively. A HR monitor (H3; Polar Electro, Kempele, Finland) was worn for both baseline and field testing. Participants were urged to adjust the seat and handlebar height to their preference on a Lode mechanically braked cycle ergometer (Groningen, Netherlands) which was used for all baseline tests.

A 10 minute warm up at a self-selected pace was completed by all participants, followed by five minutes of rest before beginning a lactate threshold (LT) test. For this test, all participants' were instructed to maintain a self-selected pedaling pace > 60 revolutions per minute (RPM) for the duration of the test. The initial resistance started at 100 watts (W) for females and 150 W for males. Resistance was increased every three minutes by 25 W for females and 30 W for males. Participants' LT was defined as the highest intensity achieved with less than a 1.0 $mmol \cdot L^{-1}$ increase in blood lactate (BL) concentration above the previous intensity, follow by subsequent increases of 1.0 $mmol \cdot L^{-1}$ or greater with increase in workrate. Power output (PO), BL, and HR were assessed during the last 15 seconds of each 3 minute stage. These variables were recorded at each participant's LT and used for comparison between field and baseline tests.

Following a 10 minute rest, participants' completed a maximal oxygen consumption ($\dot{V}O_{2max}$) test. Expired respiratory gases were measured using a breath by-breath automated gas-analysis system (Vmax29, Sensor-Medics, Yorba Linda, CA). An incremental ramp protocol was used for this test. The initial resistance started at 0 W and continually increased by 50 W and 83 W, per minute, for females and males, respectively. The test was completed when participants' reached volitional fatigue or were unable to maintain a cadence of ≥ 60 RPM. The highest W achieved during this test was considered the participants' peak power output (PPO). HR, PO, oxygen consumption ($\dot{V}O_2$), and pedal cadence were monitored throughout testing.

A medium or large frame Mukluk 3 (Salsa Cycles, Bloomington, Minnesota, USA) fat bike was used by participants based on their body height and preference. The fat bikes used had a rigid frame, meaning there was no suspension system. The medium frame was 43.18 cm while the large was 48.26 cm. Both fat bikes were equipped with the Surley Nate tire which is 66.04 cm tall by 10.16 cm wide. The tires were kept at an inflation pressure of 55158 Pascal (8 PSI) on the ET and 27579 Pascal (4 PSI) on the ST. The lower inflation pressure used on the ST was meant to increase the contact area of the tire on the snow, resulting in more traction. This inflation pressure was also suggested by local bike shop experts for the terrain conditions. The fat bikes were equipped with all of the same components and weighted before testing. The medium and large fat bike weighted 16.00 and 16.11 kg, respectively.

The ET and ST field tests were separated by approximately 5 months. During the ET field test, participants rode a fat bike on a XC trail, composed of dirt, packed-sand, rocks, leaves, and tree roots. ET field testing was completed over four different days with temperatures ranging from 4.4 ºC to 12.7 ºC with an average temperature of 8 ºC. During the ST field test, participants rode the same fat bike on the same trail. A snowmobile equipped with a modified grooming device, similar to a cross country ski trail groomer, provided a packed, and groomed ST. ST field testing was completed over two consecutive days with temperatures ranging from -6 ºC to -2 ºC with an average temperature of –3 ºC. Warmer temperatures leading up to the ST field test caused the ST to melt and re-freeze. Participants' described the ST as hard packed, but not icy. The ST surface remained stable with no additional snow or melting during the ST field test. The trail was 6 km long and included approximately 130 meters of climbing and 120 meters of descending.

All participants were familiar with the test trail. After arriving at the trail location, participants' completed a 15 minute warm-up ride to allow for familiarization with the fat bike. After the warm-up, participants rested for five minutes and were allowed to make final adjustments to the fat bike or clothing they were wearing. All participants were required to wear a helmet. Additionally, during the ST field test, gloves and appropriate clothing were required.

Participants completed each field test in a TT format. This meant completing the trail as fast as possible, while maintaining safety. HR was used to quantify exercise intensity, examining average heart rate (HR_{avg}), and peak heart rate (HR_{peak}). In addition, a global positioning system (GPS) watch (RC3 GPS, Polar Electro, Kempele, Finland) was used to assess time to complete the trail, average speed ($speed_{avg}$), and max speed ($speed_{max}$). Immediately following completion of each ride, measures of post ride BL were taken. Lastly, participants reported their average rating of perceived exertion (RPE) in relation to the trail conditions, using a 1-10 scale.

