RELIABILITY AND VALIDITY OF A MODIFIED ANAEROBIC TREADMILL TEST TO DETERMINE ANAEROBIC CAPACITY IN MALE NCAA DIVISION II SOCCER PLAYERS

By

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ABSTRACT

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Kenji Murao

Anaerobic capacity is an important performance variable for soccer athletes to compete at higher levels of competition. The purpose of this study was to develop a sports-specific anaerobic capacity test for soccer players that could be administered on commercial treadmills found in most exercise facilities. The Wingate Anaerobic test (WAnT) is the most common test for anaerobic capacity, however it is a cycle ergometer test, which is not sports-specific to running type athletes. The Anaerobic Speed Test (AST) is an anaerobic capacity test on a treadmill, however the testing protocol (20% incline) cannot be done on commercial treadmills because they have a maximum incline setting of 15%. The modified Anaerobic Speed Test (mAST) protocol (15% incline, 244 meter/min) was developed through the use of an ACSM metabolic equation to predict energy expenditure equivalent to that of the AST. 15 subjects playing soccer at the NCAA Division II level participated in this study. Subjects participated in three testing days, one AST trial and two mAST trials all done on separate occasions. Total run time in seconds was recorded for each trial. Mean AST run times (60.5±10.6) had a significantly strong, positive correlation ($p<0.001$) with mean Trial 1 mAST run times (71.9±9.5).

Mean Trial 1 mAST run times (71.9±9.5) had a significantly strong, positive correlation ($p<0.001$) with mean Trial 2 mAST run times (75.7±10.2). These findings suggest that the mAST is a valid and reliable measure of anaerobic capacity that is sports-specific to running-type athletes and can be administered on commercial treadmills.

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INTRODUCTION

Both aerobic and anaerobic energy systems contribute significantly towards soccer performance (Stolen et al., 2005; Al-Hazzaa et al., 2001). Although the sport can be enjoyed at any level, studies suggest that well developed aerobic and anaerobic energy systems are critical for athletes who aspire to play at elite levels of competition (Stolen et al., 2005; Bangsbo, 1994, Magal et al., 2009; Karakoc et al., 2012). Aerobic energy systems, often measured via maximal oxygen uptake (VO_2max), help prevent fatigue and meet the oxygen demands of working muscles, while well-trained anaerobic energy systems are associated with faster and more explosive movements such as sprinting, jumping, kicking, tackling, and changing speed (Ekbolm, 1994). Although aerobic energy systems are heavily required to maintain performance throughout an entire soccer match, decisive game-changing and possibly game-winning plays require explosive bursts of speed and power provided by anaerobic energy systems (Coutts et al., 2009; Rhodes & Mosher, 1992). Anaerobic capacity represents the total energy produced by anaerobic sources (phosphagen system, anaerobic glycolysis, and lactate formation) and is one of the most common variables measured in soccer performance (Nikolaidis et al., 2011; Chtourou et al., 2012; Karakoc et al., 2012; Meckel et al., 2009).

Anaerobic capacity is a commonly measured variable in soccer performance studies (Miller et al., 2011). The most common test for anaerobic capacity, which can also be considered the gold standard, is the Wingate cycle ergometer test (WAnT) (Almeida, Pereira, Campeiz, & Maria, 2009; Keir, Thériault, & Serresse, 2013). The test commonly consists of a maximal, 30-second sprint on a cycle ergometer with a resistance set at a specific percentage of the subjects' body weight. The WAnT provides data that can help coaches optimize training programs for soccer players. However, some studies suggest that the physiological application of the WAnT for soccer players may not be appropriate based on the premise that the Wingate is conducted on a cycle ergometer, whereas soccer is a running-type sport (Meckel et al., 2009).

