DETERMINATION OF ANAEROBIC PERFORMANCE VIA MAXIMAL SPRINT
FIELD TEST

A THESIS SUBMITTED TO THE GRADUATE DIVISION OF
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BY
ANDREA S. HARMON

Thesis Committee:
Ronald K. Hetzler, Chairperson
Iris F. Kimura
Nathan M. Murata
MISSING PAGE NO.

AT THE TIME OF MICROFILMING/SCANNING
We certify that we have read this thesis and that, in our opinion, it is satisfactory in scope and quality of a thesis for the degree of Master of Science in Kinesiology and Leisure Science.

Thesis Committee

[Signatures]

R. K. [Chairperson]

[Signatures]

[Signatures]
ACKNOWLEDGEMENTS

~To my committee, Dr. Hetzler, Dr. Kimura and Dr. Murata, I could not have begun to finish this if it was not for your dedication and guidance. I have learned so much from working with you over the past two years. Thank you for having confidence in me.

~To my family: without your love and support none of this would have been possible. You created a foundation for me that has enabled me to reach for and get anything that I want. Though we were half a world apart in distance, you were always right here in my heart. Before leaving home you said “never give up your dreams...you can do anything you set your mind on” So in finally finishing this thesis, its time for us to follow another dream...

~Finally to my friends here, my new ohana. You are such amazing people that have taught me more then I ever could have learned in the classroom. We have been through a lot together, and I would not have wanted to go through this endeavor with anyone else.

   Bret: You became another brother to me, though we are capable of disagreeing on everything. You exposed me a whole new world. I can never thank you enough for your impact on my life. I’ll never go to a karaoke bar without thinking of you!

   Kelly: You were there for me when I needed a true friend the most, when I didn’t have anyone else to turn to. Oh the memories we created here, the penthouse will never be the same again.

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MAHALO HAWAII for creating the best two years of my life...so far!
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ABSTRACT

The purpose of this study was to compare the specificity of the WAnT and a recently developed 200 meter sprint, Hawaii Anaerobic Run Test (HART), by evaluating the performance of seventy seven male and female runners and cyclists and untrained males and females on both tests. The HART protocol consisted of a five minute warm up followed by a 200 meter sprint on a track. The WAnT was performed in the laboratory using a cycle ergometer to perform a 30 second sprint against a weighted flywheel. Finger prick blood lactate samples were taken seven minutes after completion of each test.

Pearson product moment correlation coefficients were generated comparing power data from the WAnT with velocities and momentums from the HART. Strong correlations were found between peak and mean momentum and power (r=0.82, r=0.78, respectively). Data from this study suggest that the HART is a valid field test for evaluating anaerobic power during running.
Introduction

Anaerobic power is an area in fitness testing that has been extensively studied. It is of interest due to the high energy demands in many team and individual sports. Anaerobic power is characterized by explosive spurts of energy of a short duration which rely on the adenosine ATP PCR system and the anaerobic glycolytic system for energy production. Numerous tests to assess anaerobic power have been developed; however, there are many shortcomings in these tests. For example, comparing the validity of different tests is difficult, since tests have different outcome variables, units of measurement, and not all tests involve the same metabolic systems (Patton & Duggan, 1987).

The Wingate Anaerobic Cycle test has been shown to be valid and reliable (Bar-Or, 1987) and is commonly used to assess anaerobic power in athletes. Due to specificity of training it is uncertain if the Wingate Anaerobic Cycle Test results in accurate anaerobic power values for runners. Power data from the WAnT include peak power (watts), mean power, and fatigue index. Unfortunately, existing anaerobic running test protocols do not yield data in a form which can be directly compared to the Wingate Test.

Sprint tests have been used to look at the anaerobic output in runners using elapsed time as the variable of interest (Beckenholdt, 1983; Cooper et al., 2004; Schnabel & Kindermann, 1983). Laboratory treadmill protocols have been developed to investigate anaerobic power in runners which measure oxygen uptake in ml·kg⁻¹·min⁻¹ and maximal oxygen deficit (Nummela et al., 1996). Although different anaerobic power tests have been used, problems such as the unavoidable contribution of the aerobic energy
system and to a certain degree the skill and agility required to complete tests such as the shuttle run make interpretation of the results difficult (Nummela et al., 1996)

The Margaria – Khalman step test has been a popular anaerobic power test due to its short duration, however, it is too short to measure the power of the anaerobic glycolytic system (Tharp et al., 1984). Treadmill tests have been conducted at different workloads, speeds and distances to assess work and power outputs (Baker & Davies, 2002; Basset & Boulay, 2000; Cooper et al., 2004; Maxwell & Nimmo, 1996; Moreira-da-Costa et al., 1984; Vandewalle et al., 1987). Treadmill running protocols make data collection easy, but encounter problems. Such problem include having difficulty finding their ideal pace, harder to reach maximal speed, and less energy is required for treadmill running then running on land (Schnabel & Kindermann, 1983). Therefore another test needs to be created specifically for runners, which controls for the some of the above limitations of previous anaerobic running tests.