Descriptive data were determined using the SPSS statistical software package (Version 21). A paired *t* test was used to compare variables between field conditions, including, time to complete the trail, $speed_{avg}$, $speed_{max}$, HR_{avg}, HR_{peak}, post ride BL, and RPE. A paired *t* test was also used to examine changes in the participant's physical fitness between testing sessions. Baseline variables included $\dot{V}O_{2max}$, maximum HR (HR_{max}), PPO, BL at LT, PO at LT, HR at LT, and RPE at LT. All data are presented as mean ± standard deviation (SD). The level of statistical significance was set at $P < 0.05$.

RESULTS

Results of the ET and ST baseline laboratory testing sessions are shown and compared in Table 1. Significant differences were noted for body mass, $\dot{V}O_{2max}$, and PO at LT, between testing sessions. Descriptive data for the ET and ST field tests are shown and compared in Table 2. Significant differences were noted between temperature, time to complete the trail, BL, $speed_{avg}$, and $speed_{max}$.

DISCUSSION

To our knowledge, this is the first study to describe and compare the exercise intensity and performance aspects of riding a fat bike on an ET vs. a ST. When examining performance variables, time to complete the trail was significantly faster (P = 0.00) during the ET field test compared to the ST field test with a mean time to complete of 21:23 ± 2:10 and 29:11 ± 4:09, respectively. Additionally, $speed_{avg}$ (17.0 ± 1.6 km/hour vs. 12.5 ± 1.9 km/hour) and $speed_{max}$ (40.4 ± 4.6 km/hour vs. 33.1 ± 6.3 km/hour) were significantly faster (P = 0.00) on the ET vs. the ST, respectively. The participants in this study were all recreationally trained mountain bikers. Although their mean $\dot{V}O_{2max}$ was much lower than those of elite XC mountain bikers examined by Impellizzeri et al. (2002), the $\dot{V}O_{2max}$ of participants in the current study are similar to those of amateur mountain bikers (Berry, Woodward, Dunn, Edwards, & Pittman, 1993; MacRae, Hise, & Allen, 2000; Vaitkevičiūtė & Milašius, 2012). A limitation of the current study, though, is that $\dot{V}O_{2max}$ significantly declined when tested during the ST baseline test. Participants' mean $\dot{V}O_{2max}$ measured during the ET baseline was 4.47 ± .88 $L \cdot min^{-1}$ vs. 4.25 ± .76 $L \cdot min^{-1}$ (P = 0.04) during the ST baseline test. Relative to body weight, the mean $\dot{V}O_{2max}$ during the ET baseline was 60.2 ± 7.1 $mL \cdot kg^{-1} \cdot min^{-1}$ vs. 55.7 ± 7.0 $mL \cdot kg^{-1} \cdot min^{-1}$ (P = 0.00) during the ST baseline test. This is important to note because Impellizzeri et al. (2005a) showed that, in a heterogeneous group of riders, maximal aerobic power and capacity normalized to body mass explained about 80% of the variance affecting off-road performance. In contrast, Impellizzeri et al. (2005b) found no correlation between maximal aerobic power and performance in a homogenous group of elite XC mountain bikers. Therefore, the performance of the heterogeneous group of amateur mountain bikers examined in the present study, was likely affected, in part, by the significant decrease in $\dot{V}O_{2max}$ between field tests.

Although all participants were avid mountain bikers, not all of the participants had experience with snow biking, and reported not cycling as frequently leading up to the ST field test. This may have contributed to the significant decrease in PO at the participants' LT between baseline tests (231 ± 51 W vs. 212 ± 48 W, $P = 0.04$). If the participants' were not able to maintain the same PO as during the ET field test, this may have also contributed to slower completion of the trail during the ST field test. However, PPO was not significantly different between baseline tests.

Even though mountain biking and snow biking are similar, the current researchers believe that the composition of the ST may have been more difficult to maintain the same speed on as the ET. The groomed ST was composed of a narrow single-track trail, measuring approximately 60 cm wide throughout the trail. Whereas the ET contained both single and double-track trail sections. The wider double-track trail found in some areas on the ET may have allowed more room for error in relation to steering, resulting in faster speeds. Nonetheless, on the ST, participants averaged 74% of the $speed_{avg}$, and 82% of the $speed_{max}$, measured on the ET.

