ANAEROBIC CAPACITY MEASURES IN ACTIVE HEALTHY ADULTS AGES 18-29: NORMATIVE REFERENCE VALUES AND DIFFERENCES BETWEEN SEX

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ABSTRACT

ANAEROBIC CAPACITY MEASURES IN ACTIVE HEALTHY ADULTS AGES 18-29: NORMATIVE REFERENCE VALUES AND DIFFERENCES BETWEEN SEX

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The purpose of this study was to develop normative reference values for the modified Anaerobic Speed Test (mAST), an anaerobic capacity test that can be administered and completed on a commercial treadmill. The mAST of 15% grade has been created as one of the only protocols based on the original AST protocol of 20% grade. However, no percentile norms currently exist for this protocol, limiting its usefulness and interpretation of results. This paper presents normative values for active healthy adults ages 18-29, separated by sex. The sample consisted of 276 active healthy volunteers (161 men and 115 women). All mASTs were completed on a motorized commercial gym setting treadmill for determination of subjects' time (seconds) and work (kJ). Time to fatigue was 47 ± 10 sec for women and 38 ± 13 seconds for men. Women fatigued at 80.8% of the total time men did ($p < .05$). Total work for women (12.8 ± 4.3kJ) was 57.1% of the values observed in men (22.4 ± 5.53 kJ) ($p < .05$). Women's mass corrected work (0.20 ± 0.070 kJ/kg) was 71.0% of men (0.28 ± 0.06 kJ/kg) ($p < .05$). Normative reference value tables were generated for time and both absolute (kJ) and relative values (kJ/kg) for total work. The norms for time and total work produced from this study are considerably higher than previously developed norms and

more practical because of the use of both male and female active healthy populations and the use of a commercial treadmill.

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INTRODUCTION

Specific movements involved in several sports and careers such as lifting heavy objects, sprinting, jumping, change of direction, etc., are all anaerobic and are in many cases required to be efficient, productive, and successful.

Anaerobic capacity is defined as the maximal rate of adenosine triphosphate (ATP) resynthesized via anaerobic metabolism by a living organism during short term duration, maximal effort exercise (13). The maximal rate of ATP produced directly affects the total work possible to perform during a high intensity exercise bout (30). Mechanical work output that primarily utilizes anaerobic metabolism can be considered anaerobic work capacity (19). Anaerobic resynthesis of ATP occurs primarily through two energy systems; hydrolysis of ATP through systems such as the phosphagen system, as well as catabolism of carbohydrates by means of glycogenolysis and glycolysis. The combined sum of these two main systems is termed anaerobic capacity (10). Anaerobic power and capacity play a crucial role in short, intense maximal effort exercise with high power outputs (13), prompting research investigating anaerobic capacity and how it functions (12).

Anaerobic capacity can be quantified by means of all out exercise or constant load tests (4). Other direct methods of assessing anaerobic capacity are available, but they are invasive and expensive in comparison to measuring mechanical work (29). Currently, there are three primary modes of measurements to quantify anaerobic capacity: the maximum accumulated oxygen deficit method, the critical power method, and the gross efficiency method (14, 24). More practically, anaerobic capacity can also be quantified using Joules (J) calculated from total work completed in a maximal exercise bout (4). All of these measurements are useful in determining an individual's anaerobic capacity, as there is currently no "gold standard" for what should be measured to quantify anaerobic capacity as it stands now (28).

A major component of any form of exercise fatigue. Fatigue, generally speaking, is defined as "the acute impairment of exercise performance that includes both an increase in the perceived effort necessary to exert a desired force or power output and the eventual inability to produce that force or power output." (9) There are two primary ways fatigue can occur in the body; metabolic and neurological. Psychological factors that arise because of these two factors also play a key role in one's decision to stop exercise. Sensations resulting from fatigue and exhaustion introduce a perceived feeling of increased effort, which may become overwhelming enough that it can cause the individual to stop all physical activity.

