RELIABILITY OF HAND HELD STOPWATCHES DURING H.A.R.T. FIELD TESTING

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ACKNOWLEDGEMENTS

I dedicate this page to all of the special people in my life that helped me with the completion of this thesis.

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ABSTRACT

The purpose of this study was to assess the reliability of split times obtained by hand held stopwatches (HHS) compared to electronic timing (ET) during a 200-m sprint. Twenty-six timers were given instruction and practice until good agreement was achieved between ET and HHS.

Two HHS timing methods were compared with ET: single-split timers (SST) and multiple-split timers (MST). Trained runners (8 males, 10 females) participated in this study. A repeated measures ANOVA was used to determine the validity. Reliability was analyzed using Intraclass Correlation models.

No differences were found between the five MST ($p = 0.092$). An ICC of 0.92 indicated high reliability. ET resulted in significantly faster times than MST or SST ($F = 4.73, p = 0.009$). High ICC values (ICC model (2, 3) = 0.96 and 0.99) indicated that the two HHS methods were reliable. It was concluded that ET should be the method of choice.
PART I

Introduction

Maximal aerobic power and aerobic contribution during dynamic exercise can be readily measured in a laboratory setting. Anaerobic fitness is more difficult to measure and involves invasive techniques to ensure accuracy. (Bangsbo et al., 1990) Several techniques are available to assess an individual’s anaerobic work capacity including: vertical jumping, sprinting, treadmill running, staircase climbing, and cycle ergometry (Baker & Davies, 2002; Bangsbo et al., 1990; Bulbulian et al., 1996; Vandewalle et al., 1987).

The Wingate Anaerobic Test (WAnT) has been established as the gold standard for assessing anaerobic power and capacity for cycling (Bangsbo et al., 1990; Bar-Or, 1987; Bulbulian et al., 1996; Tharp et al., 1984; Vandewalle et al., 1987). Due to the specificity of training, the WAnT has been shown to be an accurate assessment tool of anaerobic power and capacity for cyclists; however, this test may not be sufficient for runners (Baker & Davies, 2002; Falk et al., 1996; Nummela et al., 1996; Taunton et al., 1981). A number of tests have been developed in an attempt to accurately assess the anaerobic power and capacity of a runner (Bar-Or, 1987; Falk et al., 1996; Nummela et al., 1996). However, the only protocol of the afore-mentioned studies that was designed to elicit data similar in structure to the WAnT is the protocol done by Falk et al. (1996). An elaborate laboratory set up fell to a disadvantage to the Falk design. A new protocol, the Hawai‘i Anaerobic Run Test (HART), was designed to specifically assess the
anaerobic capacity of runners and to give information similar to the results derived from the WAnT.

Several studies, including the HART study, have incorporated electronic infrared timing gates (ET) to assure accurate measurements of elapsed time (Grant et al., 2003; Liow & Hopkins, 2003; Marks, 1994; Sands et al., 2005; Young et al., 1995). The use of ET can virtually eliminate timing error, but the expense may limit its application for HART field tests. A more practical and less expensive alternative form of measuring sprint variables is the use of hand held stopwatches (HHS) (Brooks et al., 2002; David & Sullivan, 2005; Rantanen et al., 1998).

There is limited research on the reliability of a HHS compared to ET; therefore, the purpose of the present study was to test the reliability of a HHS compared to ET during HART field tests. Specifically, this protocol examined the validity and the reliability of hand-held stopwatches using two methods of hand-held timing compared with an electronic timing system. In the first method, multiple-split timers (MST) stood in the center of the track and recorded each 25-meter split. In the second method, single-split timers (SST) were spread around the track at 25-meter increments and recorded only one interval time per trial. It was hypothesized that there would be no difference between the ET when compared to the MST and SST and the three methods would be equally reliable.
Method

Subjects

The timers were given oral and written instructions on information about hand placement, standing position, stopwatch operation and the start/stop protocol (See appendix A). Prior to data collection, timers were allowed to practice starting their stopwatch when given a visual cue, which was the flash of a strobe light attached to the starting unit; and stopping their timing device when a practice runner passed through a timing gate. The subjects were required to practice until there was good agreement between their HHS and the ET.

Runners

The runners for this study included 8 males (mean age 33.6 ± 11.4 yrs) and 10 females (20.1 ± 2.7 yrs) trained runners (range: ~2 to 20 hours/week) and cyclists (range: 5 to 7 hours/week). Before initial testing, subjects were provided with a verbal and written explanation of the purpose, procedure, benefits, time demands and possible risks associated with participation in the study (See Appendix B). Informed consent was obtained following the above explanation, allowing the subjects to ask questions and by signing an informed consent form approved by the institutional review board for use of human subjects at the University of Hawai’i.

Anthropometric Measurements of the Runners

Heights were taken through using a stadometer (model #67032; Country Technology, Gays Mills, WI). Body weight was determined using a Cardinal DETECTO certifier scale (model #442; Web City, MO). Skinfolds were taken in duplicate in a
rotational order, if the measures varied by more than one millimeter a third measurement was taken. The averages of the measurements were used to represent each site. The three site Jackson Pollack equations (triceps, superiliac, and thigh for females; chest, abdominals and thigh for males) were used to estimate body density which was subsequently converted to percent body fat using Brozek's equation (Brozek et al, 1963).

Research Design

Split times were obtained using two HHS test protocols: Single-Split Timers (SST) and Multiple-Split Timers (MST). The two testing protocols were compared to the "gold standard" electronic timer (ET) to determine reliability. Independent variables were: HHS and the ET. Dependent variables were: split times taken at each 25-meter mark.