When examining physiological variables, the mean HR_{max} recorded during the ET (190 ± 6 $beats \cdot min^{-1}$) and ST (191 ± 7 $beats \cdot min^{-1}$) baseline laboratory testing sessions were not significantly different. Therefore, we chose to calculate exercise intensity during field testing sessions as a percentage of the HR_{max} observed in the lab (% HR_{max}*Lab*). During the ET field test, participants' HR_{avg} was 176 ± 9 corresponding to 92.5 ± 4.7% HR_{max}*Lab*. During the ST field test, participants' HR_{avg} was 175 ± 15 corresponding to 92.2 ± 8.2% HR_{max}*Lab*. These data clearly show that riding a fat bike on both an ET and ST, in a TT format, can be completed at a very high exercise intensity. This exercise intensity is similar to those observed in elite cross-country mountain biking competitions lasting 147 ± 15 minutes, where the HR_{avg} of four competitions was 90 ± 3 % of HR_{max} (Impellizzeri et al., 2002). This exercise intensity is even higher than short duration road cycling TTs lasting 10 ± 2 minutes and 39 ± 11 minutes, corresponding to 89 ± 3% of HR_{max} and 85 ± 5% of HR_{max}, respectively (Padilla, Mujika, Orbañanos, & Angulo, 2000).

The observation of similar HR between field conditions is interesting and may be misleading. It has been shown that lower heart rates will be recorded for a standard exercise bout when undertaken in the cold as opposed to 20° C (Beelen & Sargeant, 1991; Febbraio, Snow, Stathis, Hargreaves, & Carey, 1996; Layden, Patterson, & Nimmo, 2002; Weller, Millard, Stroud, Greenhaff, & Macdonald, 1997). This is likely caused by the peripheral vasoconstriction associated with low skin temperatures in cold environments. This would shunt more blood to the central volume, increase venous return, increase stroke volume, and thus lower heart rate (Nimmo, 2004). However, this is unlikely, as all participants' during both field tests were dressed in appropriate clothing and described having a comfortable body temperature after completion of the ride. However, three participants' complained of having cold feet after completion of the ST field test.

Another reason for similar HR_{avg} between field tests may have been a higher contribution of isometric muscular activity on the ST. Similar to DH mountain biking, HRs have been suggested to be inflated due to a higher contribution of isometric muscular activity in order to control the bike (Burr et al., 2012; Hurst et al., 2013; Sperlich et al., 2012). Although grip strength or muscular activity differences were not observed in the present study, the current researchers believe that the composition of the ST may have caused apprehension in riders, resulting in increased isometric muscular contractions in order to control and stabilize the fat bike on the ST. Future studies should seek to quantify and compare muscular activity, strength changes, and apprehension between different surfaces such as an ET and a ST.

Another main finding of this study was significant differences in post ride BL concentrations. Although HR and RPE were similar between field tests, post ride BL concentrations were significantly lower during the ST field test. It may be possible that the longer duration of time to complete the ST, allowed more time for removal of BL. Another reason for lower BL concentrations during the ST field test may be explained by the cold environmental temperatures, which were, on average, – 3.7° C. Therminarias, Flore, Oddou-Chirpaz, Pellerei, and Quirion (1989) examined effects of acute exposure to cold on BL response during exercise. They used an incremental exercise protocol on a cycle ergometer at a moderate temperature of 24° C (MT) and cold temperature of – 2 ° C (CT). They showed that $\dot{V}O_2$ was higher during the CT compared to MT at rest and during nearly every exercise intensity. Additionally, they showed that the LT of participants, during CT, was significantly increased by 49% expressed as absolute $\dot{V}O_2$, and 27% expressed as exercise intensity as compared with MT. Blood lactate concentrations were shown to be higher at light intensities and lower at heavy exercise intensities during the CT compared to the MT. They also measured catecholamines and free fatty acids (FFA) during both conditions. Norepinephrine and FFA were greater in the CT compared to the MT. They suggested that the difference in FFA level suggests that alterations in fat metabolism, possibly initiated by enhanced secretions of norepinephrine, may have contributed to a decrease in BL production. However, results in this area are mixed as neither Starkie, Hargreaves, Lambert, Proietto, and Febbraio (1999) nor Febbraio et al. (1996) found differences in BL concentrations when exercising in the cold.

In conclusion, performance differences aside, the present study shows that snow biking through the use of a fat bike can be completed at a very high exercise intensity. The HR response suggests potential for similar aerobic training adaptations with ST vs. ET riding, however $\dot{V}O_2$ should be measured in future research to verify this. In a practical sense, competitive mountain bikers may use snow biking as a training method to maintain or improve aerobic fitness during winter months. Additionally, snow biking may help maintain or improve technical skills related to dynamic bike handling, whereas this is not conceivably possible through typical winter training methods completed on a stationary bicycle.

