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## Does Distance Climbed in a 30-S Maximal Effort Test on a Simulated Climbing Machine Correlate with Wingate Variables?

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DOES DISTANCE CLIMBED IN A 30-S MAXIMAL EFFORT TEST ON A SIMULATED  
CLIMBING MACHINE CORRELATE WITH WINGATE VARIABLES?

By

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2016

A thesis submitted in partial fulfillment  
of the requirements for the

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## Thesis Approval

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Does Distance Climbed In a 30-S Maximal Effort Test on a Simulated Climbing Machine  
Correlate with Wingate Variables?

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## Abstract

Does distance climbed in a 30-s maximal-effort test on a simulated climbing machine correlate with Wingate variables?

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**Introduction:** The Wingate Anaerobic Test (WAnT) is used to assess anaerobic capacity by measuring total work. In addition to total work, the WAnT measures peak power, mean power, relative peak power, and fatigue. There are lower-, upper-, and full-body alternatives to the WAnT that can be used to measure anaerobic capacity, but there is little data on these alternatives. It may be beneficial to have a full-body assessment of anaerobic capacity, as many sporting events have full-body anaerobic demands. Simulated climbing machines are becoming popular modes of exercise. They have been compared to treadmill running and cycling in terms of maximal aerobic capacity. The correlations between climbing and both treadmill running and cycling  $VO_{2max}$  are .87 and .84, respectively (3).  $VO_2$  and heart rate increase linearly on the climber with increasing workloads, similar to treadmill running and cycling (3). Not only does the climber elicit similar metabolic responses to treadmill running and cycling, Braehler & Blank (6) found that the climber can elicit a higher  $VO_{2max}$  than rowing in female rowers. To date, no study has examined maximal-effort climbing to assess anaerobic capacity. Therefore, the purpose of this study is to test if a distance climbed 30-s maximal-effort test on a simulated climbing machine correlates with WAnT variables, specifically total work (anaerobic capacity).

**Participants:** 32 apparently healthy males and females (16 each) were recruited from the University of Nevada, Las Vegas. Two participants did not complete all the sessions due to reasons unrelated to the study and are not included in the analyses. **Wingate Protocol:** All participants performed the WAnT protocol on the Monark Ergomedic 894E (Sweden). Test resistance was calculated at 7.5% of the participant's body mass (kg). Participants warmed up for

about 3-5 minutes, depending on the participant, with no resistance and rested for one minute before the start of the test. A 5-second countdown was used to begin the test. Participants were instructed to be pedaling as fast as they could at 1 second left of the countdown. Resistance was applied by the researcher pushing the handlebar button, and participants were given verbal encouragement to pedal as fast as they could during the thirty seconds. **Climbing Protocol:** Participants performed a similar protocol to that of the WAnT on a VersaClimber™ SM Sport Model (Santa Ana, California). Participants warmed up for about 3-5 minutes, depending on the participant, with the lowest resistance, then rested for one minute. Following a 5-second countdown, participants began to climb as fast as they could on the lowest resistance and the thirty seconds started by using the bluetooth module to the VersaBlue App. **Results:** Thirty participants fully completed the study. Total work on the WAnT and distance on the climber were found reliable (ICC of .990 and .937), and the second trial for each participant was used for analysis. The bivariate correlation between WAnT total work and climber distance climbed was 0.81, explaining a very large amount of variance (~65%). When adding body mass into the prediction, the amount of variance explained is about 83%. MPO and PPO on the WAnT were both reliable (ICC .83 and .96). When separating by sex, bivariate correlations for total work and distance climbed for males was .61 ( $p < .05$ ) and for females .22 ( $p > .05$ ). Large, statistically-significant differences between males and females were found for PPO, MPO, total work, and distance climbed for both the climber and WAnT. **Discussion:** The current study's findings provide evidence that the simulated climbing machine can possibly be a device used to measure anaerobic capacity with further studies. The use of simulated climbing can be advantageous in measuring anaerobic capacity because it involves a large muscle mass and is simple to perform.

However, simulated climbers may need a means to measure and control force if they are to be a validated device to measure anaerobic capacity.

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## Chapter 1: Introduction

The Wingate Anaerobic Test (WAnT) is used to measure anaerobic capacity by measuring total work. It was developed in the 1970s and has become a widely used assessment, likely because of its reliability and validity. In addition to anaerobic capacity (total work), the WAnT measures peak power, mean power, relative peak power, relative mean power, and fatigue. Peak power is assumed to reflect the capacity of high-energy phosphates to generate energy and average power is assumed to reflect glycolytic capacity (17). Average power also reflects the ability of the muscles to maintain high power (4).

There are lower-, upper-, and full-body alternatives to the WAnT that can be used to measure anaerobic capacity, but there are little data on these alternatives. It may be beneficial to have a whole-body assessment of anaerobic capacity, as many sporting events have whole-body anaerobic demands. Simulated climbing machines, such as a VersaClimber™ or Jacob's Ladder™, are becoming popular modes of exercise and have been compared to traditional ergometers such as treadmill and cycle. Ballor et al. (3) found that  $VO_{2max}$  (maximal oxygen consumption during exercise) elicited by a climber is about 93% of a person's  $VO_{2max}$  elicited by a treadmill, which is similar to the percent of  $VO_{2max}$  elicited by swimming or on a cycle ergometer. The correlations between climbing and both treadmill running and cycling  $VO_{2max}$  are .87 and .84, respectively (3). Both heart rate and  $VO_{2max}$  increase linearly on the climber with increasing workloads, similar to treadmill running and cycling (3). Not only does the climber elicit similar metabolic responses to treadmill running and cycle ergometry, Brahler & Blank (6) found that the climber can elicit a higher  $VO_{2max}$  than rowing ergometry in female rowers. To date, no study has examined maximal-effort climbing to assess anaerobic capacity.

