FACTORS RELATED TO CYCLING PERFORMANCE

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There were two primary goals in this investigation. The first goal was to determine if results from field tests (time-trials and a Conconi incremental test) are related to performance in mass-start long-distance bicycle races. The second goal was to investigate inter-relationships among field test variables. The testing variables measured were critical velocity (CV), Conconi anaerobic threshold (AT) velocity, 4mM AT velocity, fatigue index, peak blood lactate, and anaerobic work capacity.

Participants were USCF 30 category 1 through 5 cyclists. Participants performed one 20.75 km and two 10.37 km all-out tests in the field. They also performed an incremental test. The tests were performed at one-week intervals. Results from the field tests were compared to recent mass-start racing performance. Results indicated that Conconi AT velocity was related to performance in a 161-km race. There was also a relationship between 4mM AT velocity and CV and between Conconi AT velocity and 4mM AT velocity. It was concluded that field tests might provide information about performance ability in mass-start long-distance bicycle races.

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CHAPTER I

INTRODUCTION

An understanding of the relationship between physiological measures and sport performance can enhance the training and performance of athletes. Over the years, several methods have been developed to help athletes to compete at a higher level. Several studies have tried to evaluate relationships between physiological and mathematical measures and athletes' performance.

Two common types of racing events in cycling are time trial (TT) and mass-start races. TT is a race in which competitors start one at a time, usually at 30-s or 1-min intervals. The winner is the cyclist who completes the course fastest. In mass-start races, the riders start at the same time, the winner being the first rider to cross the finish line. Although speed is important in mass-start races, tactics and teamwork are equally vital. For example, groups of riders often "attack" and take a lead, working together to increase it while their teammates try to block and slow down the main group.

According to Burke (1986), two types of aerodynamic drag affect the cycling performance: pressure (or form) and skin-friction drag. Pressure drag results when the flow of air fails to follow the contours of a moving body. The separation changes the distribution of air pressure on the body, causing a low pressure on the rearward surfaces and high pressure on the forward surfaces resulting in a drag force. Skin-friction drag results from the viscosity (or stickiness) of the air. Viscosity causes shear forces in the boundary layer of air next to the body.

Because air resistance is the major limitation on bicycle speed, most of the tactics used in bicycle racing are based on exploiting this effect. Drafting means following another cyclist so closely that the leading cyclist takes the brunt of the wind resistance and acts as a windbreak for the drafting cyclist. Riding in the slipstream of another rider can dramatically reduce the aerodynamic drag force. Not only does drafting reduce the high pressure at frontal surface, but also reduces low pressure at the trailing surface. Drafting then reduces the algebraic sum of the aerodynamic drag forces (Kyle & Burke, 1984). Drafting is often used in mass-start races, but is not allowed in TT races.

In mass-start races, cyclists often have to lead the group and then drop back to draft. A cyclist who recovers quickly has an advantage over the other riders. The fatigue test was developed to measure how well the cyclists could recover from leading the group.

Several researchers have identified physiological measures that correlate with cycling performance. These have varied from examining the relationship between maximal oxygen uptake (VO_2max) and performance (Coyle et al., 1991), the relationship between ventilatory threshold (VT) and TT performance (Hopkins & McKenzie, 1994; Hoogeveen, Schep, & Hoogsteen, 1999), the relationship between critical power (CP) and TT performance (Smith, Dangelmaier, & Hill, 1999), and the relationship between anaerobic capacity and event specificity (Craig et al., 1995).

The cycle ergometer has been the most common means of determining a cyclist's physiological and biomechanical parameters (Hagberg, Mullin, Giese, & Spitznagel, 1981; Sjogaard, 1984). Performance in these conditions is represented by the mechanical power output, which is the product of the friction force and velocity of the flywheel. The friction force is overcome by forces exerted efficiently on the pedals by the legs of the cyclists. This power output is measured in watts.

In road and indoor cycling, on the other hand, performance is most usually represented by the cyclist's riding speed. The cyclist must overcome two types of resistance to generate movement: rolling resistance and air resistance. Rolling resistance has been shown to depend on the individual's body mass, the inflation pressure of the tires, and the characteristics of the road surface and the tires. Air resistance on the other hand depends on the frontal area of the cyclist and his bicycle, air density, wind conditions, and the speed of motion (di Prampero, Cortili, Mognoni, & Saibene, 1979).

Several studies have investigated the relationship between laboratory measures and TT performance. However, there have been no studies evaluating factors related to mass-start performance. There is also lack of scientific data comparing cycling performance with field test variables.

Purpose

The primary purpose of this investigation was to determine if results from field tests (critical velocity, fatigue test, and incremental test) are related to performance in mass-start long-distance bicycle races. The secondary purpose was to examine inter-relationships among the field test variables.

Statistical Hypothesis

The null hypotheses were: 1) there is no relationship between results of field tests and performance in mass-start races; and 2) there are no inter-relationships among the field test variables.

Working Hypotheses

Field test data can provide information related to sport performance. It was hypothesized that: 1) CV is related to performance in mass-start races; 2) anaerobic threshold (AT) is related to performance in mass-start races; and 3) fatigue test results (perhaps in combination with CV or AT) are related to performance in mass-start races.

Significance of Investigation

If the working hypotheses were supported, then athletes would have a method of evaluating their own fitness without the need for expensive laboratory tests. Cyclists would also be able to predict their race performance from the test results using calculated CV, anaerobic work capacity (AWC), a fatigue index, and AT. To this day, there has not been a study examining the relationship between field tests and mass-start race performance.

Delimitations

This investigation was delimited in the following ways:

1. Participants were local USCF category 1 to category 5 cyclists.
2. Participants reported results of road races and TT races.

Limitations

1. Participants self-reported race results.
2. Not all participants reported results from races.
3. Only a few cyclists had results from the same races.
4. Testing was affected by weather conditions.
5. Cyclists may not have given full effort during all tests.

CHAPTER II

REVIEW OF LITERATURE

Several studies have been performed with the goal of determining the best way to predict performance. Researchers have identified physiological variables that correlate well with performance. In this chapter, discussion focuses on previous investigations that have dealt with different methods of determining physiological variables related to performance. Time trial performance is related to VO_2max (Coyle et al., 1991), VT (Hopkins & McKenzie, 1994), and CP (Smith et al., 1999). In addition, track cycling is related to maximal accumulated oxygen deficit (Craig et al., 1995). A brief summary of the pertinent studies is prescribed below.

Physiological Measures

Anaerobic capacity is an individual's ability to generate short-term anaerobic energy and perform work using this energy. Anaerobic capacity can be presented by a parameter called AWC (i.e. "anaerobic work capacity") (Monod & Scherrer, 1965) or by the maximal accumulated oxygen deficit (Craig et al., 1995).