The purpose of this study was to compare the results from the WAnT to a recently developed 200 meter sprint, the Hawaii Anaerobic Run Test (HART), by evaluating the performance of male and female subjects on both tests. Measurements of peak, mean, and percent decrease of velocity and momentum during the HART were compared to peak, mean and percent decrease in power from the WAnT. Additionally, post exercise blood lactate values from the WAnT were compared with post blood lactate values from the HART.
Method

PARTICIPANTS

Seventy-seven males and females participated in this study. Participants ranged from untrained but physically active to trained. The subjects were recruited from the community and the general university population. Demographic data including height, weight and skinfold measurements were obtained in the laboratory.

RESEARCH DESIGN

Anaerobic power and capacity was determined using the Wingate Anaerobic Test (WAnT) and the Hawaii Anaerobic Run Test (HART). Peak velocity, mean velocity, percent decrease in velocity, peak momentum, and mean momentum from the HART were compared to peak power, mean power and percent decrease in power from the WAnT.

WINGATE ANAEROBIC TEST: This 30s maximum sprint was performed on a Monark 834 cycle ergometer (Monark, Stockholm, Sweden). Participants warmed up for 5 minutes with 1kg resistance on the flywheel, they were instructed to pedal at varying speeds including short sprints. The seat height was adjusted for each person and their toes firmly strapped into a toe clip on the pedals. Resistance on the flywheel was set to .075 percent of body weight. Participants were instructed to pedal as fast as they could, to remain seated, and not to pace themselves during the test. The test began by a verbal command of "Start pedaling, Three, Two, One, Go." Participants were able to accelerate during the countdown in order to reach their maximum speed by the time the resistance was added to the flywheel using the basket technique on the word "Go." Verbal encouragement was provided for all participants throughout the thirty seconds.
Mean power, peak power and percent decrease in power were collected each second with using a hardware software package from SMI Inc. (St. Cloud, Minnesota).

**HAWAII ANAEROBIC RUN TEST (HART):** The HART trials were performed on a Mondo track (Mondo USA, Lynnwood, WA) at the University of Hawaii, Manoa. Participants started with a five minute individual warm up. Speedtrap II (Brower Timing Systems, Draper, UT) photoelectric timing cells were placed at: 25, 50, 100, 150, 175, and 200 meters to record split times during the sprint. Participants used a standing start and began the sprints with a standard track gun start of “Ready, Set, Bang.” They were instructed to run as fast as they could, without pacing themselves, all the way through the last timing cells. Verbal encouragement was given to all participants throughout each sprint.

**BLOOD LACTATE:** Finger prick blood lactate samples were drawn from participants seven minutes following the completion of each test. Blood was mixed 1/1 with a lysing agent and stored on ice until all tests were completed and subsequently stored at -20 degrees C. The samples were then thawed and analyzed using a YSI 1500 Sport Lactate Analyzer (Yellow Springs Instrument Co., Inc., Yellow Springs, OH). Prior to analysis of the blood, the instrument was calibrated with known standard solution.

**DEMOGRAPHIC DATA:** Subjects' height, weight, and skinfold measurements were taken on the same day as the WAnT, prior to testing. Heights were measured using a wall mounted stadiometer, with their shoes off. Lang skinfold calipers were used, and the average of three measurements was analyzed. Males were measured at the chest, abdominal, and anterior thigh, while women were measured at their triceps, superior iliac
crest, and anterior thigh at sites as described by Jackson and Pollock (1985). The gender appropriate three site equation was used to determine percent body fat (Jackson and Pollock 1985).

**STATISTICAL ANALYSIS**

SAS version 9.1 was used to create descriptive statistics. Pearson product moment correlation coefficients were generated comparing power data from the WAnT with velocities and momentums from the HART. The alpha level was set to 0.05.
Results

Demographic data collected on participants can be found in Table 1. Total number of participants was 77. They were divided by gender and training.

Table 1. Description of Participants N=77 (mean ± StDev)

<table>
<thead>
<tr>
<th></th>
<th>Mass (kg)</th>
<th>Height (cm)</th>
<th>Age (years)</th>
<th>% Body Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>75.83 ± 8.84</td>
<td>176.31 ± 17.42</td>
<td>26.93 ± 8.25</td>
<td>9.57 ± 4.32</td>
</tr>
<tr>
<td>Females</td>
<td>60.98 ± 11.08</td>
<td>164.42 ± 10.03</td>
<td>26.62 ± 10.67</td>
<td>18.94 ± 4.32</td>
</tr>
</tbody>
</table>

Table 2. Subjects’ peak and mean values of power, velocity, momentum, and percent decrease from the WAnT and HART (mean ± StDev)

<table>
<thead>
<tr>
<th>Variables</th>
<th>WAnT</th>
<th>HART</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Power (watts)</td>
<td>678.44 ± 184.46</td>
<td></td>
</tr>
<tr>
<td>Mean Power (watts)</td>
<td>578.95 ± 163.07</td>
<td></td>
</tr>
<tr>
<td>Peak Velocity (m/s)</td>
<td></td>
<td>7.13 ± 1.02</td>
</tr>
<tr>
<td>Mean Velocity (m/s)</td>
<td></td>
<td>6.08 ± 0.91</td>
</tr>
<tr>
<td>Peak Momentum (mass*v)</td>
<td></td>
<td>493.05 ± 121.05</td>
</tr>
<tr>
<td>Mean Momentum (mass*v)</td>
<td></td>
<td>421.40 ± 121.05</td>
</tr>
<tr>
<td>Percent Decrease</td>
<td>42.20 ± 11.21</td>
<td>21.31 ± 7.29</td>
</tr>
</tbody>
</table>

Measures of peak power, peak velocity, and peak momentum are listed in Table 2. A strong correlation was found between peak momentum and peak power (r=0.82, p=0.0001). Peak momentum also had a high correlation with peak velocity (r=0.79, p=0.0001). A moderate correlation exists between peak power and peak velocity (r=0.55, p=0.0001).