Simulated climbing machines can be advantageous to athletes because they involve full-body exercise. Full-body exercise is important because it increases a greater amount of energy expenditure compared to only upper- or lower- body exercise (1). While there are many demonstrated benefits of simulated climbing, common limitations are the lack of a precise measurement of force that could be used in fitness and performance testing such as anaerobic capacity. Since simulated climbing machines are partially weight bearing, a surrogate measure of work might have utility in measuring anaerobic performance. Therefore, the purpose of this study is to test if a distance climbed 30-s maximal-effort test on a simulated climbing machine correlates with WAnT variables, specifically total work (anaerobic capacity).

## Chapter 2: Literature Review

### Wingate Anaerobic Test (WAnT)

The most commonly used test of anaerobic capacity is the WAnT. It was developed at the Department of Research and Sport Medicine of the Wingate Institute for Physical Education and Sport in the mid 1970's (4). It was designed to be inexpensive, easy, and accessible, due to the commonly available equipment (4). The WAnT measures peak power, mean power, anaerobic fatigue, and anaerobic capacity (total work). Peak power is assumed to reflect the capacity of high-energy phosphates to generate energy and average power is assumed to reflect glycolytic capacity (17). Average power also reflects the ability of the muscles to maintain high power (4).

The WAnT is a modification of the Katch test which used a set resistance of 6 kg for men and 5 kg for women during a 40-second all-out sprint on a cycle ergometer (17). The WAnT, however, uses a relative resistance of 7.5% of the participant's body weight. This percentage of body weight was chosen based on a study of young untrained individuals, but the norms of resistance for trained individuals range from 9-10% of the individual's body weight (4). Evans and Quinney (1981), as cited in Bar-Or (4), suggested the optimal force is based on the individual's bodyweight and leg volume, but this has not been supported in other studies.

**Wingate reliability.** Madrid et al. (16) had cyclists perform the WAnT three times, and they found high intraclass correlation coefficients (ICC) for peak power, mean power, fatigue index, heart rate, and perceived exertion across all three tests (0.788-0.988). Another study tested seventeen elite taekwondo athletes to test the reliability of the WAnT by taking it twice and found ICC values of 0.95 for fatigue index, 0.75 for peak power, and 0.70 for mean power (20).

The WAnT has been studied in different high ambient temperatures and humidity, with varying hydration, and performing a warm up or not before the test to test validity with as many different variables as possible (4). The WAnT produced reliable results in neutral, hot, and humid climates. The participants performed the WAnT in all three climates and found that the means for peak power were similar at 6.82 W/kg (neutral), 6.92 W/kg (humid), and 6.74 W/kg (hot)(4). When participants performed the WAnT at euhydration and three levels of hypohydration, the mean power values were similar at 639, 644, 631, and 636 W (4). Further research may be needed to test how reliability is influenced by warm up time but researchers found that warming up prior to exercise increased mean power by 7% but not peak power (4). Another study examined a shuttle run where participants ran 20 meters, as fast as possible, 12 times. Run time was compared to the WAnT and a treadmill exhaustive run protocol. The groups performed each test two times to determine reliability. The shuttle run ICC was .96, treadmill ICC was .97, and the WAnT ICC was .83. They found a high negative correlation (-.89) between the time of the shuttle run and the WAnT power output (22). Based on this prior research, the WAnT appears to be a reliable test to measure anaerobic capacity.

**Wingate duration.** The duration of the WAnT was based on pilot observations of multiple durations. Researchers found that at longer durations, participants would try to "save" their power in order to last the whole time which causes inaccurate results (4). Since the Katch test is longer (40 seconds), it may result in higher total work, but lower mean and peak powers (4). Another study examined test-retest reliability of 15 second WAnT (10). WAnT<sub>15</sub> had a high test-retest reliability (ICC) for peak power (0.989), mean power (0.993), and fatigue index (0.854). One study used a 20 second WAnT to predict the results of the typical 30 second WAnT (2).

That study found that mean power output had the highest coefficient of predictability (Pearson  $r$ ) at 0.97 while peak power was at 0.71. The researchers concluded that the 20 second WAnT is a valid test of anaerobic power and could potentially replace the typical WAnT. They also tested its ICC for both peak power and mean power output and found that WAnT<sub>20</sub> (0.98 and 0.90) and WAnT<sub>30</sub> (0.98 and 0.95) have a high reliability (2).

**Wingate validity.** To validate the WAnT, researchers have correlated it with sprinting, short-distance swimming, short-distance ice skating, and the vertical jump (4). The  $r$ -values produced were 0.75 or more, with the strongest association with sprinting and 25-m swimming (4). A 15-s version of the WAnT (WAnT<sub>15</sub>) to the WAnT<sub>30</sub> showed that the WAnT<sub>15</sub> is a valid assessment of peak power and mean power (10). The WAnT<sub>30</sub> had a higher fatigue index (60.5% vs. 39%) than the WAnT<sub>15</sub>, as would be expected. Based on this prior research, the WAnT appears to be a valid test to measure anaerobic capacity. The WAnT is also likely to predict performance best in cyclists because of the mode. A study on the validity of the WAnT for the evaluation of elite runners found that there were no significant differences between the sprinters (100m and 400m) and longer distance runners (800m +) in peak power (871 W vs. 777 W) and mean power (735 W vs. 634 W). They concluded that the WAnT is not a useful tool to predict performance of elite runners. (14). The WAnT has been modified for a rowing ergometer (15) and they found that this modified rowing WAnT correlated significantly ( $r^2=.83$ ) with 1,500 m rowing performance (15).

