Comparison of 30 second cycling sprint field tests with the Wingate Anaerobic Power Test

Walter Carl Ammons

The University of Montana

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A Comparison of 30 Second Cycling Sprint Field Tests
with the Wingate Anaerobic Power Test

by
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B.S., University of Montana
1981

Presented in Partial fulfillment
of the Requirements for the Degree of
Master of Science
UNIVERSITY OF MONTANA
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Approved by

[Signatures]
Chair, Board of Examiners
Dean, Graduate School

Date
July 1, 1991

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ABSTRACT

Ammons, Walter Carl, F., Master of Science, September, 1990 Health and Physical Education

A Comparison of 30 Second Cycling Sprint Field Tests with the Wingate Anaerobic Power Test (32 pp.)

Director: Kathleen E. Miller, Ph.D.

A comparison of similar duration field and laboratory sprint tests was conducted to examine the similarity of standing and sitting test protocols. The need for examining the similarity of controlled environment laboratory tests such as the Wingate Anaerobic Power Test (WnAT) with field tests is seen in the general literature. Use of indoor laboratory tests to help ascertain the fitness level of cyclists is very important to the athlete and coach. Systematic evaluation of cyclist's fitness throughout the racing season and off season would enable the careful design of optimal training schedules for cyclists.

The scope of this research was to examine the similarity of a 30 second laboratory test with a 30 second field test. Secondary research questions looked at were the similarity of standing and sitting laboratory sprint tests at two different resistance settings (normal and +5%) with corresponding body position field tests on flat or 5% incline hill.

From a subject pool of 50 subjects, 29 successfully completed all of the lab and field tests. Correlational analysis of the different tests revealed similarities between increased workload of hill sitting and flat sitting field tests, the increased workload standing vs normal standing WnAT, and the increased workload sitting vs normal sitting WnAT. Finally all flat field tests were significantly correlated with the standing and sitting normal WnAT as well as the +5% increase WnAT. Field sprint sitting and standing tests were there significant correlations. Increased resistance lab sprint tests correlated with with standard resistance setting sprint lab tests. Standing and sitting field sprint tests did not correlate with any lab sprint tests. The flat sprint field tests correlated with all the lab sprint tests. Non-significant standing field tests suggest that a greater degree of skill complexity may be required to complete the standing test which requires a greater degree of muscular involvement when sprinting (supporting, as well as propelling themselves). The results indicated the important relationship of designing specific duration tests to test specific power measures in human subjects.
ACKNOWLEDGEMENTS

The author wishes to express his appreciation to Drs. Kathy Miller, Richard Lane, Michael Zupan, Don Latham, Thomas Whiddon, and Lawrence Burger for their continued inspiration and encouragement. Special thanks to the Missoula, MT; Spokane, WA; and Salt Lake City, UT; area cyclists for their persistence and interest in the completion of this research.

W.C.F.A
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Chapter One
THE PROBLEM

Introduction

In the last decade, the Wingate Anaerobic Power Test (WnAT hereafter) has been used extensively to evaluate the relative power capacities of individuals in many different physical activities such as wheelchair athletes (6), paraplegics (8), runners (17,30,53), speed skaters (55), nordic ski racers (56), racing cyclists (57), swimmers (30,45,59), training effects in children (25,39,40), mature athletes (13), and male vs female athletes (42). Internal influences such as acid base shifts in blood Ph (47) or dehydration (15) and external influences such as environmental changes in temperature, humidity (21,22), and level of aerobic conditioning (4) also play a role in physical performance.

The WnAT is most useful in evaluating several short term anaerobic power modalities. These are, 1) the Peak Power for the first five seconds of this 30 second test, 2) the Anaerobic Capacity or average power per five second period, and 3) the Power Decline or decrement between the peak five second power interval and the final five second power interval (27,29). These modalities have been used in evaluating a variety of different subjects in a given population of cyclists. Test subjects in these studies have been evaluated for these relative power modalities and could therefore be compared with other populations. Bar-Or (11), Cumming (16), and Inbar (27) refined the WnAT 30 second bicycle ergometer test at the Wingate Institute in Israel.

In the original studies, these authors examined the explosive strength and anaerobic power capacities of children and adults (12). Bar-Or (11,55) summarized the correlation of WnAT with other physiological tests (see Table 1).