Measures of mean power, mean velocity, and mean momentum are also listed in Table 2. A strong correlation was found between mean momentum and mean velocity (r=0.81, p=0.001). Mean power and mean momentum had a correlation of r=0.78, p=0.0001. A moderate correlation was found between mean power and mean velocity (r=0.63, p=0.0001).
Table 3. Blood Lactate Concentrations during WAnT and HART (mmol ± StDev)

<table>
<thead>
<tr>
<th></th>
<th>WAnT</th>
<th>HART</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Blood Lactate</td>
<td>9.2 ± 2.9</td>
<td>11.2 ± 2.8</td>
</tr>
</tbody>
</table>

Post blood lactate levels are described in Table 3. A weak correlation was seen between peak blood lactate levels after the two tests ($r=0.37$, $p=0.001$).

Fig.1: Peak Momentum (n=77)
Fig. 2: Peak Power (n=77)

Mean Peak Power

Fig. 3: Peak Velocity (n=77)
Discussion

The most important finding in this study was the strong degree of correlation between peak and mean momentum calculated from the HART and peak and mean power from the WAnT ($r=0.82$, $r=0.78$, respectively). Previous studies have shown significant correlations to peak power output as measured by the WAnT using laboratory protocols involving treadmills and metabolic analysis (Nummela et al., 1996; Scott et al., 1990) while others have correlated WAnT results to data collected in the field using tests such as sprints, treadmill running, distance jumps, and shuttle runs (Baker & Davies, 2002; Cooper et al., 2004). However variables such as time to exhaustion or oxygen uptake are not easily compared with peak power, and have resulted in correlations with peak power ranging from $r=0.45$ to $r=0.70$ (Nummela et al., 1996). Therefore, although momentum cannot be directly converted to power, due to the high correlation ($r=0.82$), the expression of momentum which includes the athletes' weight may be a more valid indicator of potential power than elapsed time or oxygen deficit. Additionally, because the HART utilizes a 200 meter sprint to test for running anaerobic power an argument can be made for face validity. Furthermore, examination of figures 1 and 2 reveal the shape of the power and momentum curves obtained from the WAnT and HART protocols are similar indicating similar levels of metabolic perturbation. Correlations between peak and mean power derived from the WAnT with various anaerobic running tests are presented in Table 4.

Nummela et al. (1996) studied the Maximal Anaerobic Run Test (MART), in which subjects performed treadmill sprints on a “four degree grade” with increasing speed until exhaustion. Maximum power (expressed as the estimated oxygen demand of
running) from the MART yielded a low correlation with peak power from the WAnT ($r=0.45$). In the present study the correlation between momentum and peak power in the WAnT was $r=0.82$, indicating a stronger relationship between the outcome variable of the HART (momentum) and peak power than the outcome variable of the MART (oxygen uptake). However, the higher correlation observed in the present study may be related to the large heterogeneous subject pool which should have the effect of strengthening the correlation. Therefore comparisons of correlations achieved using different subject populations must be viewed with caution.

Peak blood lactates collected at approximately 7.5 minutes post exercise have been suggested to be valid indicators of anaerobic capacity (Fujitsuka et al., 1982). The American College of Sports Medicine states that one indication that subjects have reached VO$_2$ max would be blood lactate values above 8.0 mmol (ACSM guidelines for exercise testing and prescription). Thus values exceeding 8.0 mmol should indicate a heavy reliance on anaerobic energy production with higher values indicating greater anaerobic capacity. Nummela and coworkers reported mean peak blood lactate concentrations of $15.6 \pm 3.2$ mmol$\cdot$L$^{-1}$ for the MART and $13.2 \pm 2.4$ mmol$\cdot$L$^{-1}$ for the WAnT. In contrast peak lactate values in the present study were $11.1 \pm 2.9$ mmol$\cdot$L$^{-1}$ from the HART and $9.2 \pm 2.8$ from the WAnT. Although values in the present study were lower than those recorded by Nummela et al. the studies were similar in that both tests resulted in higher blood lactate values in the running test than in the WAnT. Additionally, the mean lactate values in the present study suggest a high degree of anaerobic contribution during both the HART and WAnT. Scott et al. studied twelve NCAA Division I Varsity track athletes and four university students. Peak blood lactate
concentrations five minutes following the maximum accumulated oxygen deficit (MAOD) ranged from $12.7 \pm 2.2 \text{ mmol}^{-1}$ to $16.5 \pm 2.0 \text{ mmol}^{-1}$. Differences in mean peak lactate values can probably be attributed to differences in training status and fitness of the subject populations of the various studies.