The major anaerobic pathway is glycolysis, which is the breakdown of glucose to lactate (La). Therefore, peak blood La level reflects anaerobic contribution. Peak blood La is the highest lactate measured after exercise. The harder the exercise intensity, the more lactate appears in the blood. In maximal exercise, where anaerobic contribution is maximal, peak La serves as a measure of anaerobic capacity.

The AT or lactate threshold (LT) represents the highest exercise intensity that can be sustained without an anaerobic contribution. In 1982, Conconi, Ferrari, Ziglio, Droghetti and Codeca reported a practical field test for measuring AT. According to Conconi et al., there is a deflection in heart rate (HR) that occurs concurrent with the lactate threshold. HR and speed data are collected during a graded test on the tract, during which the speed increases after a short distance. A linear increase is evident in HR and speed until a point where speed increases to a greater extent than HR. Heart rate deflection (HR_d) is the point where the relationship between HR and speed becomes nonlinear. This point is referred as Conconi AT.

Conconi et al. (1982) tried to determine AT by a noninvasive field test in runners. They hypothesized that, above AT, there would be an increase in running speed at least in part independent of VO_2 and possibly of HR. They noted that if a downward deflection from the expected linearity of the HR-speed relationship could be observed, this phenomenon could be used to evaluate AT indirectly and noninvasively. Two hundred ten male middle-and long-distance runners participated in the study. Participants performed 8-12 laps on a 400-m track. Their initial running velocity was 12-14 $km \cdot h^{-1}$, and it was increased slightly (avg. 0.5 $km \cdot h^{-1}$) every 200-m. The velocity of the last 200-m fraction ranged from 18 to 25 $km \cdot h^{-1}$. The authors correlated AT with a LT. The results of this study showed that HR-intensity relationship provides a means for determining AT. This determination is noninvasive and can be carried out while the athlete performs his usual physical activity. This can also be applied to other sport activities.

The region in which blood La shows a systematic increase equal to or above a level of 4mM is termed the point of onset of blood La accumulation (Yoshida et al., 1987). Often, the terms LT and onset of blood La accumulation are used interchangeably.

The 4.0mM AT value for onset of blood La accumulation implies a maximum exercise intensity that a person can sustain for a prolonged period.

Another measure of submaximal aerobic power is CP. The critical power concept is based on the relationship between power (or velocity) and time to exhaustion. If the researcher is using a cycle ergometer that gives intensity in watts (power), this is critical power. It can be defined as the asymptote of the relationship between power and time to fatigue, the slope of the relationship between work and time, or the y-intercept of the relationship between power and time^{-1} (Monod & Scherrer, 1965). However, if the tests are performed in the field or if a treadmill is used, the slope is a critical velocity (CV). When exercise intensity is measured in terms of velocity, as in running, swimming, or outdoor cycling, critical velocity can be determined as the asymptote of the relationship between velocity and time to fatigue, the slope of the relationship between distance and time, or the y-intercept of the relationship between velocity and time^{-1} (Smith et al. 1999).

Several studies have demonstrated that estimates of the CP parameter are related to aerobic fitness in non-trained cyclists (Housh et al., 1992). As noted by Hill (1993), CP appears to represent a maximal work rate that can be sustained from 30 to slightly over 60 min. This is equal to the duration of many TT events.

Relationship between Laboratory Measures and Performance

Coyle et al. (1991) evaluated the physiological and biomechanical factors associated with elite endurance cycling performance. Fifteen male category 1 and 2 cyclists participated to the study. The participants simulated a 40-km TT in the laboratory by cycling on an ergometer for 1-h at their highest power output. In addition, they completed an incremental cycling test to measure VO_2max and LT. The results of this study indicate that 1-h power output is highly related to the cyclist's VO_2 at LT (77.7% VO_2max). Also, actual road racing 40-km TT performance (56.2 ± 0.8 min) was highly correlated (r=-.88) to the average work rate their cyclists could sustain for 1-h. The authors concluded that laboratory performance tests of similar duration to a race event could help predict cycling performance.

A similar study was done by Hopkins and McKenzie (1994). They investigated the relationship between noninvasive measures of laboratory performance and performance in a 40-km TT. The participants were eight male competitive cyclists and triathletes. The participants completed an incremental exercise test to exhaustion and a 40-km TT. TT performance (61.7 ± 2.3 min) was most closely related to the power output at the VT (341 ± 24 W) and VO_2max (68.0 ± 3.0) expressed as $ml \cdot kg^{-1} \cdot min^{-1}$. This data indicate that simple laboratory measures can predict TT performance in trained cyclists.

Craig et al. (1995) examined the relationship between the time required to fully utilize the maximal accumulated oxygen deficit and event specificity of track cyclists. The measure of the maximal accumulated oxygen deficit has been proposed as a measure of anaerobic capacity. VO_2max, power output, and anaerobic capacity were measured in 12 track endurance cyclists and 6 sprint cyclists. Sprint cyclists could fully express their anaerobic capacity within a 70 s all-out test (66.9 ± 2.2 $ml \cdot kg^{-1}$) and the track endurance cyclists within 300 s (62.1 ± 11.0 $ml \cdot kg^{-1}$). The results indicate that assessment of the maximal accumulated oxygen deficit should be done under exercise conditions specific to the athlete's event.

Hoogeveen, Schep and Hoogsteen (1999) investigated the validity of the ventilatory response during incremental exercise as an indication of exercise performance. Fourteen male elite cyclists who had trained at least 4 years, 13 $h \cdot wk^{-1}$, participated in the study. The participants completed two different tests. An incremental cycling test was done, and expired gases, HR, and VO_2 were measured. Two to three weeks later, the participants completed a 40-km TT. The authors concluded that the AT (4350 ± 340 $ml \cdot min^{-1}$) determined using the V-slope method (VCO_2 compared to VO_2) and the VE/VO_2 method showed significant correlations with TT performance (58.0 ± 1.4 min). In addition, HR at the ventilatory threshold (176 ± 8 $beats \cdot min^{-1}$) and maximum HR (192 ± 8 $beats \cdot min^{-1}$) both showed significant correlations with HR (175.3 ± 7.1 $beats \cdot min^{-1}$) during the TT.

In the study done by Smith et al. (1999), CP was evaluated as an indicator of aerobic fitness in trained cyclists. They also investigated the relationship between CP and TT performance. There were 13 participants (9 men, 4 women), category 2 and 3 cyclists. The participants made six laboratory visits where they did an incremental cycling test and five constant power cycling bouts to exhaustion to determine CP (299 ± 61 W). They also completed two 17-km TT one week apart. The results from these tests were used to determine relationship between laboratory measurements, 17-km (26.6 ± 1.1 min), and season's best 40-km TT times (59.6 ± 3.1 min). It was concluded that CP is strongly related to measures of ventilatory threshold (r=.90) and VO_2max (r=.93), and is therefore a valid index of aerobic fitness. In addition, CP was more related to the TT performance of competitive cyclists (r=-.77 to -.91) than were VT and VO_2max (r=-.71 to -.87). Therefore, it presents an attractive alternative to the measures typically used to assess fitness and predict performance.