CHAPTER II – LITERATURE REVIEW

Overview of Snow Biking with a Fat Bike

Due to the novelty of snow biking through the use of a fat bike, there is no published research on the physiological demands or performance aspects of the sport. By reviewing existing literature on mountain biking and comparing the bikes, terrain, and environmental conditions, this review aims to determine the physiological and performance demands that a rider may experience when snow biking, riding a fat bike.

Cross-country Mountain Biking

Cross-country (XC) style riding is the traditional form of mountain biking defined by riding trails of varying technical difficulty through forest or mountainous terrain. Single-track or double-track trails, depending on the width of the path, are ridden. Trails consist of a mix of uphill, flat and downhill sections. XC riders normally use hard-tail bikes, which only have a front suspension system. Different aspects of XC riding have been investigated by a variety of studies.

Downhill Mountain Biking

Downhill (DH) mountain biking is another popular form of mountain biking defined by trails of steep terrain that includes man-made or natural jumps, vertical drops and banked corners known as berms, which help maintain speed. A shuttle vehicle or chairlifts typically transport riders to the top of the mountain. This results in trails consisting of mostly downhill terrain. DH riders typically use full suspension gravity bikes, which have front and rear suspension systems with a large amount of travel in order to absorb the rough terrain and drops.

Exercise Intensity Profile – Cross-country Mountain Biking

The exercise intensity profile of elite XC mountain bikers has been examined during competition (Impellizzeri et al., 2002). Heart rate (HR) was used to quantify exercise intensity during four international races. The average altitude climbed was 1,430m and the mean competition time was 147 minutes. They showed that exercise intensity during cross-country competitions are high, with 82% of total race time spent above the lactate threshold (LT). Also, the average HR (HR_{avg}) of the four competitions was 90 ± 3% of maximum heart rate (HR_{max}) that corresponded to 84 ± 3% of maximal oxygen consumption ($\dot{V}O_{2max}$).

Similarly, Stapelfeldt, Schwirtz, Schumacher, and Hillebrecht (2004) confirmed and extended the findings of (Impellizzeri et al., 2002) by measuring both HR and power output (PO) in elite cross-country mountain bikers over 15 races. During the races, HR_{avg} was 91% of HR_{max}, and mean PO was 246W or 3.5 W/kg. Additionally, high PO oscillations (69% coefficient of variation) were noted, indicating that cross-country events are high intensity activities characterized by intermittent effort.

Exercise Intensity Profile – Downhill Mountain Biking

Burr, Drury, Ivey, and Warburton (2012) have examined the physiological demands of a typical DH mountain bike ride. Experienced participants completed one self-selected DH trail. Riding oxygen consumption ($\dot{V}O_2$), grip strength, and HR were measured and compared with baseline VO_{2max} testing. After completion of the ride, substantial muscular fatigue was evident in grip strength, which decreased 5.4 ± 9.4 kg (5.5 ± 11.2%, p = 0.03) post-ride. The mean $\dot{V}O_2$ while riding was 23.1 ± 6.9 $ml \cdot kg^{-1} \cdot min^{-1}$ or 52 ± 14% of $\dot{V}O_{2max}$ with corresponding HRs of 146 ± 11 bpm (80 ± 6% HRmax). Interestingly, the participants' heart rates were inflated in comparison with the actual metabolic demands of the downhill ride. The authors suggested that the HR inflation observed could have been a result of isometric contractions necessary for DH riding, including hand grip contribution when controlling the handlebars, core stabilization (potential Valsalva maneuvers), and standing on the pedals. Therefore, they suggested that HR may not be a sufficient means of measuring exercise intensity in DH mountain biking.

Recently, Hurst et al. (2013) used an accelerometer and global positioning system (GPS) based approach to evaluate the activity profiles of DH mountain bikers. Elite participants performed single runs on one man-made (MM) and one natural terrain (NT) DH courses under race conditions. A 5 Hz global GPS unit, including a 100 Hz triaxial accelerometer were used. GPS was used to determine the temporal characteristics of each run for velocity, run time, distance, effort, heart rate (HR), rider load (RLd) which reflects instantaneous rate of change in acceleration, and accumulated rider load (RLdAcc), which reflects change in acceleration over the event duration. Significant differences were found between NT and MM courses for mean velocity (P = <.001), peak velocity (P = .014), mean RLd (P = .001) and peak RLd (P = .002). Significant differences were also found both within and between courses for all velocity parameters, when analyzed by intensity zone (P <.05). No significant differences were found between courses for HR parameters by zone, though significant differences were revealed between

HR zones within courses (*P* <.05). This study indicated that course terrain has a significant impact on the activity profiles of DH riding and that GPS can provide a practical means of monitoring these differences in activity. The following paragraphs provide a description of structural and component characteristics that a fat bike, XC, and DH mountain bike have and how their differences may alter physiological and performance demands while riding.