Metabolic fatigue occurs through physiological processes in the body that can become disrupted or altered during exercise. During exercise, the equilibrium of the body's internal environment is thrown out of homeostasis due to increased body temperature and the production of metabolites within the muscle cells. When these metabolites and generated heat are released into the body, the individuals steady state is interrupted, resulting in stress to the internal environment. Metabolites such as lactate and hydrogen ions, ammonia, inorganic phosphate, and Mg^{2+} contribute to disruptions in energy production, pH levels, rate of muscle contraction, and contraction force (2).

Because anaerobic energy supplies are depleted and waste products build up very rapidly, metabolic fatigue plays a large role in the cessation of maximal exercise.

The second major mechanism, neurological fatigue, is a lesser known and studied aspect of exercise fatigue. CNS fatigue has been described as “a subset of fatigue associated with specific alterations in CNS function that cannot reasonably be explained by dysfunction within the muscle itself.” CNS fatigue is generally considered to be the case when full power output cannot be reached despite the subjects’ full motivation to do so. In relation to neurological factors, it has been documented that “psychological factors” can affect exercise performance as well and any disruption between the brain and the muscles that perform physical movements will lead to muscular fatigue (20). Mechanisms that are believed to be the cause of CNS fatigue include a reduction in corticospinal impulses reaching motoneurons, and/or inhibition of motoneuron excitability by afferent feedback from the muscle itself (9). These responses to maximal exercise may either contribute or even be the primary reason an individual stops a maximal exercise bout, even if they are physically capable of continuing for longer periods.

Out of all anerobic tests, the 30 second Wingate Anaerobic Power Test (WAT) is the most cited test for measuring anaerobic capacity and has been used for a wide variety of activities such as the biathlon and wrestling (16); however, there are several limitations. The WAT is highly specific when it comes to the energy systems used and does not allow for specific muscle activation patterns required for most sports outside of cycling and possibly speed-skating (7). Few studies have investigated the treadmill as a valid and reliable means of conducting a more sports specific anaerobic capacity test.

A test of anaerobic capacity using a treadmill is beneficial, as it assesses one's capacity to repeatedly perform these movements. Athletes or others such as police officers, firefighters, and military personnel that rely more heavily on anaerobic energy systems can greatly benefit from testing themselves regularly using an anaerobic capacity test. Comparing results to a table of percentile normative ranks allow for even further practical use when assessing anaerobic capacity.

One method used to measure anaerobic capacity using a treadmill is the protocol used by Cunningham and Faulkner (8), which uses a speed of either 7 mph (187.8 m/min) or 8 mph (214.6 m/min) and a grade of 20% for a short exhaustive exercise bout to fatigue. This protocol was developed and tested, but no validity or reliability data was available for decades after its creation, and no studies were available to use to support this test as a sufficient test to be used as a primary anaerobic capacity test, and no studies had validated the Cunningham & Faulkner protocol in comparison to the WAT, the most cited test as mentioned before. The protocol of 8 mph at a 20% grade was validated and deemed reliable by Thomas et al. (2002) with high, positive correlation coefficients (.88 to .97) and a moderately high correlation for both total and relative power outputs at .82 and .74, respectively when looking at the AST against the WAT (28). However, this test is not widely accessible and is limited primarily to lab settings, as the grade of 20% is higher than most commercial treadmills will go.

To create a better accessible anaerobic capacity test, a modified version of the AST using a 15% grade and speed of 9.1 mph was created and validated, which allowed for the test to be performed on commercial treadmills that typically have a maximum grade of 15% (19). Values using the 15% grade and 9.1 mph speed were found to be valid and reliable compared to the AST with a high, strong positive correlation of 0.95 (21). However, no normative data currently exists for this modified protocol and therefore has no reference as to what a good score is, or how an individual ranks compared to others. The purpose of this study was to develop normative data for the modified Anaerobic Speed Test (mAST) for both men and women.