<table>
<thead>
<tr>
<th>WnAT Modality</th>
<th>Field Test</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anaerobic Capacity(AC)</td>
<td>vs VO₂</td>
<td>0.86</td>
</tr>
<tr>
<td>AC</td>
<td>vs sprint “prologue”</td>
<td>0.86</td>
</tr>
<tr>
<td>AC</td>
<td>vs 25m sprint run</td>
<td>0.87 - 0.90</td>
</tr>
<tr>
<td>AC</td>
<td>vs marathon</td>
<td>0.82</td>
</tr>
<tr>
<td>Power Decrement(PD)</td>
<td>vs Margaria stair run</td>
<td>0.79</td>
</tr>
<tr>
<td>PD</td>
<td>vs “court” sprint run</td>
<td>0.86</td>
</tr>
<tr>
<td>PD</td>
<td>vs fiber type</td>
<td>0.60 - 0.75</td>
</tr>
</tbody>
</table>
The correlations range from invasive techniques such as muscle biopsy ($r = 0.60-0.75$) to noninvasive "sprint" field tests ($r = 0.86$). What this indicates is that the WnAT can be used to predict relative field tests of similar duration.

Limitations on lab test prediction of field data are associated primarily with duration and intensity of the respective test modalities. For the WnAT, Peak Power, Anaerobic Capacity, and Power Decrement are distinguished by differences in duration of power production (3,19,36). Peak Power (PP), by definition, is that five second period in which the most revolutions are recorded of the six consecutive five second periods. PP has the highest correlation with field tests that are of extremely short duration (of 10 seconds duration). Ability to predict the longer duration field tests is less highly correlated (9). Anaerobic Capacity (AC) seems to be a better predictor of longer duration field tests that approach 30 seconds in length. Power Decrement (PD) also seems to be a good predictor of longer duration (up to 30 seconds) field tests where there is a lot of resistance to the effort. Another appropriate measure might be Total Power (TP) produced in the 30 seconds of the ergometer sprint test.

Additionally, body position seems to influence performance. In several articles dealing with maximal VO$_2$, Kelly, et al. (37) and Van Dorn (57) found that standing and sitting position elicited different maximal VO$_2$ results. They hypothesized that what was important was that the size of the muscle mass (lean body weight) utilized was a better predictor of maximal VO$_2$. This could also be due to other physiological (33) and skill variables, including genetic influences, the level of conditioning, and technique as possible contributing components of performance along with psychological factors such as motivation. Research using the Wingate test shows a similar relationship of muscle volume (1,55) to both Anaerobic Capacity and Power Decrement/decrease. However, results in Hunter, et al (26) showed no difference between lean body mass and performance.

Additional test design difficulties arise from such influences as motivational level (ability to endure discomfort), efficiency of rider (technique), and training/and racing schedule conflicts (when their next race occurs) (24).

The primary purpose of this research was to investigate the ability of standing and sitting positions in the WnAT to predict sprint field test performance. Total Power (TP) output in WATTS for 30 seconds (calculated as: Total Number of RPMs * Kilopound resistance * 11.765 = TP) (51) in both standing and sitting positions on the WnAT at two different resistance settings were compared with similar duration field tests on hilly and flat terrain.
For the 30 second duration sprint field tests, the units of measurement are either time or distance. To make units of similar type, it was useful to calculate distance traveled in the 30 seconds of the sprint test (as it is not practical to measure exact distances traveled on the bicycle in 30 seconds). The distance traveled could be compared with the total power produced in the 30 seconds of the WnAT.
Statement of Problem

This research was designed to examine the relationship of sitting and standing positions on the WnAT and sprint field tests in racing cyclists of varying abilities. In examining these different body positions, the author hopes to devise test criteria that are appropriate for predicting field performance in the cycling population. Two subproblems were also included. (1) test protocol (standing and sitting) as a predictor of field test performance and (2) the use of a five percent increase in resistance applied or normal resistance on the WnAT as a predictor of field test “sprint” performance on hill and flat terrain for .2 miles (about 320 meters).

Hypothesis

Null Hypotheses:
I. There are no significant correlations between similar types of WnAT and Field test body positions and increased resistance.
II. There are no significant correlations between similar body test positions for the Hill and Flat Field tests, WnAT tests, and the increased resistance.
   (1). There is no significant relationship between the standing (weight bearing and sitting (weight supported) positions in the WnAT and actual performance in similar duration field tests.
   (2). There is no significant relationship between increased resistance in the WnAT and the standing and sitting Hill or Flat Field tests.