Although there has been research conducted about the factors related to cycling performance, there is a gap between predicting cycling racing performance from field tests. Furthermore, it would be convenient for cyclists and for the coach as well to have a method of evaluating performance and fitness levels of an individual without doing laboratory testing. Several studies have compared TT performance and laboratory measures. However, no study to date has compared mass-start race performance with laboratory measures.

The purpose of this investigation was to determine if performance in mass-start cycling could be predicted from field tests. Relationships among field test variables were also investigated.

CHAPTER III

METHODS AND MATERIALS

The procedures employed to determine aerobic fitness and anaerobic fitness measurements are discussed in this section. Other topics of discussion in this section are participants' characteristics, and detailed description of the testing procedures.

Participants

The participants for the study were 30 category 1 through 5 cyclists. There were 14 category 5 cyclists, 8 category 4 cyclists, 6 category 3 cyclists, 1 category 2 cyclist, and 1 category 1 cyclist. Twenty-nine of them were male participants and there was one female participant. According to the United States Cycling Federation (USCF), category 1 and 2 cyclists are classified as world-class cyclists whereas category 5 cyclists are beginner racers. Cyclists can move up the categories by doing well in races. The cyclists had at least one year of experience with training and racing, had no history of abnormal exercise responses (i.e., chest pain, losing consciousness, losing balance). They were screened using the Physical Activity Readiness Questionnaire (Par-Q). The questionnaire is often used to determine readiness to begin or intensify a physical activity program. After being informed of the possible risks associated with the research, all participants signed an approved, informed consent form (See Appendix B).

Equipment

Temperature and humidity were measured every hour during testing session using a digital thermometer. Wind speed was also measured every hour using a digital wind gauge. Stopwatches were used to measure cycling times.

The SoftClix®II (Roche, Mannheim, Germany) lancing device was used to obtain blood from the tip of the cyclist's finger. Blood lactate level was determined using BM-Lactate test strips and an Accusport (Boehringer, Mannheim, Germany) portable lactate analyzer. The accuracy and reliability of determining blood La concentration using one drop of blood and Accusport La Analyzer has been previously demonstrated (Fell, Rayfield, Gulbin, & Gaffney, 1998).

The cyclists used their own helmets, racing bicycles, speedometers, and heart rate monitors (Polar, Electro OY, Finland).

Experimental Design

Each cyclist performed three tests a week apart, all on a 0.8-mile (1.3-km) paved loop that cyclists regularly used for training rides and criterium races. There were two timed efforts and one Conconi incremental test. The tests were administered on Sundays. The order of the tests was 16-loop ride, 2x8-loop ride, and Conconi incremental test with one makeup day. Some cyclists performed the tests in a different order. The participants were asked to provide five recent race results. The race results were compared with the test results to determine correlations between the two.

Cyclists were asked to be well rested for the testing sessions, and eat only lightly in the hours before testing. In addition, cyclists were asked to "give 100%" in the tests.

16-loop test

After an individualized warm-up, the cyclists rode 20.75 km (16 loops on the 1.3-km course) as fast as possible. This was an individual test, with no drafting allowed.

Time was measured to the nearest second. HR was recorded immediately after the cyclist completed the test.

<u>2x8-loop test</u>

This test involved two all-out individual efforts separated by a 3-minute recovery. After an individualized warm-up, the cyclists performed a distance of 10.37 km (8 loops on the 1.3-km course) as fast as possible. As soon as the first 8 loops were completed, one of the cyclist's fingertips were pricked with a sterile disposable lancet, and one drop of blood was collected for determination of blood La concentration. Exactly 3 minutes after completion of the first ride, the cyclist began a second identical effort, after which another drop of blood was obtained. Time in these tests was measured to the nearest second. HR was recorded immediately after each 8-loop tests.

<u>Incremental test</u>

The third test was the Conconi incremental test. This test involved 3 to 5 1.3-km stages (each being one loop of the 1.3-km course), each separated by a 1-min rest period. Speed for the first loop was individually determined for each cyclist. This was approximately 6.4 $km \cdot h^{-1}$ below his or her critical velocity, which was calculated prior to the third test. The cyclist monitored his or her speed through a computer attached to the bicycle. Speed for each successive loop was about 3.2 $km \cdot h^{-1}$ faster than the previous. As soon as each loop was completed, one of the cyclist's fingertips was pricked with a sterile disposable lancet, and one drop of blood was collected for determination of blood La concentration. HR was also recorded immediately after each loop. After the blood collection and resting that lasted 1 min, the cyclist started the next lap. The La analyzer displayed the blood La concentration within 1 min. The test was terminated when there was a marked increase (to over 4mM) in the blood La concentration.

Measures of Aerobic Fitness

CV was determined from the results of the 16-loop test and the first 8 loops in the 2x8 loops test. The slope of the relationship between distance and time is CV. Times from the 16-loop test (T16) were subtracted from the first 8-loop test (T8.1). This was divided by the distance in km and the results multiplied by 3600 $s \cdot h^{-1}$. The following equation was used: 10.37/(T16-T8.1)*3600 $s \cdot h^{-1}$ (Smith et al., 1999).

Velocity at the Conconi AT was determined from the downward HR deflection in the incremental test (Conconi et al., 1982). There should be a linear increase in HR and speed until a point where speed increases to a greater extent than HR. This was determined by visual inspection.

4mM AT velocity was determined from results of the Conconi incremental test by interpolating the La values and velocities. 4mM AT velocity was identified when blood La value increases equal to or above a level of 4mM.

Fatigue index was determined from results of the 2x8 loop tests. The difference in velocities between the two loops was determined by subtracting the first 8-loop velocity (V8.1) from the second 8-loop velocity (V8.2) and dividing this by the first 8-loop velocity. This was multiplied by 100 to obtain the percentage decline in velocity. The equation used was: ((V8.1-V8.2)/V8.1)*100%= percent decrease.

Measures of Anaerobic Fitness

AWC was determined from the 2x8-and 16-loop tests. The y-intercept of the distance-time relationship reflects AWC. CV was multiplied by time for the first 8-loop, and this was divided by 3600 $s \cdot h^{-1}$. The distance in km was subtracted from this to get AWC (10.37-(CV*T8.1/3600)) (Craig et al., 1995).

Peak blood La was measured from the 2x8 loop test. Peak blood La was the highest reading either from the first 8-loop test or the second 8-loop test.