METHODS

Experimental Approach to the Problem

This study was conducted in the Human Performance Lab at Humboldt State University. Data was collected between December 2015 to May 2019. All mASTs were completed on a motorized treadmill (Platinum Club Series Treadmill, Life Fitness, Rosemont, IL). Subjects were separated into two groups based on sex. Prior to the data collection days, subjects participated in one familiarization session to help them get accustomed to the testing procedures and protocols. Each test was completed after a thorough warm-up of 174 m/min on the treadmill for 5 minutes and a cool down of 80 m/min for at least 5 minutes to prevent injuries and fatigue.

Subjects

A total of 276 active healthy volunteers (161 male; 115 female) between the ages of 19 and 29 years of age were recruited for participation in this research (Table 1). Many subjects participated in club or recreational sports (males 30%; females 45%), but not college varsity sports such as football, soccer, track and field, etc. All subjects regularly participated in moderate or vigorous physical activity for a minimum of 3 days per week for a period of at least 4 weeks prior to participation. Moderate physical activity is defined as any form of activity that takes 3.0-5.9 METs to complete, such as brisk walking, shooting around in basketball, dancing, golf, tennis, and volleyball. Vigorous activity is defined as any activity that requires 6 or more METs to complete, such as jogging and running, bicycling, soccer, swimming, or performing heavy lifting (1). Subjects were screened for cardiovascular and musculoskeletal disease using a medical history questionnaire, an activity questionnaire, and the Physical Activity Readiness Questionnaire (PAR-Q). Subjects were asked about and were excluded from the study if they were found to have two or more cardiovascular risk factors as outlined by the American College of Sports Medicine (1). Subjects were also asked about their use of ergogenic supplements (e.g. pharmacologic aids and/or dietary supplements) that could affect their exercise performance and were excluded from the study if they regularly used them. Subjects were instructed not to perform any vigorous activity 48 hours prior to testing and were instructed to get plenty of rest (7-9 hours of sleep) the night before their lab visit and to have a light meal (general instruction; a small amount of food that is easy to digest) before they came in for testing. subjects were also instructed to avoid alcohol consumption 24 hours, caffeine consumption 3 hours and food consumption 2 hours prior to lab visits. Anthropometric measurements (height, weight, BMI) were taken during the familiarization session prior to the first experimental session. This study was approved by the Humboldt State University Institutional Review Board, and subjects were informed of the risks and benefits of the investigation prior to signing an informed consent form to participate in the study.

Table 1. Characteristics of the study sample by sex (mean ± *SD*).

Characteristics	All (n = 276)	Men (n = 161)	Women (n = 115)	Difference p for sex
Age	23 ± 3	23 ± 3	22 ± 3	96.1%, $p < 0.05$
Body mass (kg)	74 ± 12	80 ± 10	65 ± 10	81.2%, $p < 0.05$
Height (cm)	172 ± 9	178 ± 7	165 ± 7	93.1%, $p < 0.05$
Body mass index (kg/m^2)	25.4 ± 2.8	25.4 ± 2.8	23.8 ± 3	93.7%, $p < 0.05$

Procedures

Testing procedures for this short, exhaustive treadmill test protocol developed by Murao et al. (23). Each subject came in for one session to run the mAST. For safety purposes, each subject completed several practice attempts at proper mounting and dismounting technique with the moving treadmill carpet. Subjects began with a warm up at 174 m/min on a treadmill for 5 minutes (28) then given a 5-minute rest period while the treadmill was brought to a 15% grade and a speed of 244 m/min for men and 214 m/min for females. The subject was instructed to grip both handrails while straddling the treadmill with both feet set to each side of the moving treadmill belt. The subject continued to maintain their grip of the handrails as they began using one foot to accustom themselves with the speed of the treadmill. Once the subject was comfortable, the subject jumped on the treadmill with his/her hands still holding onto the handrails. Total run time was calculated from the moment they released the handrails to start running until they once again grabbed the handrails at the end of their run. Immediately following termination of the test, the treadmill was brought to 80 m/min and a 0% grade for a cool down of at least 5 minutes.