Bicycle Differences

A typical fat bike weighs approximately 14.5 kg (Barber, 2014). A light XC hard tail bike weights 9.5 kg, while a DH full suspension bike will weigh between 10.8 and 13.6 kg (Trombley, 2005). The increased weight of a fat bike comes from the extra width and diameter of the rims, tires, tubes, and frame. The wide variety of bike weights can be attributed to the materials used to make the bike frame and components. Therefore, it is likely that the heavier weight of a typical fat bike compared to other mountain bikes would result in an increased physiological demand for the rider. However, it should be noted that high-end carbon fiber fat bikes are now being sold at weights less than 10 kg (Borealis, n.d.).

Furthermore, the large tires and minimal tire inflation pressure used with a fat bike, in relation to a snow covered trail, need to be considered when examining the physiological and performance aspects of snow biking. A fat bike tire is typically 9.3 cm – 11.9 cm wide (Meiser, 2013) in comparison to an XC or DH tire width of 5 cm – 6 cm. Additionally, fat bikes typically use a tire pressure of less than 68947 Pascal (ten pounds per square inch (PSI)) (Meiser, 2013). This is much lower than the tire pressure used for XC or DH bikes, which is generally 172368.9323 - 206842.7187 pascal (25- 30 PSI). The low tire pressure of FB tires maximizes the surface contact area and raises the coefficient of friction. Therefore, these important characteristics may allow fat bike tires to gain more traction and control, especially on soft surfaces (Bertucci, Rogier, & Reiser, 2013). This tire advantage may decrease the physiological demands while riding a fat bike over soft surfaces in comparison to a XC or DH mountain bike.

The lack of a suspension system on most fat bikes is a third factor to consider when looking at physiological and performance aspects. Rough trail conditions are known to cause an increased demand on the upper body (Hurst et al., 2012), forearm musculature (Arpinar-Avsar, Birlik, Sezgin, & Soylu, 2013) and $\dot{V}O_2$ (Impellizzeri & Marcora, 2007). Suspension systems found on XC and DH mountain bikes absorb impact and help maintain tire to ground contact, allowing greater velocities to be achieved while the $\dot{V}O_2$ requirements (Berry et al., 1993), exercising HR, and muscular stress are decreased (Seifert, Luetkemeier, Spencer, Miller, & Burke, 1997). On the other hand, while snow biking, snow covers rocks and roots that a traditional mountain bike trail contains. Additionally, the large tires and low inflation pressure of fat bike tires creates a pneumatic suspension. Therefore, a fat bike typically lacks a suspension system. This could result in greater power output while riding a fat bike due to lack of “bobbing” or small oscillatory movements of the suspension. However, results are still mixed and require further research (Nielens & Lejeune, 2004). Next, environmental factors that may be experienced while snow biking will be described and how such conditions may affect neuromuscular function, power output, hydration and overall performance of the rider.

Environmental Factors

Snow biking takes place during winter months when environmental temperatures are generally subfreezing. Performance of moderate sustained exercise in cold conditions will have a variety of effects on the rider depending on the specific temperature. Faulkner et al. observed three participants in a 1979 ski marathon in which the temperature ranged from - 28 ºC to - 18 ºC (as cited in Nimmo, 2004). The skiers were operating at around 75% $\dot{V}O_{2max}$ for five to ten hours on each of the two days and were dressed in outdoor clothing. In 1979, only 6% of the skiers completed the race, compared with 29% in the previous year, because of the severe winter conditions. Many of the participants discontinued because of frostbite or discomfort. It was also suspected that muscle temperatures had dropped in spite of the relatively high exercise intensity. This would have directly affected the activity of muscle enzymes and neuromuscular recruitment. Subjective observations of uncoordinated movements of otherwise skilled skiers supported this otherwise unsubstantiated claim (as cited in Nimmo, 2004). Conditions and results may be similar in events like the Noquemanon World Championship Snow Bike Race held in Marquette, MI, USA (Noquemanon Trail Network, 2014). This is a 20K race, fat bike only, held during January when winter conditions are typically harsh.