Although the WAnT is the most popular test for anaerobic capacity in soccer players, there are other laboratory tests that may be more sports-specific for soccer. Research suggests that anaerobic testing procedures should consist of protocols that mimic sports-specific movement patterns (Meckel et al., 2009). Thomas (2002) documented that the Cunningham and Faulkner protocol (1969), known as the Anaerobic Speed Test (AST) on the treadmill served as a reliable (r=.97) and valid (r=.82) measure of anaerobic capacity based on values significantly correlating with WAnT scores for collegiate and professional level soccer players. The AST is a maximal, treadmill running protocol where the subject runs until exhaustion with the treadmill set at a 20% incline and a speed of 214.4 meter/min. The test was designed to last about 30-60 seconds to primarily stress anaerobic energy systems. The treadmill test requires subjects to run on a treadmill, which is more sports-specific to movement patterns in soccer than a cycling test.

However, the problem with the AST is that the testing protocol requires an incline setting of 20%, which is often a setting limited to special exercise-testing treadmills. Commercial treadmills found in most exercise facilities are limited to a maximum 15% incline setting. Therefore, the first purpose of this study was to develop an anaerobic capacity test that could be administered on commercial treadmills to increase the feasibility and accessibility of an anaerobic capacity test for larger populations.

The newly developed anaerobic capacity test evaluated in this study will be referred to as the modified Anaerobic Speed Test (mAST). The original AST protocol, designed by Cunningham and Faulkner (1969), was converted through the use of an ACSM metabolic equation to predict equivalent estimated energy expenditure to develop the mAST protocol. The second purpose of this study was to determine whether the mAST protocol was a valid and reliable measure of anaerobic capacity in Division II men's soccer players. The last purpose of this study was to develop a regression equation from the newly developed mAST to allow comparison of mAST data to normative data previously established for the AST.

METHODS

Experimental Approach

Following a verbal and written explanation of all risks and benefits associated with this study, subjects signed an informed-consent form approved by the Humboldt State University (HSU) Internal Review. Data collection took place on four separate occasions within a two-week period at HSU's Human Performance Lab. All trials were completed on a Quinton Q-stress motorized treadmill. All testing was scheduled in the afternoon to control for diurnal variations. Prior to official data collection, subjects participated in 1 familiarization session to help them get accustomed to the testing procedures and protocols. Subjects completed one AST followed by two trials for the new, mAST, each with a minimum of 48-hours rest in between. Each test was completed after a thorough warm-up and cool down to prevent injuries and fatigue. Subjects were instructed not to perform any vigorous activity prior to all testing. All subjects were informed not to eat three hours before testing and not to consume any caffeinated or alcoholic beverages eight hours before the test. Lastly, subjects were reminded to stay hydrated prior to the test as well as after.

Subjects

Subjects consisted of 15 current members of the NCAA Division II Humboldt State men's intercollegiate soccer team, ages 18-22 years. Subjects of this study displayed good health and were injury-free. During data collection, the team trained four to five times a week on the soccer field in addition to two strength-training sessions in the gym.

Anthropometric measurements were taken during the familiarization session prior to official data collection days. Body fat percentage was measured through the use of an ACSM (Jackson and Pollock method) seven-site skinfold protocol. The mean and standard deviation (SD) of anthropometric data for the test subjects are represented in Table 1. (Table 1 about here)

Procedures

Anaerobic Speed Test Protocol

Testing procedure for this short, exhaustive treadmill test followed protocol used by Thomas (2002), originally developed by Cunningham and Faulkner (1969). Subjects began with a warm-up running at 174 meter/min at 0% grade on a treadmill for 5 minutes (Thomas, 2002). The subject was then given a 3-minute rest period while the treadmill was brought to 214 meter/min at a 20% grade. The subject was instructed to hold both handrails, straddling the treadmill with both feet set on either side of the moving treadmill carpet. The subject continued to hold onto the handrails as they began to brush one of their feet along the moving treadmill carpet in the motion of a running stride to accustom them-selves with the speed. Once the subject felt comfortable, they jumped on the treadmill with both feet and the test began as soon as the hands let go of the handrails. The total run time was measured with a stopwatch from the moment the subject let go of the handrails until the subject once again grabbed the handrails at the end of their run. Immediately following termination of the trail, the treadmill was brought to a 0% grade and 54 meter/min for a cool down of at least 15 minutes (Thomas, 2002). For safety purposes, the subjects completed several practice attempts for proper mounting and dismounting technique with the moving treadmill carpet during the familiarization session.