Scott et al. (1990) the MAOD as an indicator of anaerobic capacity. Expired air was collected and continuously analyzed while subjects ran on a treadmill at a constant speed with an increasing grade of 3% every two minutes until voluntary exhaustion (exhaustion was 9-14 minutes). Oxygen deficit (ml/kg) was correlated against peak power output from the WAnT ($r=0.70$). Participants in the MAOD study also ran 300m, 400m, and 600m sprints; time in seconds from the sprints were also correlated against peak power from the WAnT ($r=-0.54$, $r=-0.36$, $r=-0.35$ respectively). When trying to relate anaerobic capacity from sprint running to anaerobic capacity from the WAnT (mean power), higher correlations are found using mean momentum rather than sprint times. In the present study there was a moderate correlation between mean velocity and mean power ($r=0.63$); however there was a stronger correlation between mean momentum and mean power ($r=0.78$).

Cooper et al. (2004) experimented with a multistage shuttle run test (MSRT) to look at anaerobic capacity in seventy-two female game players. The MSRT consisted of subjects running 15m while listening to an audiocassette cue for an increasing speed control until exhaustion. Total distance, maximum number of runs, and time to exhaustion were correlated with mean power output achieved in the WAnT ($r=0.67$, $r=0.69$, $r=0.72$ respectively). The correlation between mean power and mean momentum in the HART study was $r=0.78$. Outcome variables from the HART and the MSRT have
similar relationships to mean power; however, the MSRT does not yield data indicative of peak power.

Baker and Davies (2002) compared multiple anaerobic power tests (30m sprint, 40m high intensity shuttle run (HISR), vertical jump and horizontal jump) to peak power output from the WAnT. Time in seconds from the sprints and shuttle run, along with distance in centimeters and meters from the vertical and horizontal jumps were the variables related to peak power. There exists a moderate correlation of r=0.51 for all variables with peak power from the WAnT. It should be noted that the correlations in this study were obtained using twelve trained sprinters which constituted a rather small homogenous subject population.

Patton and Duggan (1987) compared different tests of anaerobic power to the WAnT. Fourteen male subjects completed a WAnT, an isokinetic endurance test on the knee extensor muscles, the step test of Margaria et al., and two sprints (50m, and 200m). Peak torque (Nm·kg⁻¹) and peak power had a correlation of r=0.68. Peak power from the Margaria step test correlated with peak power from the WAnT (r=0.64). Time from the 50m and 200 m sprints had a negative correlation with peak power from the WAnT (r=-0.71, r = -0.54 respectively). In the present study the correlation between peak power and total time to complete the 200 meter sprint was r = -0.60, which was similar to the results of Patton and Duggan. However, the correlation between mean power and 200 meter time in the present study (r=-0.65) was lower then that reported by Patton and Duggan (r=-0.82).

In summary, the HART resulted in higher correlations with WAnT results than those previously reported. When velocities were converted to momentum the strength of
the relationship between the outcome variables from the HART compared to the WAnT were significantly improved. In conclusion data from the present study suggest that the HART is a valid field test for evaluating anaerobic power during running.

Table 4. Correlations of various anaerobic power tests to the WAnT variables peak power and mean power.

<table>
<thead>
<tr>
<th></th>
<th>Peak Power</th>
<th>Mean Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scott et al</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAOD Oxygen Debt</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>300 m Sprint</td>
<td></td>
<td>-0.54</td>
</tr>
<tr>
<td>400 m Sprint</td>
<td></td>
<td>-0.36</td>
</tr>
<tr>
<td>600 m Sprint</td>
<td></td>
<td>-0.35</td>
</tr>
<tr>
<td>Baker &amp; Davies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 m Sprint</td>
<td></td>
<td>0.51</td>
</tr>
<tr>
<td>40 m HISR</td>
<td></td>
<td>0.51</td>
</tr>
<tr>
<td>Vertical Jump</td>
<td></td>
<td>0.51</td>
</tr>
<tr>
<td>Horizontal Jump</td>
<td></td>
<td>0.51</td>
</tr>
<tr>
<td>MSRT</td>
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<tr>
<td>Cooper et al</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N=36</td>
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<td></td>
</tr>
<tr>
<td>Total Distance</td>
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<tr>
<td>Max # of Runs</td>
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<td>0.69</td>
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<tr>
<td>Total Time</td>
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<td>0.72</td>
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<td>N=13</td>
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<tr>
<td>Max Power</td>
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<td>Patton &amp; Duggan</td>
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<tr>
<td>N=14</td>
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<td>50 m Sprint</td>
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<td>200 m Sprint</td>
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<td>0.54</td>
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<tr>
<td>Peak Torque</td>
<td></td>
<td>0.68</td>
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<tr>
<td>Margaria Step</td>
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<td>0.65</td>
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<tr>
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<tr>
<td>N=77</td>
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<tr>
<td>Momentum</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>0.78</td>
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PART II
REVIEW OF LITERATURE

Post Exercise Blood Lactate Concentration:

Ohkuwa et al. (1984) investigated peak blood lactate as an indicator of anaerobic capacity in sprinters and long distance runners. Eight sprinter, eight long distance runners, and seven untrained subjects participated in a 400-m and 3,000-m maximal run, immediately after which blood lactate samples were drawn.