Just as cold temperatures affect moderate sustained exercise, such temperatures also affect high intensity exercise. Bergh and Ekblom (1979) noted a negative change of 5.1% per ºC change in muscle temperature for sprinting on a cycle ergometer. Sprinting in snow biking is crucial for gaining speed and passing opponents during races. Thus, proper clothing is critical to prevent muscle cooling and subsequent decreases in performance while snow biking. Conversely, if the rider over-dresses, hyperthermia may lead to reduced muscle activation and power output (Abbiss et al., 2010). The proper choice of clothing while snow biking will depend on environmental factors such as temperature, precipitation, and wind along with the individual rider's anthropometry.

Another consideration for exercise in the cold is the risk of developing dehydration. Mears and Shirreffs (2014) recently examined the voluntary intake of water during and following exercise in a cold environment compared with a warm environment. In each trial subjects sat for 30 min before cycling at 70% $\dot{V}O_2$peak (162 ± 27W) for 60 min in 25.0 ± 0.1 °C, 50.8 ± 1.5% relative humidity (RH; warm) or 0.4 ± 1.0 °C, 68.8 ± 7.5% RH (cold). Subjects then sat for 120 min at 22.2 ± 1.2 °C, 50.5 ± 8.0% RH. Ad libitum drinking was allowed during the exercise and recovery periods. Urine volume, body mass, serum osmolality, and sensations of thirst were measured at baseline, post-exercise and after 60 and 120 min of the recovery period. Sweat loss was greater in the warm trial (0.96 ± 0.18 l vs. 0.48 ± 0.15 l; P <.0001) but body mass losses over the trials were similar (1.15 ± 0.34% (cold) vs. 1.03 ± 0.26% (warm)). More water was consumed throughout the duration of the warm trial (0.81 ± 0.42 l vs. 0.50 ± 0.49 l; P =.001). Cumulative urine output was greater in the cold trial (0.81 ± 0.46 v 0.54 ± 0.31 l; P =.036). Thirst sensations were similar between trials (P >.05). It was concluded that the cold appears to have a blunting effect on thirst response. Thus, while snow biking, participants should attempt to stay hydrated to avoid the negative effects of dehydration.

In conclusion, snow biking through the use of a fat bike allows bikers to enjoy riding in the winter months when trails are covered in snow. There is no direct research on snow biking or riding a fat bike. However, the literature on other types of mountain biking and environmental factors point to snow biking, using a fat bike, having an equal or greater physiological demand on the rider compared to riding on an earthen trail. The weight of the fat bike, composition of the trial, and environmental conditions, will all influence the specific demands encountered by the rider.

CHAPTER III – CONCLUSIONS AND RECOMMENDATIONS

Conclusions

To our knowledge, the present study provides the first examination and comparison of performance aspects and exercise intensity while riding a riding a fat bike on an ET vs. a ST. Results of this study show that, when completed in a TT format, riding a fat bike was significantly slower on a ST vs. an ET. In addition, there was no significant difference between RPE, HR_{avg}, or HR_{peak} between trail conditions. However, BL concentrations were significantly lower following completion of the ST. It was demonstrated that riding a fat bike on both an ET and ST can be completed at a very high exercise. The HR_{avg} during both field tests corresponded to 92 % of the HR_{max} observed in the laboratory. This is similar to exercise intensities observed in XC mountain biking competitions.

Recommendations

Future studies should attempt to measure VO_2 to verify the high level of aerobic demands suggested by the HR data observed in the present study. Additionally, to allow for a more accurate comparison of performance aspects between an ET and ST, future studies should attempt to test participants who have maintained the same level of fitness between field conditions. Lastly, the current researchers believed that the ST may have caused apprehension in riders, resulting in slower riding speeds and increased isometric muscular contractions in order to control and stabilize the fat bike on the ST. Future studies should seek to quantify and compare muscular activity, strength changes, and apprehension between different surfaces such as an ET and a ST.

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APPENDIX A – Table 1

Table 1. Participant results of ET and ST baseline laboratory testing sessions.