### **Alternatives to the Wingate**

Lower body alternatives to the WAnT include jumping tests, shuttle runs, and treadmill sprints. Many studies have used jumping tests for anaerobic capacity and compare it to the WAnT because jumping invokes the stretch-shortening muscle actions (21). One jumping test

that was studied is called the Bosco test, where the participant jumps as high and fast as possible for 60 seconds (5). It is meant to be comparable to the WAnT in duration because contact time to the ground is approximately 30 seconds (21). Another study found a large correlation of 0.70 between mean jump height in the Bosco test and mean power output from the WAnT. Peak lactate at the end of the tests had a correlation of 0.51 (9). Zemkova and Hamar (23) had participants do an "all-out tethered run" for 30 seconds and compared it to their performance on a 30-second all-out isokinetic cycling sprint at a revolution rate of 100 rpm which is similar to the WAnT. Participants were tethered to a wall behind the treadmill and ran all out at 13 km/h (about 8 mph). Drag force was calculated and running power was measured during the tethered running. They found that there was a high correlation between tethered running and isokinetic cycling in mean power ( $r=0.920$ ), maximal power ( $r=0.877$ ), and fatigue index ( $r=0.896$ ) (23). This suggests that tethered running is a valid alternative to the WAnT.

Unlike lower body alternatives, there are few upper body alternatives to the WAnT. Upper body assessments may be important for individuals in sports, such as kayaking, wheelchair racing, and others. There is a WAnT upper body assessment that is used to measure upper body anaerobic power which uses an arm crank. Unlike the lower body WAnT, the upper body WAnT does not have a substantial amount of research on it; however, it can measure work,  $VO_{2max}$ , and power output (18).

Another upper body alternative, while not a WAnT, is the double-arm anaerobic work test. This test was used in a study to measure upper body strength and mean, peak, and minimum power output in elite junior oarsmen and club level rowers (12). The assessment consisted of a double-arm anaerobic work test where participants had to use both arms to turn a bar connecting

the cranks of two cycle ergometers (12). They wanted to see how these variables can predict rowing performance and if the double-arm anaerobic work test can test anaerobic variables. They found that the power elicited during the double-arm anaerobic work test can predict the performance of junior oarsmen 91.8% of the time (12).

There are also full-body alternatives to the WAnT that have been studied (15, 20). One study found that 30-s maximal rowing test can predict the 1500-m time of young rowers, where mean WAnT power explained variance in 1500-m time (15). Another possible full-body alternative is the taekwondo-specific anaerobic test. Rocha et al. (20) studied a new method to assess anaerobic capacity in 17 male elite taekwondo athletes by having them kick a punching bag for 30 seconds and measuring the force of the kick and the amount of techniques (2 kicks). Peak power output, mean power output, fatigue index, and anaerobic capacity were then calculated from the force, number of techniques, and time (30 seconds). These variables were compared to the WAnT and was found to have a correlation of 0.64 for peak power and 0.65 for mean power which were statistically significant (20).

### **Simulated Climbing Machines**

Simulated climbing machines have been compared to treadmill running and cycling in terms of metabolic demands. Laddermills (Jacob's Ladder™) and climbers (VersaClimber™) have increased in popularity. Jacob's ladder™ is a non-motorized laddermill so the user is creating the power themselves (1). Studies have shown different results between laddermills and both treadmills and cycle ergometers. Males that performed a laddermill exercise had a higher  $VO_{2max}$  in climbing (54 ml/kg/min) compared to both treadmill running (52 ml/kg/in) and cycling (45 ml/kg/min) (11). Females did a little better in treadmill running (45 ml/kg/min)



compared to climbing (44 ml/kg/min) and cycling (41 ml/kg/min) and it was more consistent than the males  $VO_{2max}$  when comparing all three devices (11). Healthy college students performed a  $VO_{2max}$  test on both a treadmill and a laddermill (1). It was found that  $VO_{2peak}$  on the ladder (41 ml/kg/min) was lower than  $VO_{2peak}$  on the treadmill (45 ml/kg/min) and it was significant (1). It was found that the laddermill exercise can be an alternative due to its lower impact forces compared to a treadmill (1).

The VersaClimber™ is an exercise device developed in 1981, which has been studied in the context of aerobic fitness. The instruction manual states:

“To climb, the person stands in a vertically erect position with both feet level on pedals while grasping two hand grips set at about shoulder height. To initiate climbing motion, step down on one-foot pedal while pushing up on the hand grip. When the foot and hand move vertically downward, the other foot and hand move vertically upward and then alternate synchronously. A cyclic action of the arms and legs is performed that simulates motion of climbing an endless ladder for any selected step height, time, rate and distance. A microcomputer monitors and displays climbing performance, heart rate, calories, distance, time and gives audible instructions and motivational messages during the exercise. The machine is oriented at a 75-degree climb angle” (7).

Ballor et al. (3) found that  $VO_{2max}$  elicited with a simulated climbing machine is 93% of that elicited by a treadmill, which is similar to the  $VO_{2max}$  elicited by swimming or on a cycle ergometer. The correlation for  $VO_{2max}$  between climbing and treadmill running was .87 and the correlation between the climbing and cycling was .84. This indicates that the climber is just as effective as the cycle ergometer and treadmill in measuring  $VO_{2max}$  (3). They also found that

$\text{VO}_{2\text{max}}$  and heart rate increase linearly with increasing workloads similar to treadmill running and cycling (3). Not only does the climber elicit similar metabolic responses to treadmill running and cycle ergometry, Braehler & Blank (6) found that the climber can elicit a higher  $\text{VO}_{2\text{max}}$  than rowing ergometry in female rowers. The climber was also compared to rowing in addition to treadmill running (6). It was found that  $\text{VO}_{2\text{max}}$  (about 55 ml/kg/min vs. 50 ml/kg/min) and minute ventilation (153.7 l/min vs. 143.28 l/min) was higher during climbing compared to rowing (6). It was believed that the climber may have elicited a higher  $\text{VO}_{2\text{max}}$  than treadmill running due to it being a whole-body exercise. It is possible that the climbing protocol as well as good climbing technique must have been ideal and helped to elicit a higher  $\text{VO}_{2\text{max}}$  in female rowers. In another study, healthy college students had a lower  $\text{VO}_{2\text{max}}$  (38.7 ml/kg/min vs. 44.9 ml/kg/min) elicited during the climbing exercise compared to a treadmill protocol (13). It may be that the climber is better with submaximal exercise testing instead of max testing due to many participants not being able to reach the criteria for a true  $\text{VO}_{2\text{max}}$  value. It is possible that the climber needs a certain technique to it so participants were not able to reach a true max due to their body failing them to do so.