Through the use of an ACSM estimated energy expenditure metabolic equation (eq. 1) (1), the original 20% grade, 214.58 m/min protocol (6) was converted to a 15% grade, 243.40 m/min treadmill protocol (23) for men and a moderate anaerobic treadmill protocol of 20% grade and 187.76 m/min was converted to 15% grade, 212.99 m/min for women (1).

$VO_2(ml/kg^{-1} \cdot min^{-1}) = 3.5 + (0.2 \times speed) + (0.9 \times speed \times grade)$ (eq. 1) (1)

VO_2 is the oxygen consumption, speed is in m/min, and grade is % slope

Anaerobic speed test using 20% incline, 214.519 meter/min protocol for males:

$85.04\ ml/kg^{-1} \cdot min^{-1} = 3.5 + (0.2 \times 214.579\ m/min) + (0.9 \times 214.579\ m/min \times 0.2)$

Modified anaerobic speed test using 15% incline, 243.403 meter/min protocol for males:

$85.04\ ml/kg^{-1} \cdot min^{-1} = 3.5 + (0.2 \times 243.403\ m/min) + (0.9 \times 243.403\ m/min \times 0.15)$

Anaerobic speed test using 20% incline, 188.757 m/min protocol for females:

$74.85\ ml/kg^{-1} \cdot min^{-1} = 3.5 + (0.2 \times 187.757\ m/min) + (0.9 \times 187.757\ m/min \times 0.2)$

Modified anaerobic speed test using 15% incline, 212.985 m/min protocol for females:

$74.85\ (ml/kg^{-1} \cdot min^{-1}) = 3.5 + (0.2 \times 212.985\ m/min) + (0.9 \times 212.985\ m/min \times 0.15)$

Total Work Equations:

$Total\ Work\ (kJ) = Mass\ (N) \times Time\ (s) \times Vertical\ Velocity\ (m/s) \div 1000$ (eq. 2) (5)

$Relative\ Work\ (kJ/kg) = Total\ Work\ (kJ) \div Body\ Mass\ (kg)$

Vertical Velocity (V_V) is the motion covered in the vertical direction. V_v is the product of the Resultant Velocity (V_R) and sin θ of the treadmill grade (5).

The modified Anaerobic Speed Test equations used exact numbers to calculate speed, but were rounded up to the nearest $1/10^{th}$ mph for each protocol when used in data collection (e.g. 243.403 m/min = 9.075 mph; rounded to 9.1 mph). Normalized work is found by dividing the total amount of work produced in kilojoules by the subject's body mass in kilograms (5).

Statistical Analysis

The normal distribution of the data was verified using a Kolmogorov-Smirnov test. Anthropometric data, time (seconds), and total work (kilojoules) are reported as mean ± standard deviation (*SD*). Sex-group differences in the anthropometric and mAST variables were analyzed by using a one-way analysis of variance. Time and total work outcome data was analyzed separately to provide percentile values for males and females. The descriptive statistics were calculated in mean, standard deviation, and their ranges. A t-test for independent means was used to verify the differences between males and females. Significance for all the statistical tests was accepted at $p \leq 0.05$.

RESULTS

Anthropometric characteristics and mAST outcomes of the study sample separated by sex are shown in Tables 1 and 2. All variables were significantly higher in males.

The average time to fatigue was 47 ± 10 seconds for males and 38 ± 13 seconds for females. The average time for females was 80.8% of the average time for males ($p < 0.001$). Total work (eq. 2) was 22.4 ± 5.5 kJ for males and 12.8 ± 4.3 kJ for females. The total work calculated for females was 57.1% of the total work for the males ($p < 0.05$) (5). After measures were corrected for body mass, sex differences were noticeably reduced. Mass-corrected total work was 0.20 ± 0.07 kJ/kg for females and 0.28 ± 0.06 kJ/kg for males. Relative to body mass, the total work for females was 71.0% of the males ($p < 0.05$).