Statistical Analysis

Correlations among the measures derived from the three tests and between the road race times and the physiological measures (Conconi AT velocity, 4mM AT velocity, CV, AWC, peak lactate, fatigue index) were calculated using standard version of SPSS (Chicago, IL). Physiological measures were also compared among racing categories using analysis of variance (ANOVA). Significance was accepted at the 0.05 level. All values are reported as the mean ± standard deviation (SD).

CHAPTER IV

RESULTS

The purpose of this study was to determine if results from field tests (critical velocity, fatigue test, and Conconi incremental test) are related to performance in mass-start long-distance bicycle races. The secondary purpose was to determine inter-relationships among the field test variables. The results of the study are presented in this chapter.

All 30 participants completed the 20.75 km test. However, only 18 participants completed the fatigue test, which included two 10.37 km trials. Since the results of first of these 10.37 km trials and the 20.75 km trial were needed to determine CV, CV could be calculated for only 18 participants. Seventeen participants completed the Conconi incremental test.

Descriptive Statistics

Mean values for age, height, and weight for the 30 participants were 30 ± 7 y, 179.6 ± 7.1 cm, and 78.4 ± 9.9 kg, respectively. Individual values are presented in Appendix A. Individual values for times, velocities, CV, Conconi AT, 4mM AT, fatigue index, peak La, AWC, and race times are also presented in Appendix A.

Test Results

Results of the 16-loop 20.75-km test

This test involved cycling 20.75 km as fast as possible. Time and HR were recorded and no drafting was allowed.

For all participants, mean time for the 16-loop test was 2240 ± 207 s. The average speed was 33.4 ± 3 $km \cdot h^{-1}$. The mean HR immediately following completion of the first test was 184 ± 9 $beats \cdot min^{-1}$. All participants completed the 16-loop test and for most of them, this was the first test completed. On the first day of testing, mean temperature was 32 ± 3°C, mean humidity was 52 ± 4 %, and mean wind speed was 1.6 ± 0.2 $m \cdot s^{-1}$.

Results of the fatigue test

The fatigue test involved performance of two all-out 8-loop 10.37-km rides, separated by 3 min. No drafting was allowed. Of the total 30 participants, only 18 completed the fatigue test. For most of the participants, the fatigue test was performed on the second day of testing, when the mean temperature was 10 ± 4°C, mean humidity was 37 ± 5 %, and mean wind speed was 3.2 ± 2.2 $m \cdot s^{-1}$.

The mean time for the first 8 loops was 1127 ± 80 s. The average speed was 33.1 ± 2.3 $km \cdot h^{-1}$ and the mean HR immediately following completion of the test was 181 ± 11 $bt \cdot min^{-1}$. The mean time for the second 8 loops was 1161 ± 76 s and the average speed was 32.1 ± 2.1 $km \cdot h^{-1}$. The average HR immediately following completion of the test was 180 ± 13 $bt \cdot min^{-1}$. The mean La value was 9.1 ± 4.1mM after the first 8 loops and 9.4 ± 3.4mM after the second 8 loops.

Results of Conconi Incremental Test

This test involved 3 to 5 1.3-km stages, each separated by a 1-min rest period. No drafting was allowed. Of the total 30 participants, only 16 completed the Conconi incremental test. Mean temperature was 12 ± 2°C, mean humidity was 35 ± 3 % and mean wind speed was 3.5 ± 1.7 $m \cdot s^{-1}$. Speed for the first loop was individually determined. This was approximately 6.4 km·h^{-1} below the cyclist's CV. Speed for each successive loop was about 3.2 km·h^{-1} faster than the previous loop. The test was terminated when there was a marked increase in La concentration. The test results are presented in Table 1.

Table 1. Conconi Incremental Test

Stage	n	Time (s)	Speed (km·h^{-1})	La (mM)	HR (beats·m^{-1})
1	16	176 ± 29	26.6 ± 4.3	3.1 ± 2.0	150 ± 12
2	16	154 ± 22	30.4 ± 4.5	4.3 ± 1.4	161± 11
3	16	140 ± 17	33.4 ± 3.8	6.5 ± 2.4	171± 9
4	7	130 ± 16	36.0 ± 1.5	7.3 ± 2.3	175 ± 7
5	1	107 ± 0	43.7 ±0.0	5.9 ± 0.0	170 ± 0

Derived Parameters

Measures of aerobic fitness

CV

CV was determined as the slope of the relationship between distance and time for the 16-loop test and the first 8-loop ride in the fatigue test. An example of this is shown in Figure 1. Mean value for CV, as determined using the method of Smith et al. (1999), for 7 participants was 31.7 ± 2.4 km·h^{-1}. CV could be derived for only 7 participants. Although 17 cyclists performed the 16-loop and fatigue tests, for 10 of these, bad weather for the fatigue test made determining CV impossible. Because of the weather, they rode 16-loops at a faster speed than the 8/8-loops.

Conconi AT

The HR_d method suggested by Conconi et al. (1982) was used to calculate the values. Conconi AT velocity was determined from the downward HR deflection in the incremental test. An example is shown in Figure 2. For 14 participants, mean Conconi AT velocity was 30.8 ± 3.3 km·h^{-1}.

4mM AT

The mean value for 11 participants was 29.2 ± 3.8 km·h^{-1}. This was determined from the results of Conconi incremental test by interpolating La values and velocity to determine the velocity associated with a La value of 4mM