While there are many demonstrated benefits of simulated climbing machines, including it being a whole-body workout, low impact, and just as efficient as other devices, the hydraulic resistance does not allow a precise measurement of force that could be used in fitness and performance testing. Hydraulic resistance also makes it harder to predict  $\text{VO}_{2\text{max}}$  since the climbing becomes more weight independent when hydraulic fluid flow is increased (3). There are no studies on simulated climbing machines measuring anaerobic capacity. Simulated climbing machines are partially weight bearing, so it is possible that work can be measured to

measure performance. This study will show if distance climbed on a 30-s maximal effort test on a simulated climbing machine correlates with WAnT variables, specifically total work. This preliminary study will allow us to see if it is possible to develop a full-body alternative to the WAnT.

## Chapter 3: Methodology

### Participants

An *a priori* sample size analysis determined that a proposed meaningful correlation (8) of  $\rho=0.75$ , p-value at 0.05 (two-tailed), and power at 0.95, required 13 participants. To account for potential attrition and sex differences, 32 apparently healthy males and females (16 each) were recruited from the local university population. The ACSM Health Risk Questionnaire (19) was used to determine health risks. In order to participate, potential participants had to meet the following inclusion criteria: male 18-44 years old or female 18-54 years old, and classified as “low risk” according to the ACSM Health Risk Questionnaire. Potential participants were excluded if they met one or more of the following criteria: <18 years old, male > 44 years old, female > 54 years old, classified as “moderate risk” according to the ACSM Health Risk Questionnaire, are pregnant or think they may be pregnant, or have an implantable device (such as a Pacemaker), or have orthopedic, cardiovascular, respiratory, or metabolic conditions. The study was conducted with approval of the Institutional Review Board of the University of Nevada, Las Vegas.

### Procedures

Participants reported to the laboratory on five different days. On the first day, age and sex were self-reported. Next, height and weight were measured, then body composition was estimated (fat-mass, fat-free mass, hydration) on the SECA mBCA 515/514 (Hamburg, Germany). Participants practiced each protocol for familiarization and the seat (WAnT) and handles (climber) were adjusted and their positions recorded for future testing sessions. Participants performed two trials each of the WAnT and climbing protocol in random order over the next four testing sessions,

totaling two trials of the WAnT and two trials of the climber for the whole study. The next four testing sessions were separated by at least two days.

**Wingate Protocol.** All participants performed the WAnT protocol on the Monark Ergonomic 894E (Sweden). Test resistance was set at 7.5% of the participant's body mass. Participants warmed up for about 3-5 minutes, depending on the participant, with no resistance, then rested for one minute before the start of the test. A 5-second countdown was used to begin the test. Participants were instructed to be pedaling as fast as they could at one second left of the countdown. Resistance was applied by the researcher pushing the handlebar button, and participants were given verbal encouragement to pedal as fast as they could during the thirty seconds. After the thirty seconds, resistance was removed and participants performed a self-paced cool down. Using the Monark ATS Software (Sweden), PPO, MPO, total work, and fatigue index were calculated and recorded.

**Climbing Protocol.** Participants performed a similar protocol to that of the WAnT on a VersaClimber™ SM Sport Model (Santa Ana, California). Participants were instructed to have an overhand grip on the climber. Participants warmed up for about 3-5 minutes, depending on the participant, with the lowest resistance, then rested for one minute. Following a 5-second countdown, participants began to climb as fast as they could on the lowest resistance and the thirty seconds started by using the Bluetooth module to the VersaBlue App. A researcher recorded distance climbed every five seconds. Participants were given verbal encouragement to climb as fast they could for the entire thirty seconds. After the thirty seconds, participants performed a cool down. Using the VersaBlue App, distance climbed at every 5-second interval and total distance climbed were recorded. In the event of the VersaBlue App malfunctioning, distance climbed at

every 5 second interval and total distance climbed were recorded by an investigator from the climber itself. Fatigue index was calculated from the maximal and minimal distances climbed during five second intervals with this equation:  $[(\text{Max} - \text{Min})/\text{Max}] * 100$ .



Figure 1: VersaClimber™ SM Sport Model

### **Statistical Analyses**

All statistical analyses were conducted using the IBM SPSS Statistics 25 software (Armonk, New York). Descriptive statistics (mean and SD) were calculated separately by sex for age,

height, weight, lean mass, fat-mass, and body fat percentage. Differences between sexes were calculated using an independent t-test. Intraclass correlation coefficient ( $ICC_{3,1}$ ) were calculated between two trials of the WAnT PPO (W), MPO (W), total work (J), and FI and between the two trials of the climber for distance and FI. Bivariate correlations were calculated for total work on the WAnT and distance on the climber. Secondary analyses used regression to predict WAnT performance based on distance climbed and body mass. Significance was set at  $p \leq 0.05$ , and Cohen's  $d$  effect sizes were calculated for pairwise comparisons.

## Chapter 4: Results

Thirty participants fully completed the study. Two participants did not complete all the sessions due to reasons unrelated to the study and are not included in the analyses (Table 1). Total work on the WAnT and distance on the climber were found reliable (ICC of .99,  $p < .001$  and .94,  $p < .001$  respectively) and precise (CV% of 2.3% and 6.1%, respectively), and the second trial for each participant was used for analysis. MPO and PPO were both reliable (.83,  $p < .001$  and .96,  $p < .001$ ). The ICC for fatigue index for the WAnT (0.24,  $p = .094$ ) was not significant, while the ICC for fatigue index on the climber was low (0.34,  $p < .05$ ) and statistically significant. Neither fatigue index was sufficiently reliable for comparison.