Single-Split Timers: All timers were issued digital stopwatches, readout to one-hundredth of a second. Eight timers were assigned to a given 25-meter mark throughout the 200-meter sprint course. The timers were given a HHS (SPORTLINE 240) to measure split times during each trial. Each timer was instructed to stand on the outside perimeter of the track on the same plane of the ET. Timers would start their stopwatch at the flash of the strobe and would stop their stopwatch when the runner broke the timing plane.

Multiple-Split Timers: Eight 25-meter time-intervals were taken during the 200-meter sprint by five timers, each using a multi-memory HHS equipped with a recall button (ULTRAK 360). Each timer was instructed to stand in the center of the track
where all eight 25-meter timing gates were visible. Timers would start their stopwatch at the flash of the strobe and recorded each split when the runner broke the timing plane.

Hawaii Anaerobic Run Test. The HART trials were performed on a Mondo track (Mondo USA, Lynnwood, WA). Testing protocol included a 5-minute warm up, followed by the HART. Subjects were instructed to sprint in the third lane, from a standing start, as hard and as fast as possible throughout the entire 200-meter distance, and not to pace themselves. The HART protocol involved a standard electronic starting system (DAKTRONIC HS-200 horn start) equipped with a strobe light. Electronically timed splits were recorded to the nearest one-hundredth of a second using the Speedtrap II (Brower Timing Systems, Draper, UT) photoelectric timing cells placed at 25, 50, 75, 100, 125, 150, 175, and 200 meters to measure the split times. Timing was initiated automatically as the cells were triggered by an electronic starting device and split times were collected as subjects disrupted the infrared signal between timing cells. Subjects participated in two trials of the HART, separated by a 20-minute rest period. Each trial was entered individually in the analysis (a total of 36 trials were analyzed).

Statistical Analysis

Data were analyzed using SPSS version 13.0. Descriptive data were generated. An Inter-Item Correlation Matrix was generated to compare correlations between each method. A repeated measures ANOVA was used to determine the validity of the two hand held timing methods when compared to ET, after considering variation due to differences in how fast the subjects completed the course. Intra-class Correlations (ICC) were calculated as described by Shrout and Fleiss (1979). Two ICC models were used.
Model ICC (2, 1) was selected (two random effects: persons and instruments) for a single approach (multiple-split). The second ICC model (2, 3) was selected (two random effects: persons and instruments) to investigate the average across the three approaches (electronic timer, single-split, multiple-split). Absolute error was calculated by subtracting the HHS from the ET and correcting negative values to positive values. The alpha level was set at $p < 0.05$. 
Results

Each runner \( (n = 18) \) participated in two trials, which were assessed individually, resulting in 36 trials total. Descriptive data of the runners were reported in Table 1. The subjects in this study were the timers (males: \( n = 10 \), age \( = 24 \pm 3.13 \); females: \( n = 16 \); age \( = 25.2 \pm 4.44 \) ) instead of the runners. There were five timers in the center of the track (MST) and eight timers located around the track (SST).

**Table 1: Anthropometric data for the 18 runners**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Males (n = 8)</th>
<th>Females (n = 10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>33.6 ± 11.4</td>
<td>20.1 ± 2.7</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>171.7 ± 11.3</td>
<td>167.6 ± 7.8</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>72.4 ± 7.1</td>
<td>62.2 ± 7.5</td>
</tr>
<tr>
<td>Body Fat (%)</td>
<td>13.8 ± 4.1</td>
<td>18.3 ± 3.9</td>
</tr>
</tbody>
</table>

*Body fat was estimated using the sum of three skinfolds using Jackson and Pollock equation (1985 phys spts med)*

A preliminary analysis was used to decide how many MST would be required to provide consistent data. It was established that there was no significant difference between MST’s across timing intervals (See Table 2).
Table 2. Twenty-five Meter Split Times for the Multiple-Split Timers (seconds)

<table>
<thead>
<tr>
<th>Item</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MST 1</td>
<td>3.96 sec</td>
<td>.43</td>
</tr>
<tr>
<td>MST 2</td>
<td>3.94 sec</td>
<td>.41</td>
</tr>
<tr>
<td>MST 3</td>
<td>3.96 sec</td>
<td>.43</td>
</tr>
<tr>
<td>MST 4</td>
<td>3.96 sec</td>
<td>.44</td>
</tr>
<tr>
<td>MST 5</td>
<td>3.83 sec</td>
<td>.39</td>
</tr>
</tbody>
</table>

Grand Mean = 3.95 seconds

Table 2 shows that the grand mean for the five MST was 3.95 seconds per split.

There were small differences in the mean splits between timers, but differences were not statistically significant (see Table 3) ($p = 0.092$). Analyses determined that of the small variation between MST (range: 0 to 0.3 seconds), 61.4% of the error was associated with measurements of time at the various distance intervals (e.g., 25m, 50m, 75m), but no interaction between timers and distances was revealed (i.e., no one timer was consistently slow or fast within certain distance intervals). Table 4 presents the inter-item correlation matrix for the MST. Correlations between the MST were high ($r = 0.864$ to $0.973$).