Modified Anaerobic Speed Test Protocol

Through the use of an ACSM estimated energy expenditure metabolic equation, the original 20% grade, 214 meter/min treadmill protocol was converted to a 15% grade, 244 meter/min treadmill protocol. Since this study is the first to use the mAST protocol, testing procedures were the same as the ones used by Thomas (2002) and Cunningham and Faulkner (1969) due to the fact that they are very similar tests. The warm-up and cool down were identical to the AST protocol. However, after the warm-up the treadmill was brought to a 15% grade incline at 244 meter/min.

Equation 1. ACSM Equation for Metabolic Calculation for the Estimation of Energy Expenditure $VO_{2max}[ml/kg^{-1} \cdot min^{-1}]$) During Common Physical Activities

$$VO_{2max}\, {}^{ml}/_{kg \times min} = 3.5 + (0.2 \times speed) + (0.9 \times speed \times grade)$$

Equation 2 Anaerobic Speed Test. 20% incline, 214 meter/min protocol

$$84.97\, {}^{ml}/_{kg \times min} = 3.5 + \left(0.2 \times 214.4\, {}^{m}/_{min}\right) + (0.9 \times 214.4\, {}^{m}/_{min} \times 0.20)$$

Equation 3 Modified Anaerobic Speed Test. 15% incline, 244 meter/min protocol

$$84.94\,{}^{ml}/_{kg\times min} = 3.5 + \left(0.2\times 243.3\,{}^{m}/_{min}\right) + \left(0.9\times 243.3\,{}^{m}/_{min}\times 0.15\right)$$

Note: The modified anaerobic speed test equation used a speed of 243.3 meter/min because it resulted in the closest estimated VO_{2max} as the original protocol. However, for the modified test protocol, 243 meter/min was rounded up to 244 meter/min.

Statistical Analyses

All data for this study is be presented as a mean +/- standard deviation (SD) for anthropometric, AST, and modified AST (mAST) values collected in the HSU Human Performance Lab. A simple correlation was run between the AST and Trial 1 of the mAST values to establish validity for the mAST protocol. A simple intra-class correlation was also run between Trial 1 and Trial 2 of the mAST to establish reliability of the new treadmill protocol. All statistics were run through the IBM Statistical Package for Social Sciences (SPSS v.21.0). Criterion for significance was set at an alpha level of $p \leq 0.05$.

RESULTS

All assumptions were checked prior to interpreting outputs for significance. According to the Shapiro-Wilk test, assumptions of normality were not violated (AST, $p= 0.856$; mAST Trial 1, $p= 0.247$; mAST Trial 2, $p= 0.181$). The assumption of independence was not violated for AST and mAST Trial 1 total run times (Durbin-Watson value= 1.85).

The anthropometric and descriptive characteristics of the men's soccer players that participated in the study are represented in Table 1 and Table 2.

Table 1. Anthropometric Data for Test Subjects

Variables	Mean ± SD
Age (years)	20 ± 1.9
Height (cm)	181.3 ± 7.9
Weight (kg)	74.8 ± 5.2
% BF	9.2 ± 4.3
BMI	22.8 ± 6.2

Values represented as a mean ± standard deviation (SD). %BF= percent body fat. BMI= body mass index.

Table 2. Descriptive Statistics for Subjects

Protocol	N	Mean Total Run Time (s) ± SD
AST (20%, 214 meter/min)	15	60.5 ± 10.6
mAST Trial 1 (15%, 244 meter/min)	15	71.9 ± 9.5
mAST Trial 2 (15%, 244 meter/min)	15	75.7 ± 10.2

Values are represented as a mean ± standard deviation (SD). Mean total run time values shown in seconds (s). AST= Anaerobic Speed Test (20% incline, 214 m/min). mAST= modified Anaerobic Speed Test (15% incline, 244-m/min).