The most important finding is that the bivariate correlation between WAnT total work and climber distance climbed was 0.81, explaining a very large amount of variance (~65%; Figure 2). When body mass is added to the prediction, there was a significant and meaningful increase in variance explained (~18%) so this prediction model  $R^2$  increased to about 83% ( $p < .001$ ). There were several large, statistically significant differences between the male and female participants (Table 1).



**Table 1. Participant Demographics (Mean  $\pm$  SD)**

	Males (n=15)	Females (n=15)	p-value	Effect Size (d)
Age (years)	24.8 $\pm$ 6.5	23.1 $\pm$ 4.1	0.41	0.32
Height (cm)	176.2 $\pm$ 5.4	159.4 $\pm$ 6.4	<.001*	2.94
Body Weight (kg)	77.0 $\pm$ 13.5	69.2 $\pm$ 13.8	0.126	0.59
Lean Mass (kg)	61.1 $\pm$ 7.9	44.9 $\pm$ 5.8	<.001*	2.42
Fat Mass (kg)	16.0 $\pm$ 7.7	24.3 $\pm$ 8.9	0.011*	-1.03
Body Fat Percentage (%)	19.8 $\pm$ 7.3	34.1 $\pm$ 6.5	<.001*	-2.14

\*Significant difference between sexes

When separating by sex, bivariate correlations for total work and distance climbed for males was .61 ( $p < .05$ ) and for females .22 ( $p > .05$ ). Large, statistically significant differences between males and females were found for PPO, MPO, total work, and distance climbed for both the climber and WAnT (Table 2). Differences between males and females for relative PPO effect size (1.87) was also very large, while relative MPO effect size (0.96) was moderate.

**Table 2. Outcome variables (Mean  $\pm$  SD)**

	Combined (n=30)	Males (n=15)	Females (n=15)	p-value	Effect Size (d)
WAnT PPO (W)	689.6 $\pm$ 211	829.6 $\pm$ 199.7	549.6 $\pm$ 101.7	<.001*	1.83
WAnT PPO (W/kg)	9.4 $\pm$ 1.9	10.7 $\pm$ 1.6	8.1 $\pm$ 1.2	<.001*	1.87
WAnT MPO (W)	502.9 $\pm$ 166.4	589.7 $\pm$ 192	416.1 $\pm$ 65.6	<.05*	1.25
WAnT MPO (W/kg)	6.9 $\pm$ 1.7	7.6 $\pm$ 2.1	6.1 $\pm$ 0.8	<.05	0.96
WAnT total work (J)	15110.3 $\pm$ 4187.7	18139.9 $\pm$ 3647.8	12080.6 $\pm$ 1830.6	<.001*	2.17
Climber distance (m)	33.4 $\pm$ 7.1	38.9 $\pm$ 5.5	27.8 $\pm$ 2.7	<.001*	2.65