Table 3. Analysis Comparing Multiple-Split Timers

<table>
<thead>
<tr>
<th>ANOVA</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Raters</td>
<td>.119</td>
<td>4</td>
<td>.030</td>
<td>2.012</td>
<td>.062</td>
</tr>
<tr>
<td>Residual</td>
<td>7.950</td>
<td>536</td>
<td>.015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8.069</td>
<td>540</td>
<td>.015</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4. Inter-Item Correlation Matrix for Multiple-Split Timers

<table>
<thead>
<tr>
<th></th>
<th>MST 1</th>
<th>MST 2</th>
<th>MST 3</th>
<th>MST 4</th>
<th>MST 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>MST 1</td>
<td>1.000</td>
<td>.871</td>
<td>.864</td>
<td>.864</td>
<td>.865</td>
</tr>
<tr>
<td>MST 2</td>
<td>.871</td>
<td>1.000</td>
<td>.948</td>
<td>.945</td>
<td>.973</td>
</tr>
<tr>
<td>MST 3</td>
<td>.884</td>
<td>.948</td>
<td>1.000</td>
<td>.958</td>
<td>.951</td>
</tr>
<tr>
<td>MST 4</td>
<td>.864</td>
<td>.945</td>
<td>.958</td>
<td>1.000</td>
<td>.936</td>
</tr>
<tr>
<td>MST 5</td>
<td>.865</td>
<td>.973</td>
<td>.961</td>
<td>.936</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Table 5 presents the results of the ICC analysis. The table may be interpreted to mean that if any one timer were used, the ICC would be about 0.92. The average ICC across all five timers was 0.98. There is no established value for an ICC to determine reliability (Weir, 2005). However, when viewed with the standard error of the mean (SEM), which was calculated to be 0.122 seconds for the MSTs, an ICC coefficient of 0.90 and above seems an acceptable indication of high reliability. This being the case, use of any one timer chosen from this group should give reliable results.

Table 5. Results from ICC Model (2, 1) for Multiple-Split Timers

<table>
<thead>
<tr>
<th>Intraclass Correlation Coefficient</th>
<th>95% Confidence Interval</th>
<th>F Test with True Value 0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower Bound</td>
<td>Upper Bound</td>
</tr>
<tr>
<td>Single Measures</td>
<td>.917</td>
<td>.895</td>
</tr>
<tr>
<td>Average Measures</td>
<td>.982</td>
<td>.977</td>
</tr>
</tbody>
</table>

Two-way random effects model where both people effects and measures effects are random.

Since the use of one MST is sufficient (ICC = 0.92) to collect reliable data, when comparisons of methods were analyzed (ET, SST, MST) MST 4 was randomly selected to evaluate that method compared to Single-Split Timers (SST) and the Electronic Timer (ET). Table 6 presents the mean of all the interval split times for the ET, MST 4, and the
Data from Table 6 suggests that mean differences between methods are small (means and SDs are all similar). Table 7 summarizes the mean differences between the three methods and shows the ranges and variance.

**Table 6. Mean Split Times for the Three Methods**

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser*</td>
<td>260</td>
<td>3.36</td>
<td>35.96</td>
<td>16.9604</td>
<td>8.98071</td>
<td>60.653</td>
</tr>
<tr>
<td>Stopwatch</td>
<td>260</td>
<td>4.00</td>
<td>35.88</td>
<td>17.3752</td>
<td>8.84250</td>
<td>78.190</td>
</tr>
<tr>
<td>Center4</td>
<td>260</td>
<td>3.95</td>
<td>36.09</td>
<td>17.3713</td>
<td>8.85215</td>
<td>78.361</td>
</tr>
<tr>
<td>Valid N (listwise)</td>
<td>260</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*ET was significantly lower than the other two methods (p < 0.05)*

**Figure 7: Summary Item Statistics of the Three Methods**

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Range</th>
<th>Maximum / Minimum</th>
<th>Variance</th>
<th>N of Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item Means</td>
<td>17.242</td>
<td>16.880</td>
<td>17.375</td>
<td>.395</td>
<td>1.023</td>
<td>.051</td>
<td>3</td>
</tr>
<tr>
<td>Item Variances</td>
<td>79.088</td>
<td>78.190</td>
<td>80.853</td>
<td>2.463</td>
<td>1.032</td>
<td>1.892</td>
<td>3</td>
</tr>
<tr>
<td>Inter-Item Covariances</td>
<td>76.249</td>
<td>75.208</td>
<td>78.253</td>
<td>3.045</td>
<td>1.040</td>
<td>2.412</td>
<td>3</td>
</tr>
<tr>
<td>Inter-Item Correlations</td>
<td>.965</td>
<td>.947</td>
<td>1.000</td>
<td>.053</td>
<td>1.056</td>
<td>.001</td>
<td>3</td>
</tr>
</tbody>
</table>

*The covariance matrix is calculated and used in the analysis.*

Data were then analyzed using an ANOVA for repeated measures, after considering the variation due to differences in how fast people cover the course. Results of the ANOVA are presented in Table 8. The significant F ratio reveals differences between the three methods (F = 4.73, p = 0.009). The ET resulted in significantly faster times than either MST or SST. Examination of the ICCs between ET and the other two methods presented in Table 9 (r = 0.947). The ICCs were high despite the significant differences between the three methods.
Table 8. Analysis Comparing the Three Methods

ANOVA

<table>
<thead>
<tr>
<th>Sum of squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between methods</td>
<td>26.744</td>
<td>2</td>
<td>13.372</td>
<td>4.743</td>
</tr>
<tr>
<td>Residual</td>
<td>1460.315</td>
<td>518</td>
<td>2.819</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1487.059</td>
<td>520</td>
<td>2.860</td>
<td></td>
</tr>
</tbody>
</table>

Grand Mean = 17.2423

a. The covariance matrix is calculated and used in the analysis.

Table 9. Inter-Item Correlation Matrix between the Three Methods

<table>
<thead>
<tr>
<th></th>
<th>ET</th>
<th>SST</th>
<th>MST 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>ET</td>
<td>1.000</td>
<td>.947</td>
<td>.947</td>
</tr>
<tr>
<td>SST</td>
<td>.947</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>MST 4</td>
<td>.947</td>
<td>1.000</td>
<td>1.000</td>
</tr>
</tbody>
</table>

The covariance matrix is calculated and used in the analysis.