Differences between groups were assessed and results showed that peak blood lactate significantly correlated with mean velocity for the 400-m run in the untrained and long distance runners ($r = 0.76, p < 0.05; r = 0.71, p < 0.05$), but had no statistical significance in the sprinters ($r = 0.38, p > 0.05$). Peak blood lactate after the 400-m run was significantly higher in the sprinters than in the other two groups.

Lacour, Bouvat, and Barthelem analyzed runners’ blood lactate concentrations after running 400-m and 800-m races. Subjects were eleven males and seven females competing in major races. Average velocity during the runs were calculated and used to find the runners’ relative performance. The relative performance was calculated as the runner’s best average velocity from the entire season.

Blood lactate samples were taken within five to ten minutes after completion of the race. The samples were then diluted and stored at room temperature until analysis was completed. A lactate analyzer was used within ten days of the sample collection. They found that neither race distance nor gender affected blood lactate production. This study also showed a significant relationship between lactate levels and their relative performance during the 400-m race ($r = 0.85$) and the 800-m race ($r = 0.76$).
Fujitsuka et al. (1982) conducted a study determining peak blood lactate concentrations following maximal treadmill running. Nineteen male subjects participated in this study and completed an exhaustive treadmill sprint lasting approximately one minute. Blood was drawn at varying intervals during 70 minutes of recovery after the completion of exercise in order to determine peak blood lactate concentrations. An examination of peak blood lactate's validity as a determinant of anaerobic performance was also made on fifteen subjects who completed maximal sprint runs of 100, 200, and 400 meters on a separate day.

The results of this study showed that blood lactate reached peak levels between 6.44 and 9.95 minutes following maximal exercise of approximately one minute, and that the mean time value was 7.65 minutes. Blood lactate concentrations at 7.65 minutes obtained in the fifteen subjects were plotted against their 100, 200, and 400 meter running times, and correlations of $r = -0.65$, $r = -0.78$, and $r = -0.79$ were found respectively. They concluded that the ability to accumulate higher levels of blood lactate may be one contributing factor to anaerobic performance capacity and that the peak blood lactate concentration at 7.65 minutes following maximal exercise may be one of the valid indicators of anaerobic work capacity in man.

Weinstein et al. (1998) examined the reliability of peak lactate, heart rate, and plasma volume following the WAnT. Fifteen males and 14 females performed two trials of the WAnT with identical resistance loads 3-7 days apart. Fingertip blood lactate samples were taken six times: before warm-up, immediately before the test, and at 3, 5, 7, and 9 minutes following the warm-up. Differences in peak lactate concentrations were
analyzed with repeated measures ANOVA and assessed for test-retest reliability via intraclass correlation coefficients. Pearson correlation coefficients were also calculated.

No significant differences were found in peak blood lactate concentrations between two trials of the WAnT. High intraclass correlation coefficients ($r = 0.926; P<0.001$) and Pearson correlation coefficients ($r = 0.86$) indicated that peak lactate concentrations following the WAnT were reliable. The authors concluded that measures of peak blood lactate concentrations following the WAnT are reliable and can be used for comparisons between subjects and treatments and as characteristics of the response to the WAnT.

Hautier, Wouassi, Arsac, Bitanga, Thiriet and Lacour investigated the relationships between anaerobic glycolysis and average velocity during sprinting. The participants for this study were 12 national level male sprinters. These performances being measured were taken from either the semi-finals or finals of the Cameroon national championships, 1992. Velocity was calculated throughout the race using the officials’ times. Blood samples were taken two to three minutes after each race and were diluted immediately to be analyzed within ten days. The lactate was correlated with the velocities from the last 165 meters of the 200 meter sprint ($r = 0.65$). The differences in lactate between the two races was correlated with the decrease in velocity from the 100-m to the 200-m race ($r = 0.76$). The results from this study suggest that anaerobic glycolysis contributes at least 55% of the energy expended at their velocities.

SUMMARY

Peak post-exercise blood lactate concentrations have been significantly related to mean velocity over a 400 meter sprint in untrained and long distance runners, and will
reach significantly higher levels in sprinters when compared to the untrained and long
distance runners (Ohkuwa et al., 1984). Other studies have results that indicate highest
post-exercise blood lactate levels are achieved at approximately 6-7.65 minutes following
maximal exercise (Fujitsuka et al., 1982; Nummela et al., 1996). Also, maximal post
exercise blood lactate concentrations have been shown to correlate with running times to
100, 200, and 400 meters (Fujitsuka et al., 1982). Peak blood lactate levels have a strong
correlation to velocity during the last 165 meters of a 200 meter sprint (Hautier et al.,
1994). Blood lactate levels have been shown to be reliable measures following
performance of the Wingate Anaerobic Test (Weinstein et al., 1998).