Alternative Hypothesis:
There is a significant relationship between the WnAT variables of standing and sitting positions, increased resistance, and correspondingly similar field test position performances. The level of significance for the correlations between WnAT predictor variable Total Power, position, and resistance is set at the \( p < .05 \) level.
Delimitations

The delimitations of this study are as follows:

1. The sample population was limited to cyclists with at least six months of training prior to the testing.
2. The protocol for the standing WnAT was identical to the protocol for the sitting WnAT with the exception of body position.
3. The standing protocol for the standing field test was identical to the protocol for the sitting field test with the exception of body position.
4. The subjects stated that they were sufficiently interested in participating in this research.

Limitations

The hill and flat sprint field tests could not represent ideal environmental conditions but were as similar as local conditions would provide.

Assumptions

The assumptions are as follows:

1. All subjects gave a maximum effort on all tests.
2. These results apply for the subject sample only.
3. All test procedures were identical and were not modified for the duration of the testing.
Definitions (**)

WINGATE ANAEROBIC POWER TEST (WnAT)- a single 30 second sprint on a bicycle ergometer against a predetermined percent of the subject's body weight in kilograms (i.e., a 70 Kg person = .083 x 70kg = 5.8 KP setting). In this research there will be either a normal (no increase) or 5% increase in the above calculation for the resistance setting (designated as such).

SEATED PROTOCOL- Subject warms up at 1 KP for 5 minutes in a seated position and on the Experimenter's command starts sprinting while remaining seated for the duration of the 30 second test.

STANDING PROTOCOL- Subject warms up at 1 KP for 5 minutes in a seated position and on the Experimenter's command, stands and sprints in a weight bearing position (supported by the body's musculature, connective tissue, and bone structure) for the duration of the 30 second test.

PEAK POWER (PP) (from standard 5 second measurements)- The 5 second period in which the greatest number of pedal revolutions is recorded, thereby indicating the highest power calculation per 5-second period for that test.

ANEROBIC CAPACITY (AC) (from the standard WnAT measurements)- The average of all six 5 second periods where the number of pedal revolutions are recorded in the WnAT.

POWER DECLINE (PD) (from the standard WnAT measurements)- The difference between PP and the final five second period (Also known as Power Decrement).

TOTAL POWER(in WATTS) - The total amount of power produced in the 30 second duration of the WnAT. This is calculated by multiplying the number of pedal revolutions in 30 seconds * Kilopond Resistance setting * 11.765 (a constant).

** these definitions were modified from those found in References 2,9,10,12,14,16,18,19,20, and 28.
SCHWINN BIODYNE BICYCLE ERGOMETER

Figure 1.
Chapter Two
The Review of Related Literature

Physiological Overview

The human body has two basic energy mobilization processes that contribute to athletic performance, the anaerobic and the aerobic metabolic (energy producing) pathways. Anaerobic metabolism can use three sources to provide energy to the cell (7). These sources are ATP, CP, and glycolysis. Which of these energy sources is used at any time is dependent on the intensity and duration of the desired power output. The greatest output comes in the form of ATP and CP, with glycolysis having the lowest instantaneous anaerobic power output. In terms of duration of output, there is enough ATP stored in each muscle cell for 3 to 4 seconds of work. When ATP is exhausted, the cell switches to CP, creatine phosphate, which is pooled within the cell. As the time of the activity increases so does the total energy expended. While ATP and CP is being depleted in the first seconds, the conversion of glucose to pyruvic/lactic acid begins. In glycolysis, an all out effort can be extended to about 90 seconds (20,23,42,47,50,59). The finite supplies of these three energy sources results in the limited amount of time available for energy output at a high level. Activity intensity must eventually be reduced because the energy output can no longer be produced at the same high intensity of output. Lower output energy source aerobic pathways are then recruited for continuation of muscular activity but at a lower intensity. From the continuation of the process of anaerobiosis through the production of pyruvic/lactic acid, and into the respiratory pathways, there is a brief increase of 13 times the original total energy available for output that lasts for up to 180 seconds before exhaustion of the energy supplies. In aerobic metabolism the energy sources are glucose, muscle glycogen, liver glycogen, protein, and free fatty acids. With abundant supplies of oxygen and substrate sources of energy, the activity can be carried on for long periods of time without appreciable reductions in available energy supply (20,38). The ability of muscle tissue to generate anaerobic power for efforts of four minutes is from the glycolitic pathway. This includes those sports requiring repeated high intensity efforts at intervals throughout the duration of the event, as in bicycle racing. Anaerobic power is defined as the production of force through a given distance in as short a time as possible or the power developed with rapid, running approach (3). In the case of bicycle racing the definition would be modified to power resulting from a rapid, vigorous body movement from a previously steady aerobic state, in as short a time as possible. When the generation of power is required beyond the three minute range, the activity is considered aerobic and is defined as the maximum rate at which oxygen can
be consumed (48,50,52). Anaerobic metabolism is actually two different processes (physio-
chemical pathways) and they are most easily explained using a time scale. The anaerobic 
system works predominantly from approximately 0 to 5 minutes. The immediate energy 
source is adenosine triphosphate (ATP) and creatine phosphate (CP) metabolism and the 
short term energy source is the glycolytic metabolism. Thereafter, the aerobic system 
supplies energies for efforts lasting approximately 5 minutes or more. The anaerobic 
process utilizes stored fuels from various sites in the body such as the muscles and the liver, 
and is characterized by the relatively finite amount of energy available from these storage 
sites, a high energy output, and resultant rapid depletion during vigorous activity.