Table 2 represents the mean total run time in seconds (s) for all 3 test trials. A regression analysis was performed between AST and Trial 1 mAST mean total run times and found a significantly strong, positive correlation (r= 0.973; p< 0.001). R^2= 0.946; this suggests that total run time for Trial 1 of the mAST can account for 94.6% of the variance in AST total run time. Through an entry method linear regression analysis, the following prediction equation was generated based on Trial 1 mAST and AST mean total run times (Figure 1): AST(s)= -17.267 + (1.082 x mAST(s)).

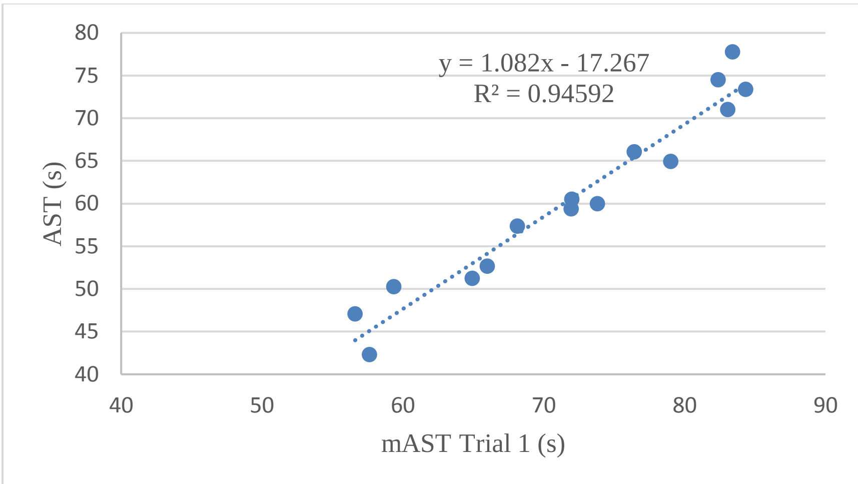

Figure 1. Relationship between the Anaerobic Speed Test (AST) and Trial 1 of the modified Anaerobic Speed Test (mAST).

A simple intra-class correlation analysis between Trial 1 and Trial 2 of the mAST produced a Pearson correlation coefficient of r= 0.983 (p< 0.001), suggesting that there is a significantly strong, positive correlation between the two trials. R^2= 0.966; this suggests that total run times for Trial 1 of the mAST can account for 96.6% of the variance in Trial 2 of the mAST total run times (Figure 2).