Variable	ET (mean ± SD)	ST (mean ± SD)	P – value
Mass (kg)	74.0 ± 9.1	76.2 ± 9.9 *	= 0.001
$\dot{V}O_{2max}$ ($L \cdot min^{-1}$)	4.47 ± 0.88	4.25 ± 0.76 *	= 0.045
$\dot{V}O_{2max}$ ($mL \cdot kg^{-1} \cdot min^{-1}$)	60.2 ± 7.1	55.7 ± 7.0 *	= 0.008
HR_{max} ($beats \cdot min^{-1}$)	190 ± 6	191 ± 7	= 0.794
PPO (W)	479 ± 90	466 ± 85	= 0.150
BL_{LT} ($mmol \cdot L^{-1}$)	3.1 ± 0.6	3.1 ± 0.5	= 0.862
PO_{LT} (W)	231 ± 51	212 ± 48 *	= 0.046
HR_{LT} ($beats \cdot min^{-1}$)	157 ± 10	158 ± 16	= 0.617

$\dot{V}O_{2max}$, maximum oxygen consumption; HR_{max}, maximum heart rate; PPO, peak power output measured during maximal graded exercise test; BL_{LT}, blood lactate concentration at lactate threshold (LT); PO_{LT}, power output at LT; HR_{LT}, heart rate at LT.
* Significantly different from ET field test ($P < 0.05$).

APPENDIX B – Table 2

TABLE 2. Participant results from the ET and ST field test sessions.

Variable	ET (Mean ± SD)	ST (Mean ± SD)	P – Value
Field temp (C°)	8.4 ± 2.9	-3.6 ± 1.2 *	= 0.000
Time (mm:ss)	21:23 ± 2:10	29:11 ± 4:09 *	= 0.000
HR_{avg} (beats·min^{-1})	176 ± 9	175 ± 15	= 0.879
HR_{peak} (beats·min^{-1})	186 ± 6	187 ± 8	= 0.617
HR_{avg} (% HR_{max}*Lab*)	92.5 ± 4.7	92.2 ± 8.2	= 0.880
BL (mmol·L^{-1})	12.1 ± 3.5	4.5 ± 2.0 *	= 0.000
$Speed_{avg}$ (km/hour)	17.0 ± 1.6	12.5 ± 1.9 *	= 0.000
$Speed_{max}$ (km/hour)	40.4 ± 4.6	33.1 ± 6.3 *	= 0.000
RPE	7.7 ± 1.0	8.1 ± 0.2	= 0.117

HR_{avg}, average heart rate; HR_{peak}, peak heart rate during field test; % HR_{max}*Lab*, percentage of maximum heart rate observed during the laboratory test; BL, blood lactate; $Speed_{avg}$, average speed; $Speed_{max}$, maximum speed; RPE, rating of perceived exertion.
* Significantly different from ET field test ($P < 0.05$).

APPENDIX C – IRB Approval

TO: Kevin Phillips

School of Health and Human Performance

CC: Scott Drum

School of Health and Human Performance

DATE: January 30, 2014

FROM: Brian Cherry, Ph.D.

Assistant Provost/IRB Administrator

SUBJECT: **IRB Proposal HS14-571**

IRB Approval Dates: 1/30/2014-1/30/2015**

Proposed Project Dates: 5/1/2014-2/28/2015

"The Physiological Demands of Snow Biking Through the use of a Fat Bike"

The Institutional Review Board (IRB) has reviewed your proposal and has given it final approval. To maintain permission from the Federal government to use human subjects in research, certain reporting processes are required.

A. You must include the statement "Approved by IRB: Project # HS14-571" on all research materials you distribute, as well as on any correspondence concerning this project.

B. If a subject suffers an injury during research, or if there is an incident of non-compliance with IRB policies and procedures, you must take immediate action to assist the subject and notify the IRB chair (dereande@nmu.edu) and NMU's IRB administrator (bcherry@nmu.edu) within 48 hours. Additionally, you must complete an Unanticipated Problem or Adverse Event Form for Research Involving Human Subjects

C. Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding. Informed consent must continue throughout the project via a dialogue between the researcher and research participant.

D. If you find that modifications of methods or procedures are necessary, you must submit a Project Modification Form for Research Involving Human Subjects before collecting data.

E. **If you complete your project within 12 months from the date of your approval notification, you must submit a Project Completion Form for Research Involving Human Subjects. If you do not complete your project within 12 months from the date of your approval notification, you must submit a Project Renewal Form for Research Involving Human Subjects. You may apply for a one-year project renewal up to four times.

NOTE: Failure to submit a Project Completion Form or Project Renewal Form within 12 months from the date of your approval notification will result in a suspension of Human Subjects Research privileges <u>for all investigators listed on the application</u>, until the form is submitted and approved.