Methodological Overview

Methodologies for testing aerobic and anaerobic power generation capacity have been 
refined greatly over the last decade. The aerobic capacity is usually measured as VO\textsubscript{2} in ml/
Kg/min and is tested using a variety of equipment and measurement protocols. For example, 
in the Astrand and Balkie protocols (2,38), the motorized treadmill and the bicycle ergometer, 
together with an open circuit gas analyzer are used to collect a subject’s expired gases (CO\textsubscript{2}) 
during a graded exercise test employing a known resistance progressively increased after 
fixed intervals of time. The Astrand or Balkie protocols measure a maximum aerobic output 
and can be predicted from the relationship of lean body mass, resistance, and time. 
Anaerobic capacities can be tested using the Margaria stair run test or the Wingate 
Anaerobic Power Test (10). These two different procedures test the body’s ability to produce 
power from ATP-CP and glycolytic energy pathways and are expressed in units of kg-m/sec 
for the stair run and in Watts for the Wingate which can be converted to similar units (5). For 
example in the Margaria stair run, the subject’s power output can be calculated as POWER 
= MASS x VERTICAL DISPLACEMENT / TIME. Hypothetically this procedure tests both the 
ATP-CP and glycolytic energy producing pathways, but the test only lasts 1-3 seconds which 
is the duration of the ATP-CP and not the glycolytic pathway. This short activity duration 
makes the assumption about ability to test energy sources with durations greater than 5 
seconds rather questionable. Usage of ATP-CP as an energy source occurs in the first 10 
seconds and the glycolytic energy pathway occurs from approximately 10 seconds to 180 
seconds. Thus, the Margaria stair run would not be an appropriate test of glycolytic activity 
(38). The Wingate Anaerobic Power Test (WnAT) is another example of a very well designed 
method of measuring several power measures of an individual’s power producing abilities. 
This test can be used to study the power output of an athlete giving a PEAK POWER (at the 
end of the first 5 seconds) measurement, a MEAN POWER measurement (average of all six
5 second periods), a POWER DECREMENT (a percent drop in the power, per 5 second period, between the peak power interval and the final 5 second interval) measurement, and TOTAL POWER for 30 seconds (3,5,27). The 30 second duration of the WnAT would seem to involve both the ATP-CP and glycolytic energy pathways, therefore making it a suitable procedure to use as a valid test of power produced by the anaerobic pathways. The question of how specific a test must be has been researched for many years (5,11,12,27,29,32,34,36). In testing aerobic capacity, modifications in both test equipment and in protocol have been attempted to make the VO$_2$ testing a more valid measure of aerobic power for specific activities (34,37,49,50,57,58). Specific equipment for cyclists would be the bicycle ergometer for testing maximal O$_2$ uptake (VO$_2$). The Wingate Anaerobic Power test on the bicycle ergometer seems the most preferred for seated cyclists (14,43,44). There are postural preferences (standing vs seated) among the various competitive cyclists at all levels of ability, especially in situations such as sprinting or in climbing hills that demand increased power output. In WnAT, there are difficulties when subjects stand, stemmming from recruitment of other stabilizing muscle groups. The athletes' arms have the additional burden of stabilizing them in an upright position while pedaling against the heavy resistance required for the Wingate Anaerobic Power Test (10,12). Lamb (38) stated that a range of 0.083% to 0.092% of the athletes' body weight in kilograms is to be used to calculate the ergometer resistance level but does not intimate exactly why there should be such a range. Several other studies indicated that there are no significant differences in mean power measurements; only those in peak power when using different resistance settings (18). Bar-Or indicated that there is indeed a range of settings that can be used with Pedal Ergometers (Table 2).

Table 2.