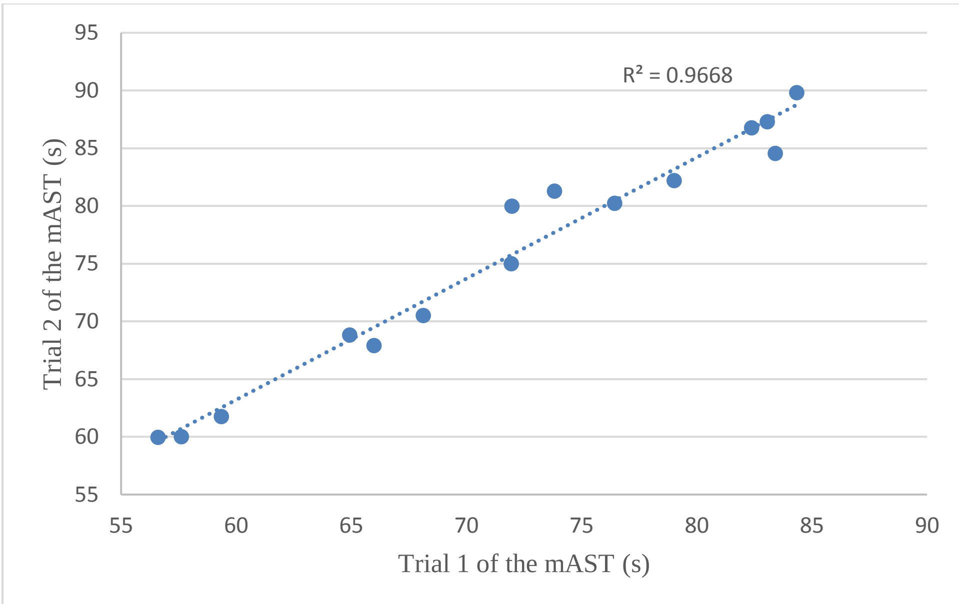

Figure 2. Relationship between Trial 1 and Trial 2 of the modified Anaerobic Speed Test (mAST).

DISCUSSION

Anaerobic Capacity

Anaerobic Speed Test

Based on previous literature, the AST has been proven to be a valid and reliable measure of anaerobic capacity (Thomas, 2002; Cunningham & Faulkner, 1969; Ekbolm, 1994). Therefore, the AST was used as the valid criterion-reference to compare the mAST in order to determine validity. Based on the significant correlation between the AST and Trial 1 of the mAST ($p < 0.001$), these findings suggest that the mAST is a valid anaerobic capacity testing protocol. Trial 1 was used instead of Trial 2 of the mAST in order to compare to the AST due to the fact that Trial 2 values may have been skewed by a learning effect. Mean total run time for the AST in this study was 60.5 ± 10.6 (s), which agrees with Beam and Adams (2011) that total run times of 60 seconds would qualify this a valid anaerobic test because it suggests that anaerobic metabolism was the predominant energy source for this test. Results of this study support previous literature, stating that anaerobic capacity is an important performance variable, indicative of soccer players ability to participate at higher levels of competition (Bangsbo, 1994; Rhodes et al., 1986).

Modified Anaerobic Speed Test

The significant correlation between Trial 1 and Trial 2 of the mAST ($p < 0.001$) suggests that the mAST is a reliable testing protocol. Although the mean total run times for Trial 1 (71.9 ± 9.5 s) and Trial 2 (75.7 ± 10.2 s) of the mAST are slightly greater than 60 seconds, Beam and Adams (2011) suggested that total run times between 60-120 seconds should still rely heavily on anaerobic metabolism. However, ideally the test should aim to last about 60 seconds for a maximal effort. The mAST protocol was developed based on the ACSM estimated energy expenditure equation that takes into account speed and grade. Based on the equation, a speed of 244 meter/min and a grade of 15% were estimated to result in the same energy expenditure as a run at 214 meter/min and 20% grade. Previous research by Harris, Debeliso, Adams, and Irmischer (2003) and Ruiz and Sherman (1999) have both found the ACSM metabolic equation to overestimate energy expenditure. The findings of these two studies may provide rationale as to why total run time for the mAST was longer than those of the AST. This is suggesting that the actual energy expenditure required for the mAST is less than predicted, therefore allowing subjects to run longer than anticipated.

A possible explanation for why total run times for Trial 2 were on average four seconds longer than Trial 1 for the mAST include the competitive nature of the athletes as well as a learning effect. The subjects were NCAA Division II athletes, therefore, by nature have a built in competitive drive to not only improve their own scores, but to try and surpass their peers as well. Another possible reason may be due to the learning effect associated with a test-retest protocol. Previous literature has proven that during the initial stages of exposure to a new movement or protocol, rapid improvements can be seen with repeated efforts during the early stages of learning (Rowland, Hinshaw, & Albarracin, 2014).

Due to the fact that this is the first study to develop and investigate the mAST protocol, there is a lack of normative data on the mAST. Therefore, a regression equation was produced to predict AST run times based on mAST values to allow the comparison of mAST data to normative data previously established for the AST. This allows for anyone who decides to use the mAST to determine relative anaerobic capacity fitness to larger subject populations until larger amounts of data are available for the mAST.