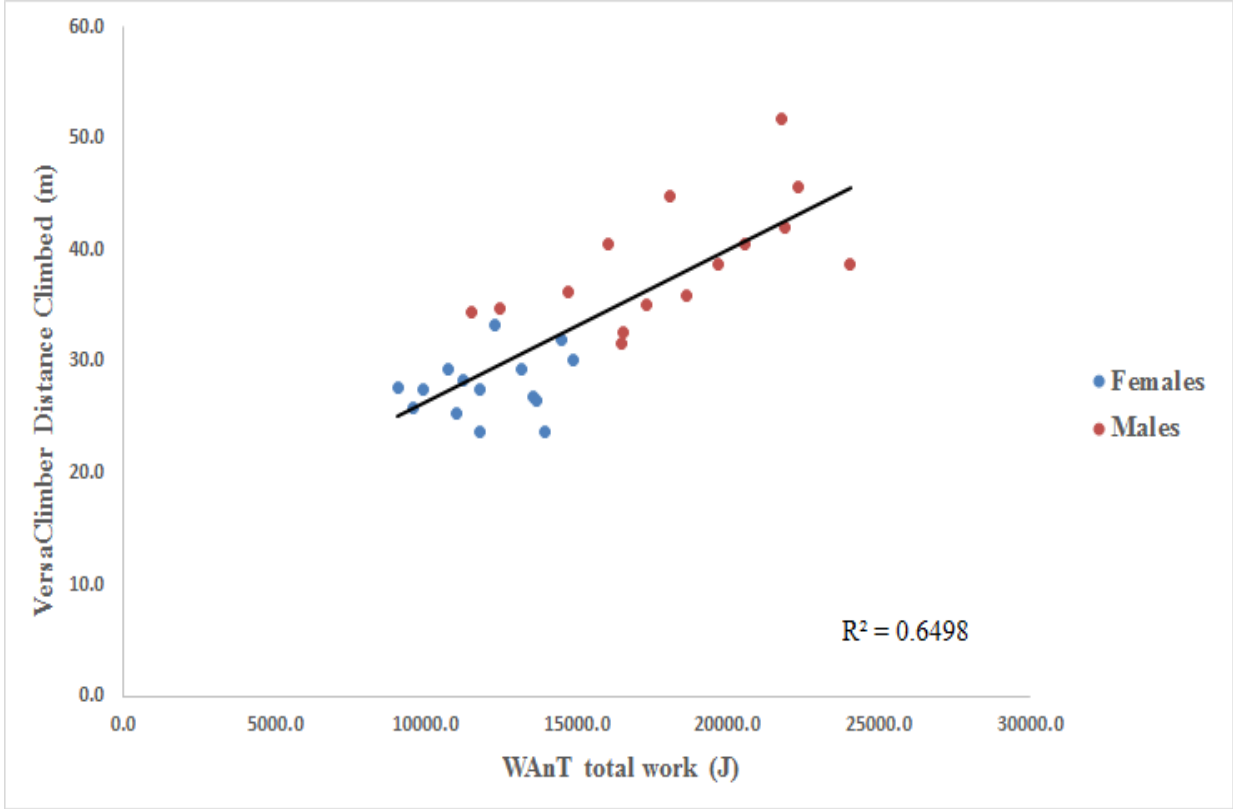
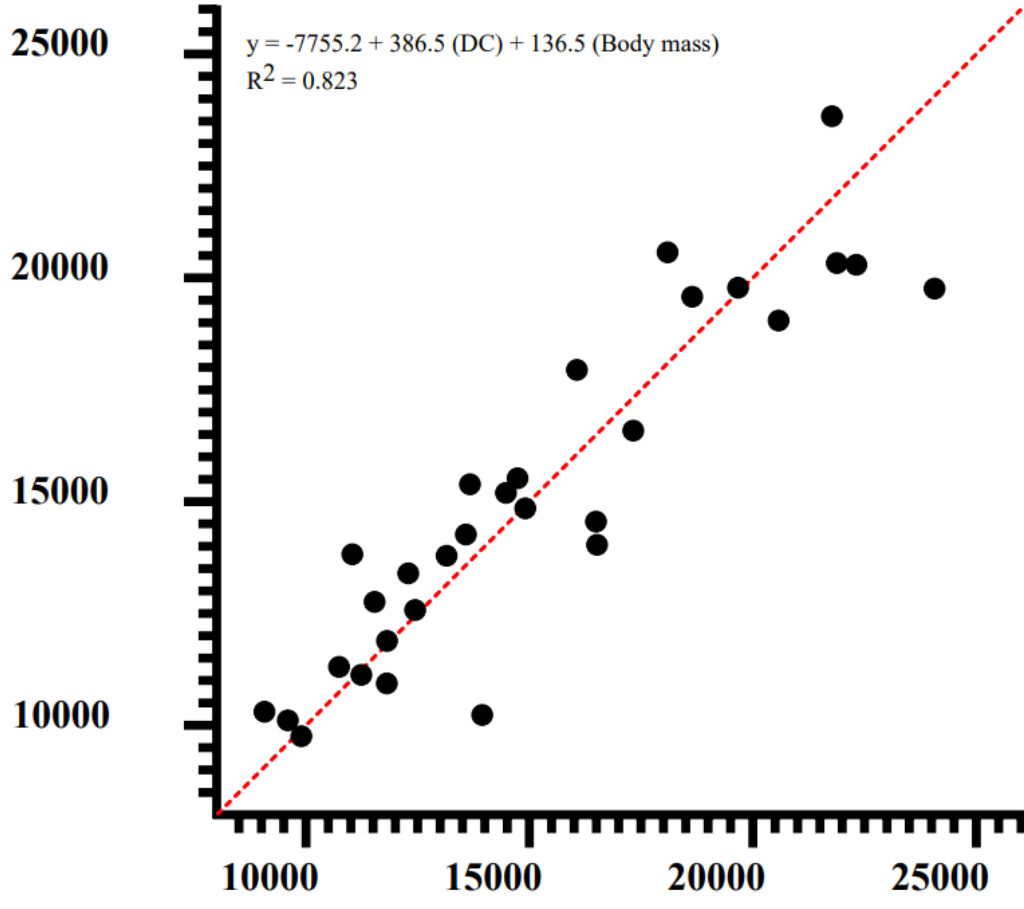
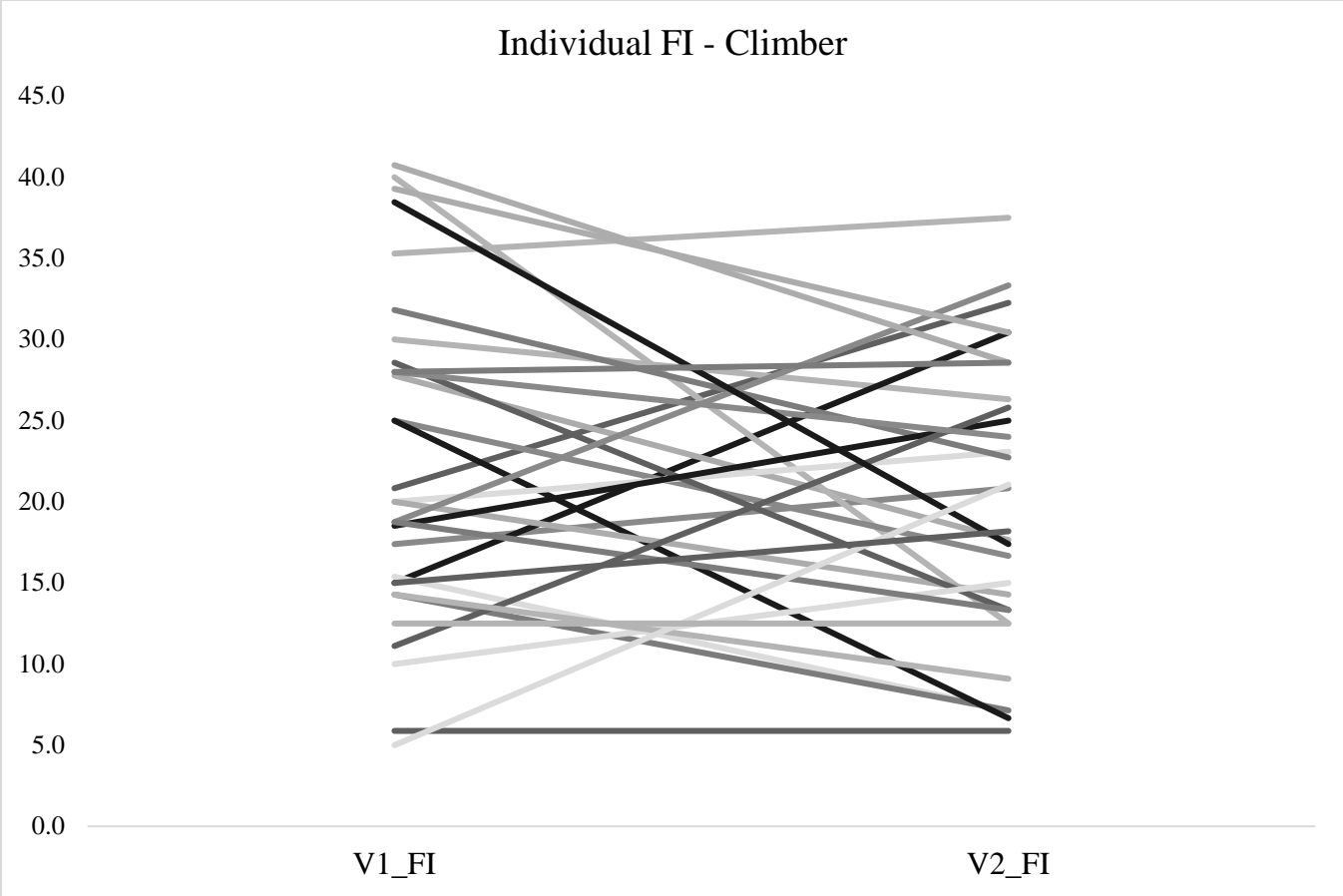