<table>
<thead>
<tr>
<th>Body Weight Kg</th>
<th>KP setting &amp; Percentage of Body Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>KP High%</td>
</tr>
<tr>
<td>65-69.9</td>
<td>5.0 (.077-.072)</td>
</tr>
<tr>
<td>70-74.9</td>
<td>5.5 (.079-.073)</td>
</tr>
<tr>
<td>75-79.9</td>
<td>5.75 (.077-.072)</td>
</tr>
<tr>
<td>80-84.9</td>
<td>6.25 (.078-.074)</td>
</tr>
<tr>
<td>&gt; 85</td>
<td>6.5 (.076)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>KP Low%</th>
</tr>
</thead>
<tbody>
<tr>
<td>65-69.9</td>
<td>3.5 (.054-.05)</td>
</tr>
<tr>
<td>70-74.9</td>
<td>3.95 (.056-.053)</td>
</tr>
<tr>
<td>75-79.9</td>
<td>4.0 (.053-.05)</td>
</tr>
<tr>
<td>80-84.9</td>
<td>4.25 (.053-.05)</td>
</tr>
<tr>
<td>&gt; 85</td>
<td>4.5 (.053)</td>
</tr>
</tbody>
</table>

These ranges are lower than those used in the University of Montana Human Performance Lab. Reasons for these differences remain unclear, they might possibly be due to
different body weight having varying effects on ability to pedal against the fixed resistance used by the United States Ski Team (56). The heavier subjects and the lighter subjects have more difficulty with the resistance setting chosen (18), possibly indicating a bias against the subjects at the two weight extremes. For this study a setting of 0.083% was used for the sitting and standing position tests (this is also the setting that the United States Ski Team uses for their fitness testing (56)). This fixed resistance setting, although seemingly biased, is a standard used in testing by the United States Ski Team and has been used for some time in the testing of athletes. Since the seated posture is more natural for cycling, a comparison of sitting and standing postures for different cyclists could be made. Modifying the procedure with a change in the body position on the ergometer to either sitting (weight supported) or standing (weight bearing) would seem to be most appropriate comparison of ability differences among cyclists. Such a modification could help develop a test protocol for cyclists that might indicate areas of strength or weakness that could be improved with changes in training. Performing the WnAT in an erect (standing) position might yield results indicating a cyclist's preference to stand when the energy (power) demands are too great to remain seated. However, the entire question might also be affected, as Kelly, et al (37) suggested, by the recruitment of additional muscles from the upper body for support, rather than from the specificity of the trained muscles for the activity that have increased their anaerobic power. Intuitively it would seem that the cyclist may not have a sufficient amount of muscle mass and biomechanical advantages to enable him to climb quickly while in a seated position as in a standing position at the higher energy outputs of a 30 second sprint. In the standing position the rider can bring biomechanical advantages, body weight, and muscular strength into use thereby decreasing the time in which he covers the sprint distance and possible recovery time from the effort (60). Disadvantages of using the standing position with cyclists would be the relative fitness level, motivation, and added demands of having to recruit musculature to support the body as well as produce the power to fulfill the requirements of a particular activity.
Chapter Three
METHODOLOGY

Subject Selection

Thirty male subjects from the communities of Missoula, Montana, Spokane, Washington, and Salt Lake City, Utah volunteered to participate in this study. All subjects had spent at least six months training prior to their participation in this research. The subjects met the following criteria:

1. Subjects were male, between the ages of 18 and 45 years old.
2. Subjects had trained for a minimum of approximately seven months (27 weeks) prior to volunteering to participate in this research.
3. Subjects stated that they were capable of maintaining a pace of at least 15mph on a short hill.
4. Subjects signed an informed consent form as specified by the University of Montana Human Subjects Committee.
Testing Procedures

Preliminary Testing

The standard WnAT was administered to six subjects. Each subject completed three WnAT sprint tests at increases of +0%, +5%, and +10% of the standard resistance setting of .083 * Kg Body Weight.

Standard Field Test

Field tests consisted of an all out sprint of approximately .2 mile, or about 320 meters on either flat or hill (approximately 5% grade) terrain.

Standard Lab Test

The Lab tests consisted of four standard WnAT's administered so that each subject did sprints in both standing and sitting positions as well as normal and +5% increase resistance setting changes.