In conclusion, this study provides evidence that the mAST is a valid and reliable testing protocol to measure anaerobic capacity in NCAA Division II male soccer players. Therefore, this study provides an anaerobic capacity test that is sports-specific to running-type sports and it can be administered on any commercial treadmill found in most exercise facilities. Since this study is the first to develop and evaluate the mAST protocol, further research is required to support the findings of this study by testing larger populations. However, the results of the current study support the use of the mAST by soccer coaches and athletes to measure anaerobic capacity.

PRACTICAL APPLICATION

The results of this study increase the feasibility of administering an anaerobic capacity test for coaches who do not have access to special exercise testing equipment. Many anaerobic capacity tests such as the Wingate cycle ergometer test (WAnT) or the AST require special exercise testing equipment often limited to specialized exercise performance laboratories in order to conduct the test. The mAST protocol can be administered on commercial treadmills found in most gyms and exercise facilities, therefore allowing for larger populations of people to conduct an anaerobic capacity test.

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APPENDIX

Medical History Questionnaire and Informed Consent

Humboldt State University Health and Wellness Institute Medical Information and History and Release of Liability

Name ____

Address ____

Home Phone _________________________ Work Phone ____

Age __________ Date of Birth __________________ Gender _______________________

The following questions are designed to help us tailor the health and fitness assessment and follow-up counseling to your personal situation. It is extremely important for us to know if you have any medical conditions which may affect your testing process or your progress in our program. Please take the time to answer these questions accurately.

Medical History

YES	NO	In the past five years have you had:
( )	( )	1. Pain or discomfort in chest, neck, jaw, or arms
( )	( )	2. Shortness of breath or difficulty breathing at rest or with mild exertion (e.g., walking)
( )	( )	3. Dizziness or fainting
( )	( )	4. Ankle edema (swelling)
( )	( )	5. Heart palpitations (forceful or rapid beating of heart)
( )	( )	6. Pain, burning, or cramping in leg with walking
( )	( )	7. Heart murmur
( )	( )	8. Unusual fatigue with mild exertion
		Have you ever had:
( )	( )	9. Heart disease, heart attack, and/or heart surgery
( )	( )	10. Abnormal EKG
( )	( )	11. Stroke
( )	( )	12. Uncontrolled metabolic disease (e.g., diabetes, thyrotoxicosis, or myxedema)
( )	( )	13. Asthma or any other pulmonary (lung) condition
( )	( )	14. Heart or blood vessel abnormality (e.g., suspected or known aneurysm)
( )	( )	15. Liver or kidney disease
( )	( )	16. Are you currently under the care of a physician?
( )	( )	17. Do you currently have an acute systemic infection, accompanied by a fever, body aches, or swollen lymph glands?
( )	( )	18. Do you have a chronic infectious disease (e.g. mononucleosis, hepatitis, AIDS)?
( )	( )	19. Do you have a neuromuscular, musculoskeletal, or rheumatoid disorder that is made worse by exercise?
( )	( )	20. Do you have an implantable electronic device (e.g. pacemaker)?
( )	( )	21. Do you know of any reason why you should not do physical activity?

If you answered yes to any of these questions, please explain.

____

Risk Factors

YES	NO	DON'T KNOW	
( )	( )	( )	1. Are you a male 45 years of age or older?
( )	( )	( )	2. Are you a female 55 years of age or older
( )	( )	( )	3. Do you have a father or brother who had a heart attack or heart surgery before age 55?
( )	( )	( )	4. Do you have a mother or sister who had a heart attack or heart surgery before age 65?
( )	( )	( )	5. Do you smoke or have you quit in the past 6 months?
( )	( )	( )	6. Do you have frequent secondhand smoke exposure?
( )	( )	( )	7. Do you know your blood pressure?_______/________mmHg-Date:
( )	( )	( )	8. What is your total cholesterol?____________mg/dL-Date:
( )	( )	( )	9. Are you taking cholesterol lowering medication?
( )	( )	( )	10. Do you know your HDL cholesterol?____________mg/dL-Date:
( )	( )	( )	11. Is your HDL cholesterol > 60mg/dL?
( )	( )	( )	12. What is your fasting blood glucose?__________mg/dL – Date:
( )	( )	( )	13. Do you exercise regularly? If so, explain.