Table 10 presents results from the ICC model (2, 3) examining the reliability between the three methods. Results in Table 10 show that for any one timing method chosen, the ICC is about 0.96 and the average across all three is 0.99. The absolute error between the two HHS and the ET are presented in Figure 1.

Table 10. Results from ICC Model (2, 3) for the Three Methods

<table>
<thead>
<tr>
<th></th>
<th>Intraclass Correlationa</th>
<th>65% Confidence Interval</th>
<th>F Test with True Value 0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lower Bound</td>
<td>Upper Bound</td>
</tr>
<tr>
<td>Single Measures</td>
<td>.984P</td>
<td>.956</td>
<td>.971</td>
</tr>
<tr>
<td>Average Measures</td>
<td>.988</td>
<td>.985</td>
<td>.990</td>
</tr>
</tbody>
</table>

Two-way random effects model where both people effects and measures effects are random.

a. Type C intraclass correlation coefficients using a consistency definition—the between-measure variance is excluded from the denominator variance.

b. The estimator is the same, whether the interaction effect is present or not.
Discussion

The most important finding of the present study was that SST and MST resulted in significantly slower times when compared to ET, casting doubt on the validity of using HHS to obtain valid results in the HART. The mean difference comparing the ET to the MST 4 and SST was about 0.39 seconds (See table 6). Therefore, if high precision is required, ET should be the method of preference. However, data from the present study suggest that either MST or SST can produce results similar to ET. The high ICC of 0.96 can be interpreted as meaning that the relative position or rank of split times for individuals in the group of runners will be maintained regardless of method. The SEM calculated as described by (Weir, 2005) for ICC (2, 3) was 0.086 seconds. Therefore, it should be possible to rank order subjects in the HART using HHS with relatively small amounts of error. Absolute errors are presented in Figure 1. Although SST and MST resulted in similar average split times, data from MST 4 resulted in larger error near the end of the trial than split times obtained by the SST method. For the MST a single error will influence multiple subsequent split times. This is not the case for SST, where a single error would result in influencing only two split times.
Figure 1: Absolute Error between ET and MST 4, & ET and SST.

![Absolute Error Graph](image)

**Multiple-Split Timers**

Relationships between the five MST are presented in Figure 2. It was necessary to analyze these data for the purpose of determining how many MST were actually needed to perform the study. Little to no variance was found between the five timers; therefore, any one MST score could provide reliable readings. The preliminary analysis was also used to determine inter-rater reliability. In the present study, ICC, type (2, 1) was determined to be 0.92. Van Loo et al., (2003) performed a similar study using five timers compared to infrared timing gates. They found similar but higher inter-rater reliability ratings (ICC, type (2, 1) = 0.998). Differences between the two studies may be explained by differences in protocol. Van Loo et al., (2003) measured walking speed over a distance of 10 meters, perhaps making it easier for the timers to collect reliable data. However, the authors did report a small but significant difference between timers and ET for the fast paced trials (~0.01 m/sec).
**MST and SST Comparison**

Figure 3 presents the relationships between the three timing methods. The ANOVA revealed significant differences when comparing the MST and SST methods with ET. Although significant differences exist, errors in timing were small (SEM = 0.122 seconds). Differences between ET and the MST and SST are likely due to reaction time. It is possible that about half of the mean error for all split times (0.16 and 0.15 seconds for MST, SST, respectively) may be attributed to reaction time. Visual reaction time in young adults has been reported to be about 0.27 seconds (Sparrow et al., 2006). Simple auditory reaction times of 0.85 seconds may be achieved (Pain & Hibbs, 2007). Therefore, if the budget allows, ET should be the method of choice. However, a visual inspection of the data suggests meaningful results could be obtained using either MST or SST (See Figure 3).
Statistically, no differences were found between the MST and the SST. However, use of MST’s has an advantage over using SST’s. A single MST can record reasonable times when compared to using multiple SST’s. Therefore, the added man power and expense of timing devices of using SST method may seem unnecessary. Examination of Figure 1 suggests slightly less absolute error especially near the end of the trial using SST. This error is probably due to the additive effect of an error in the MST protocol as previously noted. Therefore, results of the present study suggest that if using a HHS to collect HART data, a group of SST would be preferred over MST; although, use of a MST should not vary significantly from data collected using SST.

In summary, this study demonstrated a high degree of reliability when comparing MST, SST and ET times. The ET system resulted in significantly faster split times when compared to the MST or SST. This is going against the conventional wisdom that HHS will result in faster results (Nelson, 1974). It was concluded that if a high degree of
precision is needed than an ET system should be used to collect data. However, data from this study also suggest reasonable and reliable results can be obtained through manual timing, with either SST or the MST method.
PART II

Review of Literature

Anaerobic Capacity Testing

Wingate Anaerobic Test (WAnT)

Bar-Or (1987) wrote an update on methodology, reliability and validity of the Wingate Anaerobic Test (WAnT). Methodologically, he found that many laboratories have attempted to upgrade their ergometer to lessen the work load of documentation. Many studies have been done examining the tests’ duration. Bar-Or states that any test longer than 30 seconds may cause subjects to pace themselves, especially if they are older and disabled, resulting in an underestimation of peak power. However, data from some studies suggest tests involving longer duration may result in better information. High reliability and reproducibility has been reported on the WAnT (0.89-0.098). However, certain types of motivation may influence performance. The WAnT has been compared to many lab tests to determine validity including short distance tests of sprinting, swimming, and ice skating as well as the vertical jump. High correlations were only found between the two tests; sprint and swimming.