APPENDIX D – Informed Consent Form

NORTHERN MICHIGAN UNIVERSITY

School of Health and Human Performance

CONSENT TO ACT AS A HUMAN SUBJECT

Subject Name (print):_________________________________ Date __________

1. I agree to volunteer as a subject for exercise testing. I understand that this testing is part of a study entitled: “The Physiological Demands of Snow Biking through the use of a Fat Bike”. Snow biking is a new sub-discipline of mountain biking made possible through the use of a fat bike which has very wide tires. The purpose of this study is to investigate the physiological demands that occur while riding a fat bike on a mountain biking trail. The results will be compared to baseline testing and riding the same trail in the winter which will become a groomed snow trail.

   I volunteer to perform the following physical activities and authorize Kevin Phillips, Scott Drum and/or assistants who may be selected by them, to perform the following procedures:

I understand that:

(a) I will be requested to participate in four days of exercise. On the first day of testing, I will perform baseline testing in the exercise science lab at Northern Michigan University. The second testing period will consist of riding a fat bike on a section of the NTN snow bike route. The third testing period (January, 2015), will re-asses baseline data, as this variable can change due to training or lack of training. The fourth testing period (February, 2015), will consist of riding a fat bike on a snow biking trail (same as the 2nd testing period, mentioned above).

(b) On the first and third testing period, I will complete a VO_{2max} test which will determine my level of maximal oxygen consumption. This will involve a graded exercise test on a mechanically braked cycle ergometer until exhaustion. I will be wearing a heart rate monitor and a mask that covers my mouth and nose. I will also complete a second graded exercise test on a mechanically braked cycle ergometer in order to determine my lactate threshold. This will involve a finger prick using a lancet to obtain a drop of blood to analyze blood lactate levels. Additionally, my height, weight and age will be assessed.

(c) On the second and fourth testing period, I will ride a specific section of the snow bike route (approximately 3.7 miles) at the NTN south trails. I will use the same fat bike during both testing periods. I will be wearing a heart rate monitor and a GPS watch to assess time to complete the trail, average speed and max speed. Immediately following completion of the trail, blood will be obtained for peak lactate concentration. I will report my rating of perceived exertion during the ride. Lastly, time to complete the trail will be examined in each testing period.

(d) A bike will be provided for each day of testing in order to eliminate differences between bikes. (e.g., bike weight, tire width)

(e) I will be required to wear a helmet during all trail riding.

(f) Each day of testing will take 1-2 hours.

2. I understand the procedures outlined above.

3. I understand that the procedures described above could possibly involve the following risks and discomforts: mild discomfort from the finger prick needed to obtain blood, cold related disorders, cardiac issues and death due to maximal exercise, significant injury from a fall while biking and temporary muscle soreness from exercise. Every effort will be made to minimize these risks. Additionally, I understand that I can terminate any test at any time at my discretion. Moreover, I understand that I should cease any test if I experience any abnormalities such as pain, dizziness, light-headedness, or unusual shortness of breath, etc.

4. I have been advised that the following benefits will be derived from my participation in this study: I will learn my VO_{2max} which is my level of maximal oxygen consumption. This an important indicator of aerobic performance. Additionally, I will complete this test a second time, eight months later, allowing me to see if my VO_{2max} has improved. I may also feel satisfaction for volunteering in (possibly) the first study to date examining the physiological demands of riding a fat bike and snow biking.

5. I understand that Kevin C. Phillips, Scott Drum and/or appropriate assistants who may be selected by them will answer any inquiries that I may have at any time concerning these procedures and/or investigations.

6. I understand that all data concerning myself will be kept confidential and available only upon my written request. I further understand that in the event of publication, no association will be made between the reported data and myself.

7. I understand that there is no monetary compensation for my participation in this study.

8. I understand that in the event of an injury, I will not hold the researchers or Northern Michigan University responsible. Although compensation cannot be provided, assistance will be available.

9. I understand that I may terminate participation in this study at any time without prejudice to future care or any possible reimbursement of expenses, compensation, or employment status.

10. I understand that if I have any further questions regarding my rights as a participant in a research project I may contact Dr. Brian Cherry (906-227-2300) bcherry@nmu.edu, Assistant Provost of Graduate Education/Research of Northern Michigan University. Any questions I have regarding the nature of this research project will be answered by Kevin Phillips (570-877-4955) kephilli@nmu.edu or Scott Drum (970-371-2620) sdrum@nmu.edu

Subject's Signature:____

Witness:____ Date:_________

Approved by IRB: Project # HS14-571