Cycle Ergometry Tests

Coleman et al. (2005) conducted a study to assess the reliability of repeated
laboratory sprint tests in well-trained endurance cyclists. Eleven male cyclists completed
four 30 second sprints on a cycle ergometer. Peak power, mean power, fatigue index, and
blood lactate was measured and analyzed to compare the reliability of repeated
measurements. The tests were each completed on separate days. The cyclists used their
own bicycles to complete this test. The null hypothesis in this study is there will be no
difference in measurements of power for trained cyclists when using their own bikes, and
that there will be no difference in measurements throughout the four trials. They
concluded that there was no improvement in the reliability of sprints when riding on their
own cycle equipment. Also, there was no significant improvement between trials. There
was large variability in blood lactate levels, so further studies should evaluate the
variability of blood lactate concentration.
Tharp et al. (1984) studied the anaerobic power and capacity of elite, young track athletes to compare sprinters’ and runners’ and male and female performances on the WAnT. Twenty-one female and 18 male track athletes, ages 10-15, participated in the WAnT and were divided into groups of either sprinters or distance runners. Results were analyzed using t-tests in order to compare among males and females, and sprinters and distance runners. The authors define “anaerobic power” as the highest work performed during any five second period. “Anaerobic capacity” was defined as “the total work performed during the entire 30 second period.” Anaerobic power is more related to the alactic phosphagen component of energy release where anaerobic capacity is more related to the glycolytic (lactic) component of the energy release.

Results indicated that males demonstrated significantly higher anaerobic power and capacity levels than females. Also, male sprinters showed greater anaerobic power and anaerobic capacity than male distance runners. No significant differences in either anaerobic power or capacity were found between female sprinters and distance runners. The authors concluded that the WAnT can distinguish between sprint and distance running ability in males.

Patton and Duggan (1987) studied three tests of anaerobic power (50 m sprint, 200 m sprint and Margaria Step Test) to try and relate them to the Wingate Anaerobic Test, and an isokinetic endurance test. The null hypothesis for this study was that there would be no significant difference in the mean power output for the subjects’ tests of anaerobic power when compared to the Wingate. Fourteen army personnel participated in this study. Subjects were tested for two weeks, with the first week being used as a familiarization period for the tests. In the first week, the subjects performed the Wingate
Anaerobic Test and the isokinetic endurance test. Testing in the second week consisted of the 50m, 200m and the Margaria stair-climb test. All tests were performed on separate days. Correlation coefficients were calculated to determine the degree of association between all of the tests.

The results of this study showed that there are high correlations amongst certain aspects of the tests. Even though they showed strong correlations between the tests and the Wingate test, it does not mean they are necessarily interchangeable tests of anaerobic power. These tests are measuring different components of the anaerobic system. They concluded that the single best measurement of anaerobic power is the mean power; this had the highest correlations with the Wingate, isokinetic endurance and the sprints.

SUMMARY

The Wingate Anaerobic Test has been shown to be a reliable measure of anaerobic power (Coleman et al., 2005). The use of a personal bike versus an ergometer did not have an impact on performance during the test (Coleman et al., 2005). Results from Tharp et al. suggest that the WAnT is sensitive enough to distinguish between distance runners and sprinters. Male sprinters have great anaerobic capacity and power than do male distance runners (Tharp et al., 1984). The use of other tests as a determination of anaerobic power is difficult, since they do not all test the same parts of the anaerobic system (Patton & Duggan, 1987).

Sprint Tests

Nummela et al (1996) studied the reliability and validity of a maximal anaerobic running test (MART). The MART consisted of 20s treadmill runs with increasing speed
until exhaustion. Values of peak power, and blood lactate concentrations from the
MART were correlated to values from the Wingate Anaerobic Test (WAnT) and were
significant, though they did not have high correlations (r = .45, r = .53 respectively).
They concluded that the MART is a valid and reliable way to determine work capacity
during treadmill running.

Baker and Davies (2002) studied twelve elite international sprinters (six males,
six females) on a cycle ergometer test, sprint test, shuttle run test, and jump tests. A
pearson correlation matrix for the following variables was used: 30m sprint, 40m shuttle
run, 10m split, vertical jump, horizontal jump, and peak power output. Only moderate
correlations were found between power output on the cycle ergometer and the
performance tests. There were no relationships observed between the cycle ergometer
tests and the field tests (p<0.01). The findings of this study suggest that the cycle
ergometer test may be measuring a different component of the high intensity ability to
that of the field tests, and the values are not highly related to sprint/jump performance.
The results of this study also indicate that field tests specific to a sport may be a better
way to evaluate the intensity ability related to that sport.

Cooper, Baker, Eaton and Mathews (2004) investigated a multistage field test for
the prediction of anaerobic capacity in female game players. Subjects were Seventy-two
female university athletes competing in netball, rugby union, and hockey. Twenty
subjects performed the multistage shuttle run test (MSRT) twice, with no more then
seven days apart. The results of this group suggest the repeatability of this test, finding
an agreement between tests of 95%. Phase two of this study compared the MSRT with
the WAnT. Thirty-six subjects completed both tests within seven days of each other. The
mean power output results from the WAnT were compared to the predicted power output from the MSRT. These numbers had a 95% agreement. The protocol for the MSRT begins with each subject doing a five minute warm-up and five familiarization trials at a lower speed. For the actual test, a tape player with a beat set the pace for the subjects to run at 4.72 m/s. Two lines were marked fifteen meters apart. Subjects were encouraged to run maximally with the beat until they could not continue. Subjects were stopped when they did not meet the line in time two consecutive times. Verbal encouragement was given throughout the test. This study indicates that the MSRT is capable of predicting anaerobic capabilities.