Nummela, Alberts, Rijnies, Luhtanen and Ruscko (1996) conducted a study assessing the reliability and validity of the Maximal Anaerobic Running Test (MART). Subjects included 13 healthy physically active men (24.9 ± 3.4 years, 177.3 ± 4.1 cm, 70.7 ± 5.8 kg). Subjects were studied during a three week period and performed the MART twice and the WAnT once. In addition two subjects performed the third MART trial without oxygen uptake measurements on the test results (The MART is usually
performed without O2 uptake measurements). The tests were done with at least 48 hours between each test.

Data from the MART Maximal Power (Pmax) ranged from 101 to 116 and 101 to 119 ml/kg/min in the first and second MART. In the WAnT the total work values ranged from 260.0 to 357.0 j/kg. The reliability of the variables between the first and second MART ranged from 0.56 to 0.96 (p < 0.01). There were small but significant differences in Pmax (p < 0.01) between the first and second trial. Investigators concluded that the MART is a reliable anaerobic running test.

Tharp, Johnson, and Thorland (1984) conducted a study to determine the anaerobic power and capacity of young track athletes during 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 indicated that males demonstrated significantly higher anaerobic power and capacity levels than females. In addition, male sprinters developed greater anaerobic power and capacity than did the 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.

Bulbulian, Jeong, and Murphy (1996) conducted a study comparing anaerobic components of the Wingate Test and the Critical Power Test. A second purpose of the study was to assess the relationship of gender differences within the tests. Twenty-nine subjects (16 female; 13 male) participated in this study.
Each subject performed the Wingate to determine their Anaerobic Capacity. Critical power testing was tested by each subject performing three series of exhaustive work bouts on a Monark cycle ergometer, at three different power loadings. Each power loading was determined according to the subject’s physical fitness. A two to four minute warm-up was performed prior to the first work series followed by a two minute rest period. The test started with the subject pedaling at a rate of 69 rpm against an unloaded flywheel. A stopwatch and an electronic pedal revolution counter were started after resistance was applied to the flywheel. To achieve max power the pedal revolution counter was decreased to 60 rpm to ensure max power. Each subject was instructed to maintain the required pedaling speed. Aerobic power was determined on an electrical cycle ergometer using a protocol where power loads were increased 16.3 W/min to exhaustion.

Data shows anaerobic capacity and anaerobic reserve were not well correlated ($r = 0.07$, $p < 0.72$), suggesting that the Critical Power Test and WAnT do not assess the same anaerobic compartments. However, the Critical Power Test is a reliable and valid test when anaerobic reserve analysis is needed. When comparing gender differences, it was found that males were 20% higher than the females when performing the Wingate, but 6% lower when performing the Critical Power Test.

The WAnT and Muscle Specificity

Falk, Weinstein, Abramson, Mann-Segal and Huffman (1996) conducted a study to determine sprint running power output through a running specific laboratory test which they developed. Seventy-one subjects (56 males, 15 females; 11-17 years old)
participated in this study. After the subjects warmed-up on the treadmill ergometer, they were instructed to sprint as hard as possible for 30 seconds. Each subject performed the test twice to determine test-retest reliability. Nineteen of these subjects performed the test three times. All data were compared to previously collected data derived from the cycle ergometer (WAnT).

Mean and peak power developed on the treadmill increased with age in both genders. Test-retest coefficient of 0.80 and 0.81 for peak and mean power were found between the second and third test and were consistent with reported values for the WAnT (0.89 to 0.97). Power outputs on the treadmill were always higher compared to the cycle ergometer. Results of the study suggest that the developed sprint treadmill test is a reliable protocol to assess anaerobic power.

Baker and Davies (2002) conducted a study comparing high intensity cycle ergometry with similar high intensity performance field tests in a group of sprinters. Twelve members of a sprint squad underwent a series of anaerobic tests including a 30 second cycle ergometry test, a 30 meter sprint test, a 40 meter shuttle run test, vertical and horizontal jump tests.

Moderate correlations were found between peak power from the cycle ergometer test and all field performance tests (r=0.51, P>0.05). Significant correlations were found among all performance tests excluding the cycle ergometer test. The investigators concluded cycle ergometry may be measuring a different component of high intensity exercise and thus may not be an appropriate test of sprint performance.
Taunton (1981) compared the WAnT and the Margaria Power Test on middle and long distance runners. Seven long distance runners (LD) and eight middle distance runners (MD) were asked to perform the two test protocols. The WAnT consisted of 30-second all out exercise from which total anaerobic output (An30), and anaerobic output from the first five seconds (An5) were calculated. A blood sample was taken five minutes following completion of the WAnT in order to record blood lactate values. All subjects also completed a Margaria Power Test. These results were correlated with those from the WAnT.

Statistical analysis showed no difference between mean post-exercise lactate values for MD (8.6 mM) and LD (8.0 mM) groups. In addition, no difference was shown in power output from the Margaria Power Test between the two groups for the MD and LD was 109.6 and 109.5 kgm/sec. A significant difference in An5 was reported between MD and LD runners. The mean An5 for the MD group was 61.4 kpm/min/kg, while the mean An5 for the LD groups was 56.9 kpm/min/kg. No difference was found in the An30 between the two groups.

Other Anaerobic Capacity Tests

Vandewalle, Peres, and Monod (1987) reviewed research about standard anaerobic exercise tests. Tests which assess anaerobic power involve force-velocity tests, vertical jumps tests, staircase tests, and cycle ergometer tests. Maximal power values obtained from these tests are different however, they are well correlated. There are many factors involved in the differences between tests. An advantage to the force-velocity tests is the assessment of force and velocity components of power. Tests such as the staircase,
vertical jump, and cycle ergometer do not involve protocols which can assess those components of power. The mentioned subdivisions of Maximal Anaerobic Capacity Tests have been found to be neither reliable nor valid for testing anaerobic capacity. Overall, authors suggest that the preferred choice of an anaerobic test depends on the aim and subjects of the study as well as it relation to the testing session.