Fatigue index

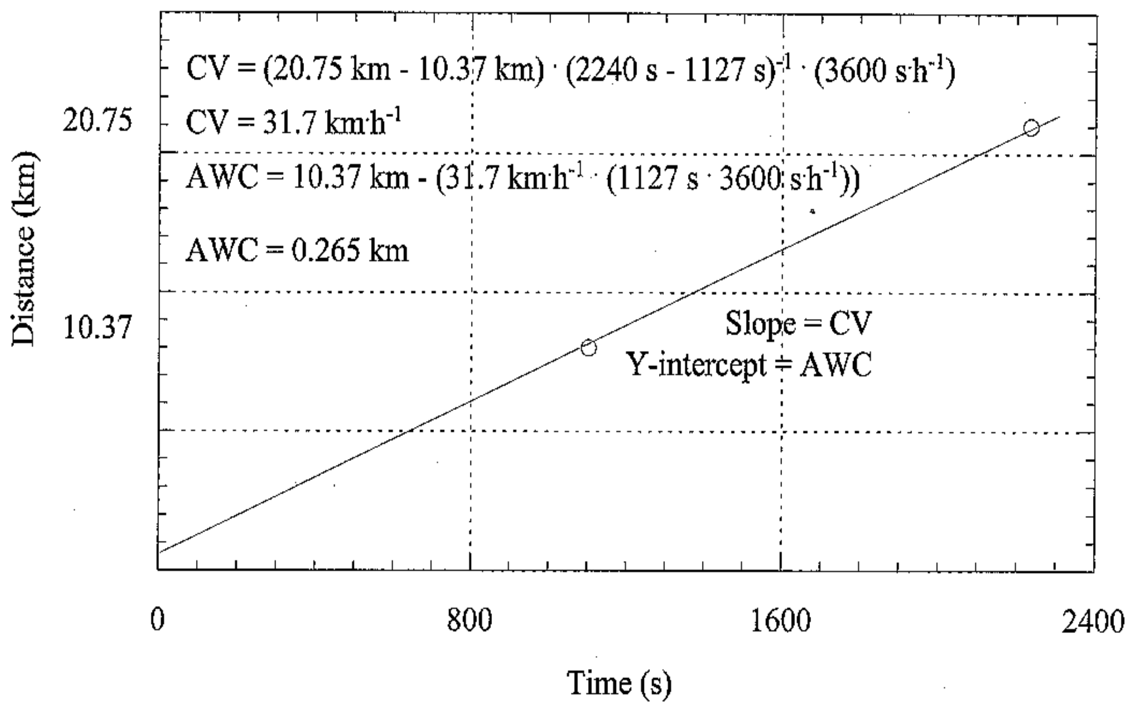
Mean fatigue index for 16 participants was 3.7 ± 2.9 %. The index was determined as the percent reduction in velocity from the first 8-loop test to second.

Measures of anaerobic fitness

AWC

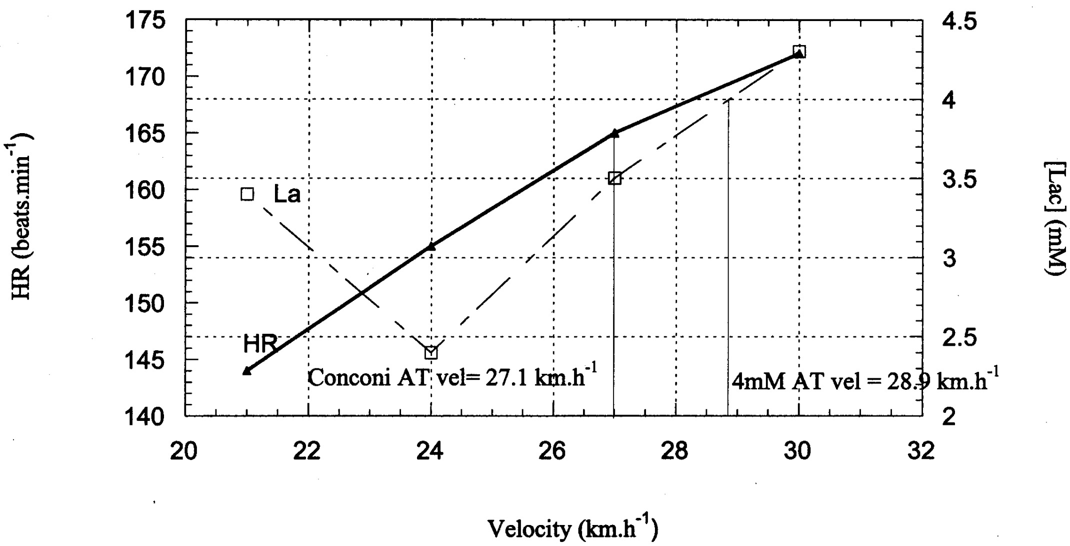
AWC was determined using the method of Craig et al. (1995) by the y-intercept of the distance-time relationship. As noted above in the paragraph providing results for CV, bad weather during the fatigue test made determining AWC impossible for most cyclists. Therefore, calculation of AWC could be done for only 7 participants. The mean value for AWC for 7 participants was $.424 \pm .315$ km.

Figure 1



CV = (20.75 km - 10.37 km) · (2240 s - 1127 s)-1 · (3600 s·h-1)
CV = 31.7 km·h-1
AWC = 10.37 km - (31.7 km·h-1 · (1127 s · 3600 s·h-1))
AWC = 0.265 km
Slope = CV
Y-intercept = AWC
20.75
10.37
Distance (km)
0
800
1600
2400
Time (s)

Figure 2


HR (beats.min-1)
[Lac] (mM)
Velocity (km.h-1)
La
HR
Conconi AT vel= 27.1 km.h-1
4mM AT vel = 28.9 km.h-1
175
170
165
160
155
150
145
140
4.5
4
3.5
3
2.5
2
20
22
24
26
28
30
32

Peak La

The peak La was determined from 2x8-loop test. The La concentration was measured immediately after the participant completed the loops. The highest value from the two 8-loop tests was used as the peak value. For 18 participants, mean peak blood La was 11.0 ± 2.8mM.

Race results

Only 11 of the 30 participants reported race results. Four did not race last year and 2 did not have exact times and distances. From the 11 who reported results from various races, 6 participated in the same race. The distance was 100 miles (160.9 km) and mean time was 306.33 ± 38.15 min, just over 5 hours. Mean speed for the participants was 31.5 $km \cdot h^{-1}$.

Relationships

Relationship between race performance and derived parameters

Correlations observed between race results and physiological measures (Conconi AT, 4mM, fatigue index, and peak La) are presented in Table 2. There were significant relationships in the expected direction between Conconi AT and race time and between race time and racing category.

There was not a significant correlation between fatigue index and race time. There was also not a significant correlation between peak La and race time or between 4mM AT and race time. The correlation between CV and AWC and 100-mile race performance could not be calculated because none of the cyclists for whom CV and AWC were derived participated in the road race.

Table 2. Correlations between race time and various measures.

Measures	n	r	p
Racing category	6	.86	.027
Conconi AT	5	-.90	.039
4mM AT	3	-.83	.375
Fatigue index	3	-.58	.610
Peak La	3	-.83	.375

Relationship among derived parameters

There was a significant relationship between CV and 20.75 km time (r =.98, p =.001) and 10.37 km time (r =.93. p =.002). These times are used to calculate CV. There was also a relationship between 4mM AT and 20.75 km time (r =.70, p =.016) and 10.37 km time (r =.73, p =.390). Correlations between 4mM AT and CV and between 4mM AT and Conconi AT were also observed. No other significant correlations were found. These are presented in Table 3.

Table 3. Correlations among derived parameters.