SUMMARY

Several tests have been studied and found to be valid measures of an athlete’s anaerobic capability. Research on a Maximal Anaerobic Run Test (MART) has shown significant but low correlations with the WAnT (Nummela et al., 1996). A multistage shuttle run test has also been developed (MSRT) to view anaerobic capacity in game players and has found strong correlations with the WAnT (Cooper et al., 2004). Sprint tests have higher correlations to the WAnT then field tests and performance tests. (Baker & Davies, 2002).
APPENDIX A

INFORMED CONSENT

To Participate in a Research Study

I. INVESTIGATORS

Principal Investigators: Andrea S. Harmon, ATC
                            Kelly M. Cunningham, ATC
                            Christopher D. Stickley, MA, ATC
                            Shannon A.K. Keen, ATC

Supervising Professor: Iris F. Kimura, PhD, ATC, PT

Department of Kinesiology and Leisure Science
University of Hawai‘i at Manoa
1337 Lower Campus Road, PE/A Complex RM231, Honolulu, HI 96822
Phone: 1-808-956-7606
Fax: 1-808-956-7976

II. TITLE

Determination of Anaerobic Performance Via a Maximal Sprint Field Test

III. INTRODUCTION

This study is part of two master’s degree theses by University of Hawai‘i graduate students. Because you are in good physical condition and participate regularly in some form of physical activity, you are being asked to take part in this research study. The purpose of this study is to examine a sprint field test of 200 meters and the Wingate anaerobic test to assess your anaerobic performance (a type of physical ability which enables one to perform high-intensity exercise in a relatively short period of time). During the sprint field test you will be video-recorded with high speed cameras for biomechanical analyses.

The reason for giving you the following information is to help you decide if you would like to participate in this study. This consent form may contain words that are unfamiliar to you. Please discuss any questions you have about this study with the research staff members. Your participation in this research is voluntary, and you will not be paid. Be assured that all information collected about you will be kept confidential. You and the researchers will be the only ones to know the individual results of your tests.
IV. DESCRIPTION OF PROCEDURES

You will be asked to submit to standard measurements of height, body mass and lower limb lengths (hip-knee length, lower leg length, and foot length). For your comfort, you may request these measurements be taken by a member of the same gender. You will also be asked to refrain from exercising, eating or drinking (except water) 4 hours prior to reporting to the laboratory so that you are well rested and well hydrated upon arrival.

Test Schedule

You will be asked to perform three test trials consisting of one trial of the Wingate anaerobic test and two trials of a 200 meter sprint test with a 20 minute rest period between trials. The Wingate anaerobic test must be performed within one week either prior to or following the 200 meter sprint tests.

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<td>1st</td>
</tr>
<tr>
<td>2nd</td>
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Wingate Anaerobic Test (WAnT)

A maximum bicycle sprint will be performed using the cycle ergometer (exercise bicycle). You will start with a 5-15 minute warm up on the cycle ergometer, a 15-second mock familiarization trial of the WAnT, followed by a 5-minute resting and stretching period. You will then participate in the 30-second WAnT protocol. After each test you will be asked what your level of exertion was, choosing from a visual scale. Heart rate will also be taken after each test. Finger prick blood drawing will then be performed before and 7 minutes after completion of the test. Your blood sample will be used to measure blood lactate level in order to determine your anaerobic capacity, which is your ability to sustain high-intensity exercise in a relatively short period of time. The blood sample will be labeled using your identification number in order to ensure confidentiality. The capacity for high intensity activity can then be assessed using these measurements. The total time of the test will be approximately 15-25 minutes.

Maximal 200 meter Sprint Field Test (SFTMax)

The SFTMax test will be performed on a 400 meter track. You are asked to wear your usual running shoes for the test. Before the tests, you will participate in a 5-15 minute warm up period, followed by a 5-minute resting and stretching period. You will then participate in the SFTMax. Sprint times will be recorded using photoelectric timers and hand held stop watches. You will also be video-recorded with high speed cameras for biomechanical analyses. Finger prick blood samples will be drawn before the test and 7 minutes after completion of the test. After each test you will be asked what your level of exertion was, choosing from a visual scale. Heart rate will also be taken after each test. This procedure will be the same as previously described in the Wingate anaerobic test. This test will be performed twice, separated by a twenty-minute recovery period. The total time of the test will be approximately 20 to 30 minutes.
V. RISKS

Due to the high intensity of the activity involved (maximal anaerobic performance), you may feel distress, nausea, fatigue, muscle pain, soreness, or discomfort. A very remote possibility of cardiac arrest exists. Temporary pain or discomfort may be felt during finger prick blood drawing. Excessive bleeding or infection from blood drawing may occur, and ecchymosis or bruising at the site is a common side effect. In the event of any physical injury from the research procedure, only immediate and essential medical treatment is available. First Aid/CPR and a referral to a medical emergency room will be provided. The investigators are First Aid/CPR certified and trained to use the portable automated external defibrillator (AED) on site. You should understand that if you are injured in the course of this research procedure that you alone may be responsible for the costs of treating your injuries.