Normative values both expressed in total work and time to fatigue are needed for this treadmill test. Table 3 contains descriptive statistics and percentile norms for the modified anaerobic test of total work and times to fatigue, respectively. Both total work and time to fatigue was significantly higher for males than females ($p < 0.05$).

Table 3 shows the normative values for total work (kJ, kJ/kg) and running time (sec). The mean total work (kJ) was normalized to body mass and lower in females, as shown in tables 2 and 3.

Finally, comparisons of the mean values for speed and grade settings (in m/sec, % grade), total work (kJ), and time (sec) from this study with sex- and age-based normative data are presented in table 4.

Table 2. Mean absolute and mass-corrected total work*, and time for men and women (mean ± *SD*).

Characteristics	All (*n* = 276)	Men (*n* = 161)	Women (*n* = 115)	Difference *p* for sex
Time (minutes)	43.3 ± 12.1	47 ± 10	38 ± 13	80.8%, $p < 0.05$
Total Work (kJ)	18.4 ± 6.8	22.4 ± 5.53	12.8 ± 4.3	57.1%, $p < 0.05$
Mass-Corrected Total Work (kJ/kg)	0.25 ± 0.07	0.28 ± 0.06	0.20 ± 0.07	71.0%, $p < 0.05$

Table 3. Percentile norms and descriptive statistics for total works and times for the modified anaerobic treadmill test.

Percentile	kJ		kJ/kg		Time	
	Male	Female	Male	Female	Male	Female
95	31.5	20.3	0.380	0.321	63	61
90	28.7	18.2	0.359	0.300	60	58
85	27.3	16.4	0.353	0.273	59	52
80	26.8	15.8	0.347	0.256	58	49
75	26.2	15.3	0.323	0.242	54	47
70	25.4	14.9	0.317	0.231	53	44
65	24.7	14.3	0.311	0.222	52	43
60	23.9	13.9	0.305	0.210	51	40
55	23.4	13.3	0.282	0.205	48	39
50	22.7	13.0	0.275	0.201	46	38
45	22.2	12.7	0.269	0.186	45	36
40	21.8	11.6	0.263	0.173	44	33
35	21.0	11.1	0.257	0.168	43	32
30	20.0	10.1	0.251	0.163	42	31
25	18.2	9.4	0.236	0.153	40	29
20	17.2	8.8	0.225	0.148	38	28
15	15.9	8.2	0.215	0.137	37	26
10	15.3	7.8	0.206	0.111	35	21
5	13.5	6.0	0.179	0.090	30	17
Mean ± *SD*	22.4 ± 5.53	12.8 ± 4.3	0.28 ± 0.06	0.20 ± 0.07	47 ± 10	38 ± 13
Minimum	11	4.4	0.150	0.060	25	11
Maximum	35.7	24.9	0.413	0.352	69	67

Table 4. Norm values for time and total work for male subjects and from cited study.

%ile	kJ		Time	
	This study (*n* = 161) †	Calmelat (*n* = 71)*	This study (*n* = 161)	Calmelat (*n* = 105)
95	31.5	28.2	63	54
90	28.7	25.3	60	50
85	27.3	23.8	59	46
80	26.8	22.4	58	42
75	26.2	21.5	54	41
70	25.4	21.1	53	39
65	24.7	n/a	52	n/a
60	23.9	19.8	51	36
55	23.4	n/a	48	n/a
50	22.7	18.6	46	33
45	22.2	n/a	45	n/a
40	21.8	17.3	44	30
35	21.0	n/a	43	n/a
30	20.0	28	42	28
25	18.2	15.2	40	27
20	17.2	15	38	23
15	15.9	12.6	37	21
10	15.3	10.9	35	19
5	13.5	10.2	30	18
Mean ± *SD*	22.4 ± 5.53	18.6 ± 5.7	47 ± 10	33.6 ± 11.3
Difference (vs. Calmelat)	~120.4%		~139.8%	