Questionnaire

The questionnaire was six questions concerning the relative amount of training and racing prior to the subject's participation in the present study (see Appendix G). Results were not tabulated as there were insufficient responses in completing and returning the questionnaire to the author. Out of a total of 29 subjects who did complete all of the testing, only 11 actually returned the questionnaire. Attempts to achieve compliance, such as follow up letters or calling the subjects on the phone, were unsuccessful in achieving a higher level of responses. Reasons for why this was the case, were personal time conflicts such as distractions from jobs, school, training, and racing.
Instruments and Test Protocol

Preliminary and Main Study Tests

Instruments used were a Schwinn Biodyne bicycle ergometer fitted with an electronic timing device utilizing a Radio Shack Model-4P Microcomputer. The timing device used consisted of a simple Hall-effect magnetic switch which sensed the onset of a strong magnetic field from a magnet secured to the crank of the bicycle ergometer. Each time the crank completed a revolution the signal produced by the Hall-effect switch was filtered electronically and the resulting signal was sent to the Radio Shack 4-P computer where the internal clock of the CPU was sampled via a special machine language interrupt program which recorded the consecutive times of each revolution for a thirty second period of time. Times for each pedal revolution were obtained and summed to obtain the number of revolutions that occurred in each of the six 5-second counting periods (as done in the standard WnAT using an individual to hand time and an individual to count the number of revolutions in each five second period) for the 30 second test time. (See Appendix D. For a more detailed description of actual test protocol.)

Field Test

Subjects used their own bicycles. Gearing was restricted to a standard 52 tooth chainring in the front and the 17 tooth cog on the freewheel of the bicycle for all subjects. This is approximately 84.2 inches of travel for each pedal revolution.
Chapter Four

RESULTS AND DISCUSSION

Statistical Analysis
The statistical comparisons were done using a Pearson Product - Moment correlation. The use of the Pearson correlation enables each individual group to be compared with all other individual groups, thus showing which of the comparisons are statistically correlated. A summary of group comparisons are seen in Table 3. The table of correlations are as follows for comparison groups of hill, flat, +5%, and 0% (normal setting). Comparisons are designated by the numbers 1 - 8.

Table 3.

<table>
<thead>
<tr>
<th></th>
<th>Hill</th>
<th>Flat</th>
<th>+5%</th>
<th>0%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ST</td>
<td>SI</td>
<td>ST</td>
<td>SI</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>.7775**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>.2441</td>
<td>.1207</td>
<td></td>
<td></td>
</tr>
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** p < .01
* p < .05
N = 29

ST = Standing
Hill = Hill .2 mile Sprint
SI = Sitting
Flat = Flat .2 mile Sprint
+5% = 5% increase in resistance (normal setting)
0% = 0% increase in resistance (normal setting)

The results are divided into two sets of comparisons according to the original hypotheses. The first set was to show the relationship of the same position for hill with flat field test sprints and increased resistance with normal resistance WnATs. The second set of comparisons was to examine the relationship of similar position field test with WnAT. The comparisons are organized in the Table 4.
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** p < .01
* p < .05
N = 29

ST = Standing  Hill = Hill .2 mile Sprint
SI = Sitting  Flat = Flat .2 mile Sprint
+5% = 5% increase in resistance
0% = 0% increase in resistance (normal setting)
**Hypothesis I.**

The results show that with the exception of the Standing Hill field test vs Standing Flat field test the comparisons all correlated at least at the $p < .05$ level. This indicates that there was similarity between Sitting Hill sprints and the Sitting Flat sprints. Also the two sets of WnAT tests were significant related, thereby rejecting the null hypothesis for all but the Standing Hill field test vs Standing Flat field test comparison.

**Hypothesis II:**

The Flat Field test comparisons with the Lab test of similar position show that the Flat Sitting and Standing tests correlated with corresponding position WnATs thereby rejecting the null hypothesis. However, the Hill Field tests did not correlate with any of the WnATs of similar position. The Sitting Hill Field test compared with the +5% Increase WnAT was the highest of this group of correlations, but was not significant at $p < .05$, therefore the null hypothesis cannot be rejected for these four comparisons (see Table 4).
DISCUSSION:

Hypothesis I.

Results indicate that the Sitting Hill and Flat field test sprints were correlated among all subjects, thus showing a between subject consistency for these field tests. This supports the research conducted by Ayalon, et al (3), Bar-Or, et al (9,11), Katch, et al (36), and De Bruyn-Prevost (19) showing the importance of having similar duration tests for seated subjects. The Sitting Flat field test sprint correlated with the Sitting Hill field test sprint, whereas the Standing Flat field test sprint did not correlate with the Standing Hill field test sprint. This shows the possibility that a greater degree of skill may be required when doing a standing sprint on the flat or uphill, perhaps with subjects of greater experience there might be a better correlation for the two standing tests. It is also possible that the involvement of additional muscles to help support the body in an upright position may be an important factor in performance of standing 30 second sprints. With the additional requirement of energy production for body position maintenance as well as propulsion a higher degree of specific fitness may be required. This is supported by both the standing $VO_2$ work of Van Dorn (57) and Kelly, et al, (37). Their research indicated that a relationship existed between body position and lean muscle mass. According to these authors, lean muscle mass played an important role in determining the $VO_2$ of subjects. Subjects with higher lean muscle mass produced higher maximal $VO_2$.