Measures	Conconi AT	4mM AT	Fatigue Index	AWC	Peak La
CV	.99 (.073), N=3	.83 (.043), N=6	.54 (.213), N=7	.19 (.680), N=7	-48 (.276), N=7
Conconi AT		.94 (.000), N=8	-.55(.159), N=8	-.83(.376), N=3	.19 (.601), N=10
4mM AT			.33 (.418), N=8	-.12 (.824), N=6	-.44 (.281), N=8
Fatigue index				-.08(.870), N=7	-.32(.224), N=16
AWC					.08 (.872), N=7

Relationship between racing category and derived parameters

In order to determine if cyclists in the higher categories performed better in tests, mean test results were compared for cyclists in racing categories 3, 4, and 5. There were only one category 1 cyclist and one category 2 cyclist and therefore they were not included in the analysis.

Category 3 cyclists had better times in the 16-loop test and in the 2x8-loop test, but only in the last 8 loops. They also had higher peak La values (13.7 ± 2.1mM) and

Conconi AT values (33.1 ± 4.0 $km \cdot h^{-1}$). Category 5 cyclists had lower values in all variables except peak La and fatigue index.

Results of ANOVA are presented in Table 4. There was a significance main effect for category on Conconi AT and 4mM. However, the Bonferroni post hoc comparison did not identify significant differences between any pairs of categories for any variable.

While not significant, there was a difference in Conconi AT between category 3 and 5 at p=.075 and between category 4 and 5 at p=.054. There was also a difference in 4mM AT between category 4 and 5 at p=.068.

Table 4. Mean values for cyclists grouped by USCF categories.

Measures	Category 3	Category 4	Category 5	Results of ANOVA
CV (km·h^{-1})	34.3 ± 0	35.4 ± 0	30.8± 1.6	$F_{2,4}$=4.825, p=.086
Conconi AT (km·h^{-1})	33.4 ± 4.1	33.2 ± .8	28.7 ± 2.5	$F_{2,11}$=5.434, p=.023
4mM AT (km·h^{-1})	31.9 ± 4.6	33.8 ± 1.1	27.4 ± 2.7	$F_{2,8}$=4.925, p=.040
Fatigue index (%)	4.75 ± 0	4.17 ± 3.7	3.26 ± 2.9	$F_{2,12}$=.193, p=.827
AWC (km·h^{-1})	.385 ± 0	.189 ± 0	.256 ± .23	$F_{2,4}$=.195, p=.830
Peak La (mM)	13.7 ± 2.1	10.8 ± 3.4	11 ± 2.3	$F_{2,14}$=.969, p=.404

CHAPTER V

DISCUSSION

The purpose of this investigation was to evaluate if results from field tests of CV, fatigue, and AT are related to performance in mass-start long-distance bicycle races. If the test results were related to race performance, this would give the cyclists a method of predicting their race performance and estimating their fitness levels. A second goal of this investigation was to determine if, in fact, a relationship existed between these variables.

Participants performed three outdoor tests. The first test was 20.75 km ride as fast as possible. The second test involved two rides of 10.37 km with 3-min rest period between. These test were performed to determine CV, fatigue index, AWC, and peak blood La. Participants also performed an incremental test to determine Conconi AT and 4mM AT. Relationships between test variables and race performance were described using Pearson correlation coefficients. In addition, relationships among various test variables were described.

Comparison of Values with Those in the Literature

Values obtained in this investigation were compared to values from previous research. Only a few investigators have compared physiological parameters using a field test. Therefore, some of the results from this study could not be compared to results from previous studies.

CV/CP is a variable that correlates highly with aerobic exercise performance (Smith et al., 1999). Therefore, it should relate well to cycling performance since cycling is mostly aerobic sport. Investigators have studied the CV/CP concept extensively.

However, the tests have been done in the laboratory using cycle ergometer, with results expressed in watts. Therefore the results cannot be compared with the results from this study.

The fatigue index was developed to compare how well the cyclists could recover from previous exercise bout. This often will happen in a race where cyclists have to lead the group and then drop back to draft. A cyclist who recovers quickly has an advantage over the others. Again, there are no research studies to compare the results.

Conconi AT and 4mM AT are both aerobic fitness measures that reflect the ability to sustain submaximal efforts. Both of these should be related to the cyclist's performance. Both Conconi AT and 4mM AT have been studied in laboratory and with different units. A few investigators have reported field tests where they used the Conconi method, but the participants were runners (Conconi et al., 1982; Conconi et al, 1996).

AWC is a measure that relates to anaerobic fitness. Anaerobic capacity is important in high-intensity efforts. It can, for example, determine how long a top-end finish sprint can be sustained. AWC has also been studied extensively in laboratory setting with different units (kJ) than in this investigation in which AWC was expressed in km. Therefore, there are no values to compare the results of this study.

Peak blood La concentration is another measure of anaerobic capacity. The mean value for peak blood La in this investigation (11.0mM) was similar to the 10.7mM value obtained by Craig et al. (1995) who evaluated 18 cyclists at maximal effort. However, these values were higher than the 7.2mM reported by Coyle et al. (1991).

Relationship between variables and performance

Outside tests are often affected by weather conditions. During the last three testing days, it was windier and colder than during the first test. This had an effect on the test results. Some cyclists also performed different tests on different days because of races they had to attend. This makes the comparison of the results difficult.

Some participants were also unwilling to give information about their recent race performance. Of those who did report race results, only a few participated in the same race. This made it difficult to compare race performance with the test results.

However, there was a significant correlation between race performance and Conconi AT ($r=.90$, $p=.04$). This suggests that measuring Conconi AT using a field test can predict performance in mass-start long-distance bicycle races. This finding is significant since many cyclists express their preference for sport-specific tests performed with equipment with which they are familiar. In addition, testing cyclists in a laboratory is expensive and requires several testing personnel. Conconi AT test, however, is a test that cyclists can perform with only a stopwatch or speedometer and a HR monitor.

There was also a correlation ($r=.86$, $p=.03$) between race performance and racing category. This suggests that the higher the racing category, the better aerobic fitness a cyclist has. This makes sense since usually the cyclists in higher racing categories perform better in races. Cyclists also move from lower category to the higher by winning races.

Mass-start race performance depends on many factors such as number of participants, environmental conditions, landscape, etc. Also drafting is a big factor determining race performance. Therefore, there is no direct correlation between test results and mass-start race performance. However, the tests can give an idea of how well a cyclist will perform in the race and what is his or her fitness level.

Significant relationships were also observed between CV and 4mM AT ($r=.83$, $p=.04$) and between Conconi AT and 4mM ($r=.94$, $p=.00$). All of these variables are used to measure aerobic fitness level. Therefore, it makes sense that these variables are correlated, and it suggests that cyclists need to measure only one of these in order to evaluate their fitness level.

Summary

The purpose of this investigation was to determine if results from field tests (CV, fatigue test, and Conconi incremental test) are related to mass-start long-distance bicycle races.

Because of the difficult weather conditions and participants not reporting race performance results, not all expected relationships were observed in this investigation. It had been hypothesized that all the measured testing variables should have been related to performance.