VI. BENEFITS

You may not directly benefit from this study although you will gain the experience of being part of a scientific experiment. You will obtain information concerning your anaerobic fitness levels and sprint running abilities. This study will provide an assessment of anaerobic performance (capacity for high-intensity exercise) without using invasive techniques.

VII. CONFIDENTIALITY

Your research records will be confidential to the extent permitted by law. You will not be personally identified in any publication about this study. A code, which will be known only to study personnel and you, will be used instead of your name on laboratory records of this study. Personal information about your test results will not be given to anyone without your written permission. In addition, all data (including video recordings) and subject (identity) information will be kept under lock and key in the Department of Kinesiology and Leisure Science Human Performance Laboratory. These materials and the video recordings will be permanently disposed of in a period not longer than 5 years.
VIII. CERTIFICATION

I certify that I have read and that I understand the foregoing, that I have been given satisfactory answers to my inquiries concerning the project procedures and other matters and that I have been advised that I am free to withdraw my consent and to discontinue participation in the project or activity at any time without prejudice.

I herewith give my consent to participate in this project with the understanding that such consent does not waive any of my legal rights, nor does it release the principal investigator or institution or any employee or agent thereof from liability for negligence.

If you have any questions related to this research study, please contact principal investigators, Andrea Harmon at 956-7421, Kelly Cunningham at 956-5162, Shannon Keen at 956-8793, Christopher Stickley at 956-7421 or you may contact Iris F. Kimura at 956-3797 at any time.

______________________________  ____________________________
Signature of individual participant  Date

If you cannot obtain satisfactory answers to your questions, or have complaints about your treatment in this study, please contact: Committee on Human Subjects, University of Hawaii at Manoa, 2540 Maile Way, Honolulu, Hawaii 96822, Phone (808) 956-5007.
Appendix B

HART DATA SHEET

SUBJECT: 
Age: ___________ Time of test: ___________ 
Height: ___________ Date of test: ___________ 
Weight: ___________

BLOOD LACTATE:

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<th>Post-test</th>
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RPE:

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TIMERS:

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| 25 M (82 ft) |
| 50 M (162 ft) |
| 75 M (240 ft) |
| 100 M (328 ft) |
| 125 M (400 ft) |
| 150 M (492 ft) |
| 175 M (574 ft) |
| 200 M (656.2 ft) |

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Appendix C
WINGATE DATA SHEET

Name: ____________________________  Subject # ____________

Gender: ______  Age: _____________

Weight: ______ lbs  Height: ______ inches

__________ kg  __________ cm

Resistance: ________ kg  Seat Height: ____________

Mean Power: __________  Peak Power: __________

Maximal Power: __________  Fatigue Index: __________

RPE pre-test: __________  RPE post-test: __________

Blood lactate
Pre-test: ________  Post-test: __________

SKINFOLDS

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</table>

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Appendix D

WINGATE INSTRUCTIONS

You will be completing a 30 second all out cycling sprint. At the start of the test you will have 3 seconds to accelerate to a maximum velocity. We will countdown 3, 2, 1, Go. You should be pedaling as fast as you can by the time the countdown reaches zero.

When the countdown reaches zero we will release the resistance and the 30 sec timer will begin. THIS IS AN ALL OUT SPRINT. YOU SHOULD PEDAL AS FAST AND AS HARD AS YOU CAN. DO NOT PACE YOURSELF. (do not stand up)

After the Wingate test we will be taking a finger prick blood lactate sample. You will be given a stopwatch after the completion of the test. You will be instructed to complete a cool down after the test. At 6 minutes, conclude your cool down and proceed to get your blood sample taken.

A Rate of Perceived Exertion (RPE) will be taken before and after completion of the Wingate. You will be asked to choose a number to describe how hard the work is for you. A rating of "6" corresponds to those feelings and sensations you have during the easiest work you can imagine, similar to sitting in a chair. A rating of "20" corresponds to the feelings you would have during the most difficult work you can imagine yourself doing, so exhaustive that you could not continue.
Appendix E

HART INSTRUCTIONS

Thank you. We really appreciate your time.

Today you will be running two 200 meter sprints. A finger prick blood sample will be taken before and after each sprint. You will be given a 20 minute rest between the runs.

To begin, Andrea will take a pre-run blood sample right before your first sprint. As soon as that is completed make your way to the start. At the start you will be instructed “On your mark, get set, GO” You should begin your run when the starter says GO.

When running, this is an All out sprint. Don’t pace yourself. Run all the way through the last timer.

When you finish the first sprint, you will be handed a stopwatch, when the watch reads 6 minutes make your way back over to Andrea to get your post blood-lactate sample taken. Leave the timer running. When the stop-watch reads 19 minutes, go see Andrea again for your second Pre-Run blood sample. Leave the stop-watch with her at this time. You will be ready to run at 20 minutes. After the second sprint, you will be handed another watch, at 6 minutes go to Andrea for your last blood sample to be taken.

Before and immediately after each sprint we will be asking for your rate of perceived exertion or RPE. This is a numerical ranking of how difficult or hard you feel you worked throughout the sprint.

Now, please prepare for the sprint by doing an individual warm-up. You will be called over to start.
### Appendix F

**Subject Information**

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