Bangsbo, Gollnick, Graham, Juel, Kiens, Mizuno and Saltin (1990) conducted a study examining anaerobic energy production through a variety of assessments: (1) accumulation of lactate, changes in ATP and CP concentrations in the active muscle, (2) released lactate from limb blood flow and arteriovenous difference pre- and post-exercise and (3) differences of O2 uptake values between the active leg and the whole body. Eight male subjects (age: 23-29 years; height: 182 cm; weight: 73 kg) participated and were instructed to perform a series of knee-extensor exercises with the experimental leg. The exercises were performed at 25% of peak aerobic work capacity followed by 10-mins of rest, then at an intense, exhaustive exercise load (mean = 65 W) lasting 3 minutes. After the rest period, each subject then was instructed to perform the same exercise for 8-10 mins each at 20, 30, 40 and 50 W. A catheter was placed in the femoral artery to measure systemic responses including pulmonary O2 uptake, heart rate, blood pressure, leg blood flow, and femoral arterial-venous differences of O2 content and lactate. Muscle biopsies were taken before and immediately after the exercise and at 3, 10 and 60 mins into rest, to determine ATP, creatine phosphate (CP), inosine monophosphate (IMP) and lactate concentration levels.
In conclusion, similar values were found for anaerobic energy release during exhaustive exercise based on ATP and CP reductions in the active muscle. Nucleotides, CP, lactate accumulation and net release of lactate contributed with a low percent of the active muscle.

**Summary.** Anaerobic capacity can be assessed through several non-invasive test protocols involving staircase climbing, cycle ergometry, vertical jumping, sprinting and force-velocity tests. The WAnT, considered to be the gold standard for assessing anaerobic capacity, has been compared to and put through many challenges to test its reliability and validity. Due to muscle specificity, other tests have been developed to reproduce results similar to the WAnT.

**Speed Measurement**

**Electronic Infrared Timing Gates**

Young, McLean, and Ardagna (1995) conducted a study to investigate the relationship between strength measures and sprinting performance and determine if the relationships varied for different phases of sprint training. Subjects included twenty (11 males and 9 females) elite junior track and field athletes. Athletes were instructed to perform maximum sprints to 50-meters from a block start. Electronic timing gates were used to measure sprint time at 2.5, 5, 10, 20, 30, 40, and 50 meter marks. Pearson correlation analysis revealed that the single best predictor of starting performance (2.5 m time) was the peak force (relative to bodyweight) generated during a jump from a 120 degree knee angle (r=0.86, p=0.0001). Stretch shortening cycle measures and maximum sprinting speed were more related to maximum speed than starting ability. It was
concluded that strength qualities were related to sprinting performance and these relationships differed for starting and max speed sprinting.

Grant, Oommen, McColl, Taylor, Watkins, Friel, Watt and Mc Lean (2003) conducted a study assessing the effect of three different ball-carrying methods has on sprint speed in rugby union football players. Subjects included 48 rugby union players (age 21 +/- 2 years, height 1.83 +/- 0.1 m, body mass 85.3 +/- 12 kg, body fat 14 +/- 5%). Subjects performed twelve 30-m sprints total (each player performed three trials under each of the three methods of ball carrying and sprinting without the ball). Each sprint consisted of a 10-m rolling start, followed by a 20-m timed section using electronic timing gates. Comparing spring 20-m using both hands (2.62 +/- 0.16s) with sprinting 20-m without the ball (2.58 +/- 0.16s), led to significantly slower time (P< 0.05). Sprinting 20-m with the ball under the left arm (2.61 +/- 0.15s) or under the right arm (2.60 +/- 0.17s) was significantly quicker than when using 'both hands' (P< 0.05), and both of these methods were significantly slower than when running without the ball (P<0.05). Results indicated that to gain speed advantage players should carry the ball under one arm.

Sands, Smith, Kivi, Mcneal, Dorman, Stone and Cormie (2005) looked at anthropometric characteristics and relationships between starting ability, sprinting ability, and jump related strength and power characteristics in US National Team Skeleton athletes. Subjects consisted of 14 athletes (male n=7; mean +/- SD: height 1.794 +/- 0.063 m, body mass 81.2 +/- 3.7 kg, age 26.9 +/- 4.1 years; female n=7; 1.642 +/- 0.055m, 60.1 +/- 5.9 kg, 27.3 +/- 6.9 years). Infrared timing gates were set up at 0, 5, 10,
15 and 30 meters to measure sprinting ability in an upright posture or crouched posture sprint. Timing gates were calibrated to an accuracy reading to 1/1000 of a second. An electronic timing system was also used to detect sled push times.

High intraclass correlation coefficients were high for sprint times ($r = 0.94$). Statistical differences were found between the first trials (1.98 +/- 0.21 s, 4.51 +/- 0.42 s) and the second trials (1.94 +/- 0.21 s, 4.51 +/- 0.42). In addition, no statistical differences were found between sled push times trials ($r = 0.94$).

Liow and Hopkins (2003) conducted a study investigating the effect of slow and explosive weight training on kayak sprint performance using an electronic timing system. Subjects consisted of 27 male and 11 female experienced sprint kayakers. Subjects were randomly put into three groups: slow weight training, explosive weight training and control (usual training). Each session consisted of 3-4 sets of two sport-specific exercises with a load of 80% 1-repetition-maximum. To determine the effects of weight training on sprint acceleration and speed maintenance, subjects performed a 15-meter kayaking sprint pre- and post weight training. Electronic timing gates were set up at 3.75-, 7.5- and 15-meter marks to determine sprint times. Both types of weight training substantially improved strength and sprint performance. The improvements in mean sprint time over 15-meters in each group were: slow, 3.4%; explosive, 2.3%; control, -0.2%. Over the first 3.75-meters, the improvements were: slow, 7.1%; explosive, 3.2%; control, 1.4%. Over the last 7.5-meters, the improvements were, slow, 2.1%; explosive, 3.0%; control, -0.8%. Results indicate that slow weight training is likely to be more effective than
explosive training for improving the acceleration phase of sprinting. Explosive weight training may be more effective in speed maintenance.