Figure 2: Sex-specific distance vs. total work plot

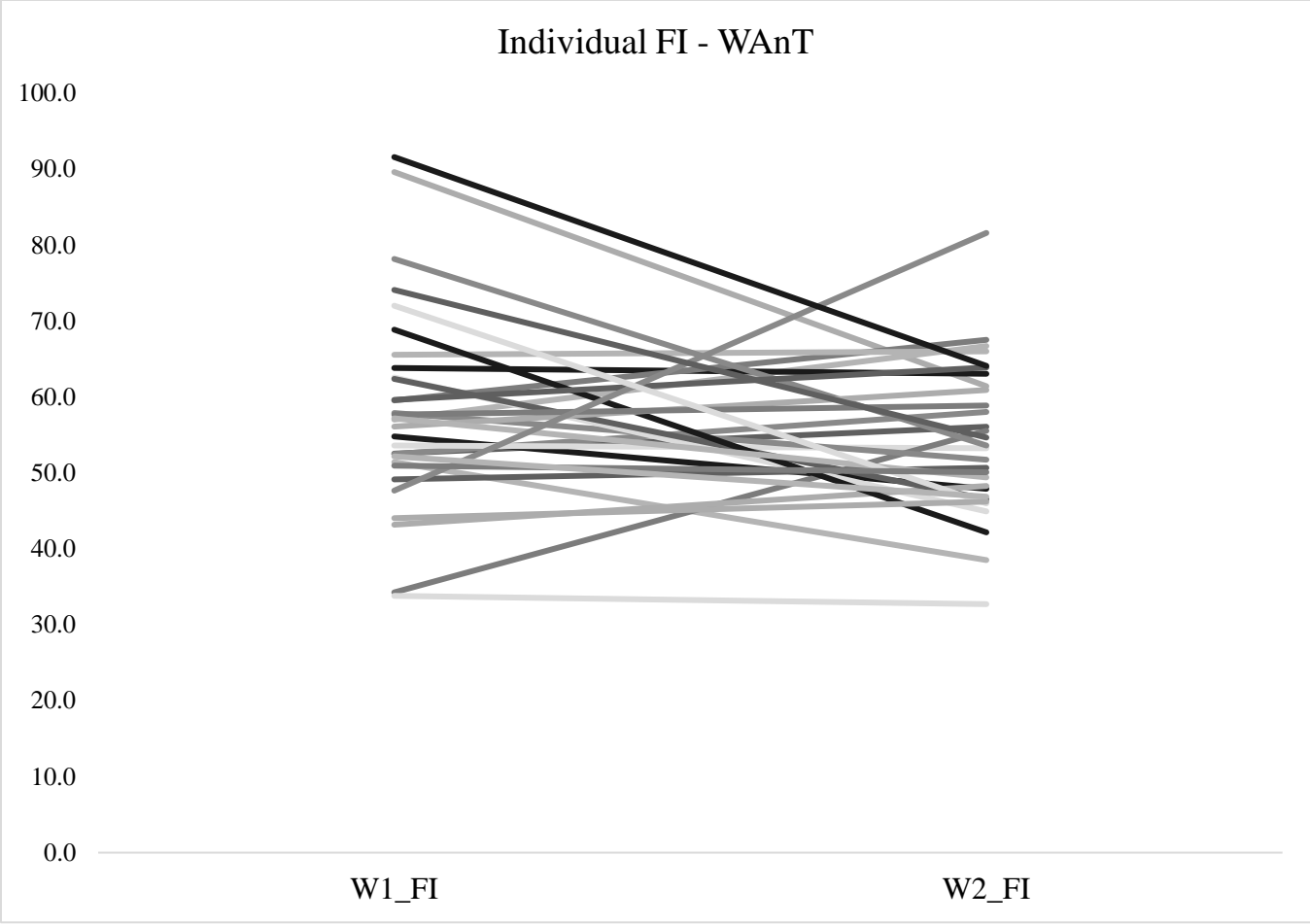


### Wingate Total Work

Figure 3: Multiple linear regression actual vs. predicted plot



**Figure 4: Climber Individual Fatigue Index**



**Figure 5: WAnT Individual Fatigue Index**

## Chapter 5: Discussion

The purpose of this study was to test if distance climbed in a maximal effort test on a simulated climbing machine correlates with WAnT variables, specifically total work. I found a large positive correlation (.81) between total work on the WAnT and distance climbed (Figure 2). This is an important finding since simulated climbing machines do not yet have the ability to measure force or apply quantifiable resistance. Distance climbed on the climber is highly correlated with total work on the WAnT. When including body mass in the correlation between distance and total work, the predicted model  $R^2$  increased to 83% (Figure 3). Body weight and distance climbed together can predict about 83% of total work.