There was a correlation between Conconi AT and mass-start race performance. This relationship was hypothesized at the beginning of the study. This suggests that measuring Conconi AT using a field test can predict performance in mass-start bicycle races.

Since comparison between race results and derived parameters were limited, relationships among derived parameters and between racing category and derived parameters were investigated. There was a correlation between CV and 4mM AT and between Conconi AT and 4mM AT.

Conclusion

As mentioned earlier, accurate measures of all variables may have not been obtained. CV could not be compared with racing performance since none of the participants who had CV values did not report race results. However, there was a correlation between CV and 4mM AT velocity.

Fatigue index was not found to be correlated to race performance, as correlations could only be calculated with three participants. Therefore, this might not be an accurate conclusion. This test is also a logical test since mass-start racing requires quick recovery from the leading of the group.

Conconi AT was found to be correlated with race performance. Therefore, Conconi AT can be used by cyclists to measure their aerobic fitness level and to predict their race performance. This test can be done without expensive lab tests using only a stopwatch or speedometer and a HR monitor.

Future Recommendations

Future research would be useful identifying the exact relationship between field tests and cycling performance. Many physiological factors have been extensively studied in a laboratory setting. However, athletes often express their preference for sport-specific tests performed with equipment with which they are familiar. Future research should concentrate on testing athletes in good weather condition. It would also be interesting to see the results of a study that used the same methods but with elite cyclists. Other field tests that predict race performance should also be designed.

APPENDIX A

VALUES FOR PARTICIPANT CHARACTERISTICS AND TESTING VARIABLES

ID	Category	Age	Height-cm	Weight-kg	T8.1 (s)	T8.2 (s)	T16 (s)	V8.1(km/h)
1	4	23	170	66	1082	1099	2109	34.5
2	3	39	170	67	1139	1099	2141	32.78
3	5	27	180	80	1156	1181	2182	32.29
4	5	27	177	83	1103	1200	2235	33.85
5	5	28	180	70	1079	1099	2250	34.59
6	5	34	175	73	1165	1175	2243	32.05
7	5	48	183	85	1182	1189	2300	31.58
8	5	25	198	95	1268	1248	2504	29.44
9	5	36	183	94	1260	1272	2537	29.64
10	2	31	180	83	1141	1186	2060	32.73
11	5	68	180	82	1136	1226	2367	32.87
12	4	20	185	77	1023	1132	2077	36.49
13	4	27	180	77	1073	1144	1998	34.79
14	4	35	180	73	1002	1032	1994	37.26
15	4	27	185	93			2134	
16	4	32	193	84	1082	1088	2074	34.5
17	3	30	175	82			2036	
18	3	39	168	58			2174	
19	3	33	175	84			2135	
20	3	25	183	84			1953	
21	1	27	180	79			1951	
22	5	35	178	77	1257	1330	2519	29.7
23	4	25	183	84			2466	
24	5	44	170	68			2514	
25	5	28	170	57	1108	1132	2160	33.69
26	4	23	178	68			2696	
27	5	34	173	93			2625	
28	3	31	193	79	1022	1073	2109	36.52
29	5	27	183	86			2350	
30	5	18	178	73			2301	

ID	V8.2(km/h)	V16(km/h)	HR16	HR8.1	HR8.2	La8.1	La8.2	Peak La
1	33.97	35.4	180		185	10.7	11.5	11.5
2	33.97	34.88	174		178	12.2	3.6	12.2
3	31.62	34.22	172		170	11.2	14	14
4	31.12	33.4	187		188	7.3	2.9	7.3
5	33.97	33.19	188	191	185	9.4	11.7	11.7
6	31.78	33.29	194	183	186	2	9	9
7	31.41	32.47	186	186	190	3	8	8
8	29.91	29.81	175	166	172	11.3	7.7	11.3
9	29.35	29.43	171	163	166	10.8	12.9	12.9
10	31.47	36.25	192	169	175	6.5	4.7	6.5
11	30.46	31.55	183		173	2	10.2	10.2
12	32.98	35.95	165	175	142	5	4.9	5
13	32.63	37.38	177	189	181	13.8	9.5	13.8
14	36.17	37.44	195	197	197	11.6	9.3	11.6
15		35	190					
16	34.32	36.01	186	175	179	10.8	12.1	12.1
17		36.67	183					
18		34.42	187					
19		34.98	186					
20		38.23	180					
21		38.28	176					
22	28.08	29.64	205	197	198	13.7	13.2	13.7
23		30.28	182					
24		29.7	170					
25	32.98	34.56	196	187	190	8.1	11.9	11.9
26		27.69	200					
27		28.45	184					
28	34.8	35.4	199	180	182	15.2	11.2	15.2
29		31.78	186					
30		32.45	181					

ID	CV	Recovery%	AWC	Conconi AT	4mM AT	Race (min)
1		1.55		33.1		
2				34.1		
3		2.12				
4	33	8.08	0.165121			
5	31.9	1.82	0.506385	27.4	29.3	
6		0.85				
7		0.59		29	27.7	
8				32.2		
9	29.3	0.94	0.085804		25.1	
10		3.79				
11	30.2	7.34	0.497411	25.7	24.5	
12	35.4	9.63	0.189571		34.6	
13		6.21				266
14		2.91		33.8	33	
15						
16		0.55		32.2		285
17						
18						
19						
20				37	35.1	270
21						
22	29.6	5.45	0.025536		28	
23				33.8		
24				30.6	31.9	343
25		2.12		30.6		319
26						
27						
28	34.3	4.75	0.38542	29	28.6	
29				25.7	25.3	355
30						

APPENDIX B

INFORMED CONSENT FORM

Subject's Name: ________________________________ Date: ________________

Title of Study: Factors Related to Bicycle Racing Performance

Principal Investigator: Vesa Naukkarinen

Co-Investigators: David W. Hill PhD, David Walters, and LeRay Ward

Before agreeing to participate in this research study, it is important that you read and understand the following explanation of the proposed procedures. It describes the procedures, benefits, risks, and discomforts of the study. It also describes the alternative treatments that are available to you, and your right to withdraw from the study at any time. It is important for you to understand that no guarantees or assurances can be made as to the results of the study.

PURPOSE OF THE STUDY AND HOW LONG IT WILL LAST:

The purpose of this study is to determine if results of field tests are related to performance in mass-start long-distance bicycle races. Participants will attend three tests sessions, each about one hour long, in a five-week period.

DESCRIPTION OF THE STUDY INCLUDING THE PROCEDURES TO BE USED:

Each cyclist will perform three tests, all on the 0.9-mile Renner Road loop that club members regularly use for training rides and criterium races. There will be two time trials and one Conconi incremental test. The order of the tests will be based on weather and availability of the testing facilities. Different cyclists may perform the tests in a different order. All cyclists will be asked to provide this season's race results.