Marks (1993) conducted a study assessing the reliability and validity of self-paced walking time as an outcome measure for osteoarthritis of the knee. Fifteen females, ages 37-74 years (mean 59.20 +/- 11.10), height 151-171 cm (mean 162.13 +/- 5.91) and weight 63-118 kg (mean 80.65 +/- 16.21) participated in this study and were instructed to walk 13-m twice on two separate occasions. Speed measurement was obtained through the use of photocells. Two photocells were set up 45 cm above the floor at either end of a 13-m walkway with a distance of 2.2 m between them. Accuracy of the photocell measurements was to the 1/100 second.

High intraclass correlations were reported for each session of the walking tests. A significant correlation was found between measurement times and results of other methodologies for evaluating osteoarthritic gait conditions. Data suggest that measurements of a self-paced walking time are a reliable and valid form for evaluating patients with osteoarthritic conditions.

Hand Held Stopwatches

Brooks, Hunter, Parsons, Livsey, Quirt and Devlin (2002) conducted a study examining reliability of the two-minute walk test in individuals with transtibial amputation. Participants included 33 subjects (23 men, 10 women; mean age ± standard error, 63.6 ± 2.0 y) with transtibial amputation and were instructed to walk as far as possible down a 40-meter path in two-minutes. Each subject performed a total of four two-minute walk tests. Speed measurements were taken by two raters using a digital
stopwatch to time each test. The order of raters was randomized on the first day and reversed for the next day. Raters were instructed to start their stopwatches when the subject started to walk and stop the stopwatch when the subject came to a complete stop.

Results indicated that within rater-reliability was high (ICC= 0.90-0.96). Between rater reliability was also high (ICC .98-.99). ANOVA showed a significant effect for day of test (P<.001) in the impatient group but no effect for therapist (P=.098) or for interaction of day and therapist (P=.710). Similarly, in the outpatient group, ANOVA showed a significant effect for day (P=.013) but no effect for therapist (P=.259) or interaction of day and therapist (P=.923).

David and Sullivan (2005) conducted a study to determine walking speeds of children and determine the most appropriate (“good enough”) walking speed if a teacher had to slow down her class line in order to accommodate a student with a limited walking ability. Forty-three elementary schools were involved in the data collection process. Subjects of the study included 370 children (ranging from kindergarten to sixth grade). They were instructed to walk at a speed (determined by the first student of the line) along a 50-ft marked path. A standard stopwatch was used to determine the speed measurement the class lines. Two raters measured the time that the first student in line, the line leader, took to walk along the 50-ft path. Each rater was asked to collect data on two classes in each grade (a total of 20 timed observations). Times were measured to the nearest second.

Reliability among the raters were reported as being high in both cases (r = 0.99). Significant speed differences were found among the different grade levels to walk 50 ft.
Mean times were significantly higher in first grade than in fifth or sixth grade; higher in second grade than in fifth grade; higher in kindergarten than in forth to sixth grades. The “good enough” times were significantly different at each grade level.

Rantanen, Guralnik, Izmirlian, Williamson, Simonsick, Ferrucci and Fried (1998) conducted a study evaluating the effect of lower limb strength importance on walking speed in older disabled females. Reserve capacity was also assessed during maximum walking speed and a minimum strength threshold was assessed during walking at a rate of 1.22 m/s. One thousand and two disabled women participated in the study and were instructed perform a knee extension strength test on both legs. Knee extension torque/body mass ratio (KET/BM) was measured by a dynamometer. Subjects were then asked to perform a maximum walking speed test of 4-m which was measured using a stopwatch. Subjects were instructed to perform a fast walk after a demonstration was shown. They started from a standing position and were told to walk as fast as possible. Stopwatches were started when subjects started walking and stopped when each subjects came to a complete stop.

The correlation between max walking speed and KET/BM was $r = 0.402 (P < 0.001)$, which as a significant predictor of max walking speed.

**Electronic Infrared Timing Gates vs. Hand Held Stopwatches**

Van Loo, Moseley, Bosman, De Bie and Hassett (2003) conducted a study to assess the inter-rater reliability and concurrent validity of walking speed measurement after traumatic brain injury. Twelve subjects (3 female and 9 male) with a mean age of 32.3 years participated in the study and were instructed to walk a total of 10 times (14-
meters) at two different paces (five times at a comfortable pace and five times at a fast pace.

Speed measurements were taken from a stopwatch and were compared to measurements taken from an infrared timing gate system. Timing gates were mounted on tripods at knee height in the beginning and end of the central 10-meters of the 14-meter walkway. As the subject interrupted the infrared beam the gates automatically commenced and ceased timing. To determine inter-rater reliability, walking speed was measured using a clinical procedure (stopwatch) by five observers. The observers were seated and had a clear view of tape marks on the floor at each ends of the 10-meter distance. They started/stopped their stopwatches when the subject’s foot crossed the tape marks. Observers wore earplugs and earmuffs so that they could not hear the beeps generated by the infrared timing gates and the stopwatches used by the other observers.