The sitting +5% and 0% WnAT tests showed a strong correlation as did the standing +5% and 0% WnAT tests. This would seem to indicate that there was little difference between WnAT test resistances with respect to body position. The strong correlation might indicate that the +5% increase over the normal resistance was not sufficient to simulate the resistance encountered when sprinting uphill or on the flat while either sitting or standing.
Hypothesis II.

The data in Table 4 show the hill standing and sitting field test sprints did not correlate with any of the WnATs, thus indicating support for Kelley, et al (37) and Van Dorn's (57) research that total body weight was critical in the production of power. The issue of lean muscle mass and test performance was not directly examined since the WnAT only requires the gross body weight of a test subject for power calculations. When the subjects were sprinting up a hill, there was an increased muscular demand from the increase in short term work requirements of displacing the body vertically during the 30 second sprint test. Additionally the possibility of confounding influences such as subject skill/experience level may have affected other comparison groups of subject test results. The author suspects that there might be a certain degree of skill and muscular specialization required which may make the standing test a better predictor of results for more experienced subjects and not a good predictor for the less experienced subjects. Muscular specialization is extremely important in developing efficient neuro-muscular systems. These systems become more efficient by virtue of both the reduction of antagonistic muscular action and the neurological changes improving the speed of appropriate muscle fiber recruitment.

The highest correlation ($r = .4892$) was between the flat standing field test sprint and the standing +5% WnAT ergometer test ($p < .01$), with a weaker but significant correlation ($r = .3953$) between the standing flat field test sprint and the standing 0% increase WnAT ergometer test ($p < .05$). This relationship shows that the standing position correlated well showing specificity of position to be a significant factor in designing laboratory tests that are sufficiently similar to field tests. Also, the author suggests different levels of motivation, conditioning, or skill level may have some sort of influence on these test relationships. The differences would be most apparent in the two extreme ends of the experience/learning continuum, with those at the bottom, beginner level being unable to perform either consistently or at a higher relative level to a given population of highly trained cyclists (note: I am excluding any hereditary differences as they are beyond the scope of this research). Further research is needed to examine these possible causes of these relationships and their resulting effects on the subjects tested.
Chapter Five

SUMMARY AND CONCLUSIONS

The results indicate that there are strong relationships between the sitting WnAT and field tests. In terms of energy production for the 30 second WnAT and field tests, there is strong support for the hypothesis that similar usage of ATP-CP as well as glycogen occurs in both sets of tests (3,19,36). This is indicated by strong correlations for the various sitting comparison groups between the WnATs and field tests. It would therefore be reasonable to consider the use of the WnAT as a controlled test predictor of power performance during the race season for highly skilled racing cyclists. This would be especially useful for tailoring training schedules to include more power related activities to improve power performance in racing.

General Recommendations for Research

Further research should be directed towards the problem of lean body weight and standing position laboratory and field tests. This could be done by determining the percent body fat in the test subjects as well as percent of lean muscle mass and dividing the subjects into high and low percent lean muscle mass. In examining these relationships the prediction of performance could be enhanced without having to resort to outdoor testing, which would be impractical during the winter months.

Selecting a group of subjects on the basis of experience and training level and test them monthly over a period of several years as they gain training volume and general experience, would allow for the examination of performance changes that occur in cyclists as they become more specific in musculature and neuro-muscular development.

Trained Cyclists

As training schedules become more personal in nature, there is a real need for the athlete to be able to evaluate his/her performance strengths and weaknesses. The use of the WnAT provides a method of evaluation for the improvement of individualized training schedules. This can be implemented by detecting weaknesses in the off season (Winter) and early season (early Spring) sprint performance and then correspondingly increasing either the number of repetitions per set of 30 second sprints, the number of sets of sprints, or number of days per week of sprint training. Strengths could be refined and weaknesses remedied by adaptation of appropriate training methods.
REFERENCES


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Appendix A.