Almost all participants were able to complete both protocols, and most results were also reliable and precise, indicating that minimal practice is needed for maximal-effort tests on this simulated climbing device. The WAnT has been proven reliable in previous studies for mean power, peak power, and fatigue index (2, 4, 10, 16, 20). Neither protocol in this study elicited a reliable result for fatigue index likely due to the participants change in effort during the second trial of each protocol (Figure 4, Figure 5). Since not all simulated climbers are the same, further research should examine the feasibility, reliability, and validity of maximal-effort tests of anaerobic capacity on ladder mills as well.

Interestingly, a correlation of similar magnitude (0.84) was found between the cycle ergometer and a climber for  $VO_{2max}$  (6). It seems that participants are able to perform similarly at varying degrees of workload on both the WAnT and climber. When validating the WAnT the r-values that were produced with short distance swimming, sprinting, etc. were 0.75 or more (4).

Comparing the climber and the WAnT showed a large correlation of .81 which is around the same r-values that validated the WAnT to anaerobic performance.

For total work and distance climbed sex specific correlations, there was a large difference between males (0.61) and females (0.22). Males had a significant correlation between total work and distance climbed while females did not. Males had a larger total work and distance climbed while females were all clustered at the bottom of the scatter plot (Figure 2), and the combined data increase the heterogeneity on both axes. Similar effects of sex were seen in a study comparing  $VO_{2max}$  on a laddermill, treadmill, and cycle ergometer (11).

Effect sizes between males and females PPO, MPO, total work, and distance climbed were between large to very large (Table 2). There were very large differences between males and females for total work (2.17) and distance climbed (2.65). It is possible that these differences are due to the very large difference of lean mass (2.42) between each sex (Table 1). The males were able to produce more work and distance climbed compared to females because of the amount of lean mass they have even though there was no difference between males' and females' mean weight (Table 1). This suggests that weight was not a huge factor between the differences in outcome variables (Table 2) but lean mass and fat mass was the main factor between differences; however, relative MPO effect size difference decreased compared to the absolute values so weight might have played a small factor in MPO (Table 2). PPO on the other hand had an increase in effect size when relative values were compared.

Fatigue index is the only variable that was not reliable between the two trials for both the WAnT and the climber; however, other studies found this variable reliable in the WAnT (16, 20). All procedures between trials for each participant were the same. Each participant's fatigue index



was plotted for both the climber (Figure 4) and WAnT (Figure 5). In both graphs, some participants had a higher fatigue index on the second trial while others had a lower fatigue index. The figure shows that there is inconsistency between the two trials for many of the participants on each device. However, there was still a reliable result for both total work and distance climbed on the devices.

There are limitations to simulated climbing machines. Climbing machines do not have a means to measure force or precisely apply resistance. The resistance in the Versaclimber™ is hydraulic, and thus not able to be accurately adjusted based on body weight. For this study, we used the lowest resistance setting. Since distance climbed was highly correlated to work on the WAnT, the Versaclimber™ can possibly be altered with force transducers so that work on the climber can be calculated and compared to total work and other variables on the WAnT.

The current study's finding shows that there is a very large, positive correlation between the climbing protocol and Wingate protocol for anaerobic capacity, and the predictability is greatly increased by adding in body mass to the regression. This shows that a simulated climbing machine can possibly be a device used to measure anaerobic capacity with further studies. It can also be concluded that the VersaClimber™ is reliable for distance climbed in a 30-s maximal test. A simulated climbing machine is a device that can be advantageous for use in measuring anaerobic capacity because of its full-body exercise capability and low impact force. It has also been compared to different ergometers and has been found to be just as efficient in measuring aerobic capacity (6). Being a total body workout device, it is possible that the simulated climbing machines, such as the VersaClimber™ can be another validated device to measure anaerobic capacity compared to the WAnT protocol.

## Appendix



### UNLV Biomedical IRB - Expedited Review Approval Notice

**DATE:** February 12, 2018

**TO:** Brian Schilling, Ph.D  
**FROM:** UNLV Biomedical IRB

**PROTOCOL TITLE:** [1158162-2] Does distance climbed in an all-out test on the VersaClimber correlate with Wingate variables?  
**SUBMISSION TYPE:** Revision

**ACTION:** APPROVED  
**APPROVAL DATE:** February 12, 2018  
**EXPIRATION DATE:** February 11, 2019  
**REVIEW TYPE:** Expedited Review

Thank you for submission of Revision materials for this protocol. The UNLV Biomedical IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a protocol design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

**PLEASE NOTE:**

Upon approval, the research team is responsible for conducting the research as stated in the protocol most recently reviewed and approved by the IRB, which shall include using the most recently submitted Informed Consent/Assent forms and recruitment materials. The official versions of these forms are indicated by footer which contains approval and expiration dates. If your project involves paying research participants, it is recommended to contact Carisa Shaffer, ORI Program Coordinator at (702) 895-2794 to ensure compliance with subject payment policy.

Should there be *any* change to the protocol, it will be necessary to submit a **Modification Form** through ORI - Human Subjects. No changes may be made to the existing protocol until modifications have been approved.

ALL UNANTICIPATED PROBLEMS involving risk to subjects or others and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

All NONCOMPLIANCE issues or COMPLAINTS regarding this protocol must be reported promptly to this office.

This protocol has been determined to be a Minimal Risk protocol. Based on the risks, this protocol requires continuing review by this committee on an annual basis. Submission of the **Continuing Review Request Form** must be received with sufficient time for review and continued approval before the expiration date of February 11, 2019.

If you have questions, please contact the Office of Research Integrity - Human Subjects at [IRB@unlv.edu](mailto:IRB@unlv.edu) or call 702-895-2794. Please include your protocol title and IRBNet ID in all correspondence.

Office of Research Integrity - Human Subjects  
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