Data showed inter-rater reliability of measuring walking speed using the stopwatch was very high for both trials. The ICC was 0.999 for each of the five comfortable trials and 0.998 for each of the five fast trials. The repeated measures ANOVA for the stopwatch measurements showed not main effect for trial (F=0.966, p=0.476) and observer (F=2.437, p=0.132), indicated that the observers did not differ significantly. The stopwatch measurements compared well with the infrared timing gates, indicating concurrent validity. There was no significant difference between the timing gate and stopwatch procedures for the comfortably paced trials using the t-test (t=1.541, p=0.152) or Friedman test (chi-squared=2.000, p=0.157). There was a small but statistically significant difference for fast-paced trials between the means (t=3.626,
Results indicated that both methods of measurement were the same.

**Summary.** Speed measurement can be obtained through the use of an electrical timing gate system as well as a stopwatch. Stopwatches seem to be an easy way of measuring speed; however, human error may result in poor data. Electronic timing systems tend to be accurate to the 1/100th of a second and may be the preferred method of choice when precise measurements are needed.

**Reaction Time**

Pain and Hibbs (2007) conducted a study to determine the minimum neuromuscular-physiological component of auditory reaction time during sprint starts. Reaction times of nine athletes from a series of up to 50 starts in four different randomized conditions (normal condition, preferred method, preloaded condition, relaxed position and guess position). Time between the set and the start signal was randomly chosen by the started within a 3-4 second duration which started 1 second after the subject was in the set position. Reaction times were measured using starting blocks instrumented with piezoelectric force transducers in each footplate, synchronized with the start signal.

Mean times of five of the nine subjects were less than 10 ms in at least one condition and 20% of all starts in the first two conditions had reaction times less than 100 ms in the non-guess positions, and 20% of all starts in the first two conditions had reaction times less than 100 ms. Results suggest that neuromuscular-physiological component of simple auditory reaction times can be less than 85 ms.
Sparrow, Begg and Parker (2006) Aging effects on visual reaction time in a single task condition and when treadmill walking.

**Summary.** Human error can be due to auditory and visual reaction times. Simple auditory reaction times have been reported to be less than 85 ms. Mean reaction times for the older population are reported to be 315 to 304 ms, and 273 to 266 ms for the younger population.
REFERENCES


APPENDICES

Appendix A
Timer Instructions

Multiple-Split Timers
You as a timer will be positioned in the center of the track with a hand-held timer where all 25 meter markers are clearly visible. The trial runs that will occur today will happen at a very fast pace. It is vital that you are prepared and ready to go immediately after you have recorded your split times.

Please follow the following steps:

1. **Keep your eye on the starter.** When his hand is raised, this indicates that the runner is ready and the start signal (starting horn) will be given VERY shortly.

2. The moment you see the flash located on the top of the starting horn, start your hand-held timer. This button is located on the RIGHT side of the timer which reads “START/STOP”.
   **It is important that you start your hand-held timer when you see flash of light NOT when you hear the horn.** **

3. As the runner passes through each 25-meter mark, press the “split time” button located on the LEFT side of the timer. You will be taking a total of EIGHT split times.

4. When the runner has passed through the last timing gate, document each split time in the appropriate slot on the time card. Click the “recall” button located on top/center of the timer and then scroll through by pressing the “split time” button.

5. Clear the timer by pressing the “recall” button and then pressing the “split time” button.

6. **KEEP YOUR EYE ON THE STARTER** and be prepared for the starting signal for the next runner.

*IF THERE IS A MALFUNCTION WITH THE ELECTRONIC INFRARED TIMER DURING THE START, A WHISTLE WILL BE BLOWN. RESET YOUR TIMER AND BE PREPARED TO START ONCE THE RUNNER IS READY.*
Single-Split Timers

There will be nine timing gates set up on the track. You as a timer will be positioned on the outside perimeter of your assigned 25-meter mark. The trial runs that will occur today will happen at a very fast pace. It is important that you are prepared and ready to go immediately after you have recorded your split time.

Please follow the following steps:

1. **Keep your eye on the starter.** When his hand is raised, this indicates that the runner is ready and the start signal (starting horn) will be given VERY shortly.

2. The moment you see the flash from the starting horn, start your hand-held timer. This button is located on the RIGHT side of the timer which reads “START/STOP”.

**It is important that you start your hand-held timer when you see flash of light NOT when you hear the horn.**

3. As the runner passes through your 25-meter mark, press the “Start/Stop” button located on the RIGHT side of the timer. You will only be taking ONE split time.

4. When the runner has passed through your timing gate, document the split time on the time card.

5. Clear the timer by pressing the “split time” button.

6. **KEEP YOUR EYE ON THE STARTER** and be prepared for the starting signal for the next runner.

*IF THERE IS A MALFUNCTION WITH THE ELECTRONIC INFRARED TIMER DURING THE START, A WHISTLE WILL BE BLOWN. RESET YOUR TIMER AND BE PREPARED TO START ONCE THE RUNNER IS READY.*
Appendix B
Sample Informed Consent

INFORMED CONSENT
To Participate in a Research Study

I. INVESTIGATORS
Principal Investigators: Supervising Professor:
Andrea S. Harmon, ATC Iris F. Kimura, PhD, ATC, PT
Kelly M. Lundquist, ATC
Christopher D. Stickley, MA, ATC
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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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<th>Schedule 1</th>
<th>Wingate Anaerobic Test</th>
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**Wingate Anaerobic Test (WAnT)**

A maximum bicycle sprint will be performed using the bicycle ergometer (exercise bicycle). You will start with a 5-15 minute warm up on the bicycle ergometer, a 15-second 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 (SFT<sub>Max</sub>)**

The SFT<sub>Max</sub> 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 SFT<sub>Max</sub>. 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 Lundquist 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.
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.

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