* Based on active men between the ages of 18 and 25 years and at a grade of 20% and a speed of 214.4 m/min (references 1 and 2)
† At a grade of 15% and a speed of 244 m/mi

DISCUSSION

The main objective of this study was to establish sex reference values for the mAST among active healthy adults aged 19-29 years and to compare values between sex. Our data in this population also confirms the common finding of higher total work in adult men compared to adult women (4). The 20% grade protocol and the 15% grade protocol have both been tested as valid and reliable measures of anaerobic capacity (23, 28), however, there are no published studies which present standardized data or reference values for the 15% grade mAST to interpret the results, only data for the 20% grade AST provided in a non-published thesis project by Calmelat (4, 6).

Calculating total anaerobic work output is important for a wide variety of skills but may be difficult to understand without relative or absolute values for comparison. These standardized normative values are a valuable asset for tracking trends in performance and recognizing when improvements have been or need to be made. The previous study that validated the Cunningham and Faulkner protocol (8) used a similar age, height, and weight range for a more accurate comparison of results between each protocol (28). In addition to absolute time and work, this present study analyzed relative work completed using a work to mass ratio to allow for a better understanding of anaerobic work capabilities between men and women. Calculating relative work output with the data provided by Calmelat (6), the male subjects had an average of 0.25 ± 0.08 kJ/kg of work completed. This is lower than the relative work output found for males in this study (0.28 ± 0.06 kJ/kg). This result is possibly due to differences in intensity for each protocol as the subjects on the mAST protocol ran longer on average than the subjects on the AST, the muscle fatigue patterns with different grades on the treadmill, different turnover rate, or just differences in fitness between the two sample groups. However, it is difficult to compare female differences in anaerobic capacity due to the lack of data (4, 6), and a lack of relative work output in existing research.

The male and female average times (47 ± 10 and 38 ± 13, respectively) both fall within the recommended time of 30 to 60 seconds, indicating these protocols are sufficient to measure one's anaerobic capacity (14, 21). Most of the percentile values calculated also fall within the 30-60 second range for both males and females, with the exception of the bottom 25th percentile for women and above the 90th percentile for men. This indicates that most of the individuals that participate in these protocols will fall within the recommended range, or not far outside of it. It has also been mentioned in previous literature that predictions of energy requirements can vary at different speeds from person to person due to factors such as mechanical efficiency, and that individualized values can be used to determine a personalized test (14). A personalized test can be helpful for altering the test for individuals far outside of the recommended timeframe or current percentile ranges given.

This time difference in fatigue between males and females can be due to many factors. As mentioned before, there is both metabolic and neurological fatigue that play a part in being unable to continue a high intensity exercise bout (2). Muscle fiber types and the amount of each type of fiber present in both male and female subjects also affect the ability to perform anaerobic work at a high intensity. Women typically have less type II fiber area compared to males (e.g. 7700 vs 4040 μm^{2}in the vastus laterals) with no gender difference between the strength to cross sectional area ratio, indicating the primary reason men may perform better in terms of muscle structure may simply be larger fiber size and more muscle mass (16, 22). In addition to muscle structure, fitness level has an impact on the level of metabolic fatigue and when the onset of that fatigue occurs. These two factors will influence the amount of metabolic byproducts produced, the ability to maintain regular muscle contractions, and the ability to maintain homeostasis, which in turn will affect the time until one fatigues (2). Furthermore, neurological fatigue from the CNS plays a less obvious role, but an important one nonetheless, in fatigue during exercise. When trying to exert maximal force without being able to meet that force in addition to experiencing disruptions between the brain and muscles, muscular contractions become harder to perform, and thus contribute to the sensation of fatigue (9). This neurological fatigue may be a factor or primary cause of cessation of maximal effort, as the physical discomfort and mental strain can be enough to discourage someone from pushing forward.