If you answered yes to any of these questions, please explain.

____

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Office Use

BMI_____ SBP_____ DBP_____ TC_____ LDL_____ HDL_____ FBG_____

Health-Related Questions

YES	NO	
( )	( )	1. Are you pregnant?
( )	( )	2. Are you allergic to isopropyl alcohol (rubbing alcohol) or latex?
( )	( )	3. Do you have any allergies to medications, bees, foods, etc.? If so please list ____
( )	( )	4. Do you have any skin problems?
( )	( )	5. Do you have any other medical condition(s)/surgeries?
( )	( )	6. Have you had any caffeine, food, or alcohol in the past 3 hours?
( )	( )	7. Have you exercised today?
( )	( )	8. Are you feeling well and healthy today?
( )	( )	9. Do you have any other medical concerns that we should be aware of?

If you answered yes to any of these questions, please explain.

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Medications

Please Select Any Medications You Are Currently Using:

Diuretics	Other Cardiovascular
Beta Blockers	NSAIDS/Anti-inflammatories (Motrin, Advil)
☐ Vasodilators	☐ Cholesterol
☐ Alpha Blockers	☐ Diabetes/Insulin
☐ Calcium Channel Blockers	☐ Birth Control
☐ Other Drugs (record below)	

Please list the specific medications that you currently take:

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____

____

What are your health and fitness goals?

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____

____

I certify that the information I have provided is complete and accurate to the best of my knowledge.

Date ________________ Signature of Subject ____

Date ________________ Signature of Witness ____

Office Use Only

____ Low Risk **____Moderate Risk** **____High Risk**

HUMBOLDT STATE UNIVERSITYRELEASE OF LIABILITY, PROMISE NOT TO SUE, ASSUMPTION OF RISK AND AGREEMENT TO PAY CLAIMS

I have read this form, and I understand the test procedures that I will perform and the attendant risks and discomforts. Knowing these risks and discomforts, and having had an opportunity to ask questions that have been answered to my satisfaction, I consent to participate in this test.

In consideration for being allowed to participate in this Activity, on behalf of myself and my next of kin, heirs and representatives, I **release from all liability and promise not to sue** the State of California, the Trustees of The California State University, California State University, Humboldt State University and their employees, officers, directors, volunteers and agents (collectively "University") from any and all claims, **including claims of the University's negligence,** resulting in any physical or psychological injury (including paralysis and death), illness, damages, or economic or emotional loss I may suffer because of my participation in this Activity, including travel to, from and during the Activity.

I am voluntarily participating in this Activity. I am aware of the risks associated with traveling to/from and participating in this Activity, which include but are not limited to physical or psychological injury, pain, suffering, illness, disfigurement, temporary or permanent disability (including paralysis), economic or emotional loss, and/or death. I understand that these injuries or outcomes may arise from my own or other's actions, inaction, or negligence; conditions related to travel; or the condition of the Activity location(s). **Nonetheless, I assume all related risks, both known or unknown to me, of my participation in this Activity, including travel to, from and during the Activity.**

I agree to **hold** the University **harmless** from any and all claims, including attorney's fees or damage to my personal property that may occur as a result of my participation in this activity, including travel to, from and during the Activity. If the University incurs any of these types of expenses, I agree to reimburse the University. If I need medical treatment, I agree to be financially responsible for any costs incurred as a result of such treatment. I am aware and understand that I should carry my own health insurance.

Date:________Signature of Subject:______________________________
Date:________Signature of Witness: ______________________________