Informed Consent
The purpose of this study is to examine differences in the power output of trained cyclists on two different test days for two consecutive standing and seated 30 second maximal bicycle ergometer tests and one field test day of two sets of two seated and two standing sprints on both flat and hilly terrain. I will be required to perform one set of two 30 second sprints while standing, with as much rest inbetween each sprint as the subject subjectively feels that he needs and one set of two 30 second sprints while seated. Whether I do the the seated set or the standing set will be previously determined (randomly assigned to groups). In each 30 second sprint conducted, the resistance, a setting of either .083 (standard resistance), or 5% (increased resistance *) times the subject's body weight in kilograms will be applied in the first second of each test. This test, modeled after the Wingate Anaerobic Power Test, has been found to be one of the most popular objective tests of anaerobic strength in athletes. The Wingate test is a laboratory test of exhaustive work, performed on a bicycle ergometer. Each of the two days of tests will take between 10 and 15 minutes to complete the two 30 second “sprints”. From this test I will gain an understanding of my anaerobic bicycling fitness. By completing these test sessions, I can judge whether my training program is sufficient or if aspects of my training need to be adjusted to improve my power output. My personal goals, relating to bicycling fitness, can be therefore be judged by my participating in these tests. If I experience problems, leg cramps, dizziness, or severe difficulties in breathing during the Wingate Anaerobic power tests I may terminate riding. My participation is voluntary and I am free to withdraw at any time of my choosing. If I have any questions concerning the tests they will be promptly answered by the tester. Confidentiality will be maintained in any published materials by references to me by numbers only. “In the event that you are physically injured as a result of this research you should individually seek appropriate medical treatment. If the injury is caused by the negligence of the University or any of its employees you may be entitled to reimbursement or compensation pursuant to the Comprehensive State Insurance Plan established by the Department of Administration under the authority of M.C.A., Title 2,Chapter 9. In the event of a claim for such physical injury, further information may be obtained from the University Legal Counsel.” I have read and understand the above statement and wish to participate in the study.

*(this setting will be determined by the findings of the pilot study which is similar to the actual research study test procedure proposed here, except for the use of only three different resistance settings for each of three tests.)

Subject__________________
Investigator__________________
Date________________________
Appendix B.

SUBJECT PHYSICAL CHARACTERISTICS

1. Age
   a. Mean: 26.5 years
   b. Range: 18 to 40 years

2. Body Weight (in KG)
   a. Mean: 72.4 KG
   b. Range: 57 to 87 KG

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## Appendix C.

### Data Sheets:

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Appendix D.

Instructions to Subjects for WnAT:
The Ss will be first asked to fill out the Informed Consent form. When this is done then the Ss were be instructed that after a 5 minute warmup, they are to perform two 30 second sprints with 5 mins rest between each effort followed by a 5 minute warmdown. In each “sprint” the S will be instructed to start pedaling as fast as they can against the preset resistance for each of the four 30 second “sprints”. The test, either standing or sitting, was predetermaned prior to each of test session using a random assignment of the order of presentation of the kind of “sprint” (standing or sitting). The resistance was then brought up to the required amount (.083 times the Ss’ body weight for the standing test and sitting test) within the first 3 seconds of pedaling. Timing of each “sprint” session is started when the maximum load is reached (at the end of the 3 seconds prior to the command to “sprint”). The S will be asked how they feel at the end of each of the “sprints” to determine if they should continue. Subjects were warned to discontinue if for some reason they might start feeling faint during the “sprint” and the test will be rescheduled for a later time.
Appendix E.

Wingate Anaerobic Power Test

The WnAT consists of a 30 second bicycle ergometer sprint test where the subject is instructed to bring his/her leg speed up as high as possible as quickly as they can when given the command to do so. The resistance is then quickly increased to the predetermined level using the formula:

\[
\text{Body Weight (in KG)} \times 0.083 = \text{Kilopound resistance setting}
\]

The timing is started when the subject has reached the predetermined resistance setting and continues until 30 seconds have transpired.
Appendix F.

Sprint Field Tests

1. Flat Sprint
   The flat sprint consisted of a .2 mile straight course measured by an Avocet bicycle computer odometer (calibrated using a wheel circumference chart supplied by the manufacturer).

2. Hill Sprint
   The hill sprint consisted of a .2 mile straight course measured by an Avocet bicycle computer odometer on an average grade of 5% for the test distance (calibrated using a wheel circumference chart supplied by the manufacturer).
Appendix G.

Questionnaire
The following are the questions that were asked of the subjects.

1. How many years have you been training to race your bicycle?
2. How many average months a year do you average riding a bicycle?
3. How many hours a week do you average during the following period of the year:
   - Winter (Jan-Feb)
   - Spring (Mar-May)
   - Summer (June-Oct)
   - Fall (Nov-Dec)
4. How many races did you compete in last year?
5. In what USCF Category do you compete?
6. How many top ten finishes did you have this last year?