Additionally, it has previously been shown that women display different muscle activation patterns that allow for increased efficiency and longer times to fatigue. A study by Semmler, Kutzscher, and Enoka (24) demonstrated that 7 of 12 subjects (1 male, all 6 females) increased their endurance by at least 100% after 4 weeks of limb immobilization due to this phenomenon, which may indicate females may have a potential to perform better than males for time to fatigue (26). This is notably different from the results of this study and what the data suggests. However, it may be because of the differences of primary energy systems used, or that female subjects may have a larger aerobic component that contributes to overall work output (15).

When comparing both absolute and relative work output (kJ; kJ/kg) between men and women, it is apparent that men typically have a higher output when compared to women. This difference between men's and women's values can also be due to significant differences in height, percent body fat, and fat free mass (18). When corrected for fat free mass, Maud et. al. (1986) found no significant difference found between male and female subjects in anaerobic power output in an assessment of three anaerobic power (kg·m/s) and two of anaerobic capacity (kg·m/min, Watts) (18).

Normative data for the Cunningham and Faulkner AST (8) show that times for male subjects are generally lower, as is the amount of work and power output, when compared to the normative values collected for the 15% grade mAST in this study (4, 6). This can also be seen when looking at the values for the initial 15% grade mAST study, which found the average times to fatigue in the AST of 60.5 ± 10.6 sec, 71.9 ± 9.5 for the first trial of the mAST, and 75.7 ± 10.2 for the second trial of the mAST (23). These values are based off collegiate soccer players, which may explain the overall higher times for both protocols. This may indicate that the current modified protocol, while still a valid and reliable measure for measuring anaerobic capacity for both active healthy males and females, does not quite match the intensity required to achieve the same times to fatigue seen in the original protocol and normative values.

A higher speed or another method of calculating equivalent intensity may be necessary in the future to create a protocol that more precisely matches the 20% grade test. The average times run by both male and female subjects in this study exceed the times run by the subjects data for the 20% grade test (6), when the purpose of the mAST is to produce work output equal to the AST. However, since there is still relatively limited data on normative values between the two protocols, it may be possible that not enough data is available to make an absolute conclusion at this time. Other standardized values such as relative work output (kJ/kg) are not available for comparison for the 20% grade AST test, which may provide a better analysis between the two protocols. Differences could also vary depending on the populations included in each study. There are also no values to compare between female subjects for the 20% grade protocol, so no assumptions or conclusions can be considered until the data becomes available for both anaerobic tests.

Future research would benefit from larger sample sizes to add to current normative values and to further represent the population. Additionally, a more detailed log of exercise habits of each subject will help in creating more normative data for specific groups based on fitness level. Research including more standardization methods such as relative work to fat free mass could also prove to be beneficial when comparing male and female subjects moving forward. It is also important to note that body composition was not measured in this study, but is important to compare relative work as it relates to lean and fat mass separately rather than just using total mass.

PRACTICAL APPLICATION

Overall, these findings provide useful data that can now be used to interpret individual performance on the mAST protocol for the general population. The results of this study provide normative values for both men and women for the mAST that can be used in a commercial or even home gym setting. Previously, there had not been percentile rankings or other normative data for this protocol that was widely available for general use and interpretation. Now coaches, athletes, and fitness enthusiasts who engage in regular physical activity not only have access to an anaerobic capacity test that is sports specific to running-type sports, but they can interpret on their own that can be administered on a treadmill wherever available and used in place of special equipment. This data can be used instead of the limited data available on this protocol and utilized in future studies analyzing normative values for this anaerobic treadmill test, or even creating more personalized tests for individuals far outside of the recommended timeframe or current percentile ranges given (17). This data will be useful for coaches, athletes, and fitness enthusiasts who requires access to an anaerobic capacity test that is sport specific, can be done without special equipment, and has data to interpret results.

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