Cyclists are asked to be well rested for the testing sessions, and to eat only lightly in the hours before testing. Adherence will be verified before each test. In addition, athletes are asked to "give 100%" in the tests. If athletes *don't* follow these guidelines, the research will be useless and results will be meaningless.

continued on next page

Subject's Name: ______________________________ Date: ______________

Title of Study: Factors Related to Bicycle Racing Performance

Principal Investigator: Vesa Naukkarinen

Co-Investigators: David W. Hill PhD, David Walters, and LeRay Ward

DESCRIPTION OF THE STUDY *continued*

Time trial #1. After an individualized warm up, the cyclist will ride 16 loops of the 0.9-mile Renner Road course, as fast as possible. This is an individual time trial, with no drafting. Cyclists will use their racing bicycle, and will wear a Polar heart rate monitor. As soon as the time trial is completed, one of the cyclist's fingertips will be pricked with a sterile disposable lancet, and one drop of blood will be collected for determination of blood lactate concentration.

Time trial #2. This test involves two all-out individual time trials separated by a 3-minute recovery. Cyclists will use their racing bicycle, and will wear a Polar heart rate monitor. After an individualized warm up, the cyclist will perform 8 loops of the 0.9-mile Renner Road course as fast as possible. As soon as this first time trial is completed, one of the cyclist's fingertips will be pricked with a sterile disposable lancet, and one drop of blood will be collected for determination of blood lactate concentration. Exactly 3 minutes after completion of the first ride, the cyclist will begin a second identical time trial, after which another drop of blood will be obtained. It is important that the first 8 loops be as fast as possible … don't hold back and try to save something for the second time trial, because … this is a test of recovery, not pacing!

Test #3 (Conconi / Lactate threshold test). This test involves 8 to 10 loops of the 0.9-mile Renner Road course, each separated by a 1-minute rest period. Cyclists will use their racing bicycle, and will wear a Polar heart rate monitor. Speed for the first loop will be individually determined for each cyclist (approximately 4 mph below his or her calculated lactate threshold velocity). Speed for each successive loop in this test will be about 2 mph faster than the previous. As soon as each loop is completed, one of the cyclist's fingertips will be pricked with a sterile disposable lancet, and one drop of blood will be collected for determination of blood lactate concentration. Tests will be terminated when there is a marked increase in the blood lactate concentration (i.e., when the athlete's speed has exceeded his lactate threshold velocity).

Subject's Name: ______________________________ Date: _______________

Title of Study: Factors Related to Bicycle Racing Performance

Principal Investigator: Vesa Naukkarinen

Co-Investigators: David W. Hill PhD, David Walters, and LeRay Ward

DESCRIPTION OF PROCEDURES / ELEMENTS THAT MAY RESULT IN DISCOMFORT OR INCONVENIENCE:

All three tests require all-out efforts. Cyclists can expect to experience all the discomforts of a race, including difficulty breathing and muscular pain.

DESCRIPTION OF THE PROCEDURES / ELEMENTS THAT ARE ASSOCIATED WITH FORESEEABLE RISKS:

Providing the one-drop fingertip blood samples is associated with the risk of pain, bruising, and infection. To minimize risks, samples will be obtained using single-use sterile disposable lancets.

Time trials on the road are associated with the risk of crashes, possibly resulting in scrapes, cuts, broken bones, or head or spinal injury. To minimize this risk, time trials will use a staggered start (2 minutes between cyclists) and drafting will not be permitted. In addition, the course will be visually inspected beforehand, and any visible obstacles will be removed, and testing will be performed only when the road surface is dry and the wind is light.

The three all-out exercise tests are associated with the risk of an abnormal cardiovascular response, of an abnormal blood pressure response, and even of a heart attack. To minimize these risks, we have recruited only cyclists who have been training and racing for at least one year, have no history of abnormal exercise responses, and pass the Physical Activity Readiness Questionnaire (Par-Q) recommended by the American College of Sports Medicine (ACSM). During the outdoor time trials, investigators will carry portable cellular phones during time trials to be used in case of emergency.

Subject's Name: ____________________________ Date: ______________

Title of Study: Factors Related to Bicycle Racing Performance

Principal Investigator: Vesa Naukkarinen

Co-Investigators: David W. Hill PhD, David Walters, and LeRay Ward

BENEFITS TO THE SUBJECTS OR OTHERS:

Subjects will be adult competitive cyclists who are seeking knowledge about their sport-specific fitness … they will learn their lactate threshold velocity from the Conconi incremental test, they will learn their critical velocity (maximal lactate steady state velocity) from the results of the 8-loop and 16-loop rides, and they will learn about their ability to recover from their performance in the second 8-loop ride.. If our hypothesis is correct, and time trial data can provide information related to sport performance, then the athletes will have a method of evaluating their own fitness without the need for expensive lab tests.

CONFIDENTIALITY OF RESEARCH RECORDS:

In all databases, participants will be identified only by a code number. In any publications, participants will not be identified by name. Either group mean data or anonymous individual data (e.g., in scatterplots) will be presented. The only exception to confidentiality is that each athlete's results will be shared with his or her personal coach.

REVIEW FOR PROTECTION OF PARTICIPANTS:

This research study has been reviewed and approved by the UNT Committee for the Protection of Human Subjects (940) 565-3940.

Subject's Name: ________________________________ Date: ______________

Title of Study: Factors Related to Bicycle Racing Performance

Principal Investigator: Vesa Naukkarinen

Co-Investigators: David W. Hill PhD, David Walters, and LeRay Ward

RESEARCH SUBJECTS' RIGHTS:

I have read or have had read to me all of the above. ________________________ has explained the study to me and answered all of my questions. I have been told the risks or discomforts and possible benefits of the study.

I understand that I do not have to take part in this study, and my refusal to participate will involve no penalty or loss of rights to which I am entitled. I may withdraw at any time without penalty or loss of benefits to which I am entitled. The study personnel can stop my participation at any time if it appears to be harmful to me, if I fail to follow directions for participation in the study, if it is discovered that I do not meet the study requirements, or if the study is canceled.

In case there are problems or questions, I have been told I can call Dr. Noreen Goggin, KHPR Graduate Co-ordinator at telephone number 940-565-2212.

I understand my rights as a research subject, and I voluntarily consent to participate in this study. I understand what the study is about and how and why it is being done. I will receive a signed copy of this consent form.

Subject's Signature: ______________________________ Date: ______________

Witness's Signature: ______________________________ Date: ______________

For the Investigator or Designee:

I certify that I have reviewed the contents of this form with the person signing above, who, in my opinion, understood the explanation. I have explained the known benefits and risks of the research.

Principal Investigator's Signature: ______________________ Date: ______________

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