NORMATIVE VALUES OF COLLEGE-AGED MEN AND WOMEN FOR THE 1.5-MILE TEST ON A TREADMILL FOR CARDIORESPIRATORY FITNESS

By

Eli Baginski

A Thesis Presented to

The Faculty of California State Polytechnic University, Humboldt

In Partial Fulfillment of the Requirements for the Degree

Master of Science in Kinesiology

Committee Membership

Dr. Young Kwon, Committee Chair

Dr. Whitney Ogle, Committee Member

Dr. Eden Donahue, Committee Member

Dr. Eli Lankford, Graduate Program Coordinator

May 2022

ABSTRACT

NORMATIVE VALUES OF COLLEGE-AGED MEN AND WOMEN FOR THE 1.5-MILE TEST ON A TREADMILL FOR CARDIORESPIRATORY FITNESS

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Physical activity has been shown to positively affect both mental and physical health. A means of determining an individual's physical fitness is a necessary tool in developing and maintaining a healthy exercise routine. The 1.5-mile run test provides an accurate and reliable estimate of VO_2 max and can be used to routinely assess cardiorespiratory fitness. The aim of this study is to develop normative data for the 1.5 mile run test for both college-aged women and men. We examine how the calculated normative data presented produced by the Cooper Institute compares to our measured values, as well as compare sex differences within this study.

A total of 397 (197 female; 200 male) moderately active individuals partook in the study and completed the 1.5-mile test on a treadmill. Normative data was generated for completion time, average speed and absolute and relative VO_2 max. There was not a significant difference between the Cooper Institute's calculated normative values and the normative data developed in this study. There was a 13.9% difference in 1.5-mile completion time between men and women, with men running at an average speed 12.3% faster than women. This difference in run performance decreased when expressed relative to body mass and lean body mass suggesting that the higher performance in men was partly due to male subjects having more lean body mass and mass in general than female subjects.

Key words: cardiorespiratory fitness, normative data, 1.5-mile run test

***This research manuscript was written for submission to Journal of Strength & Conditioning Research, and the instructions for authors are available at http://edmgr.ovid.com/jscr/accounts/ifauth.htm**

ACKNOWLEDGEMENTS

Thanks to all those who participated in this study and ran to exhaustion. To the lab techs and researchers who aided in the data collection process, I greatly appreciate your work. Finally, I want to thank Dr. Young Sub Kwon for all his direction and assistance in guiding the project from start to finish as well as my committee members who dedicated time and effort to review the project and give their feedback.

This study was performed as part of the first author's thesis project without supplemental funding. The authors do not have a professional relationship with companies or manufacturers who may benefit from the results of this study. None of the authors received funding for research related to this article. The authors have no conflicts of interest to declare.

TABLE OF CONTENTS

LIST OF EQUATIONS

LIST OF TABLES

INTRODUCTION

University years are a formative time for young adults. Students invest time gaining knowledge in fields of interest, exploring arts and sports, joining clubs, and participating in many other extracurricular activities. It is not surprising that at such a busy time, students do not always take care of their health. In a meta-analysis done by Keating et al., they found that 50% of university students did not meet the American College of Sports Medicine's (ACSM) guidelines for physical activity (Keating et al., 2005). Furthermore, in a review by López-Valenciano et al., the authors found that physical activity levels of university students around the world decreased during the COVID-19 pandemic (López-Valenciano et al., 2021). The repercussions of a sedentary lifestyle are extensive. Physical activity has been shown to positively affect brain function and cognition (Kramer & Erickson, 2007). A negative correlation has been found between cardiorespiratory fitness and depression, suicide attempts, and self-harm (Grasdalsmoen et al., 2020). In addition to mental health, physical activity affects bodily functioning. Physical activity is one of the chief methods for improving and maintaining cardiorespiratory fitness (CRF). CRF is the ability of the respiratory and circulatory systems to supply oxygen to working muscles (Kenney et al., 2019). Poor CRF has been associated with many diseases from diabetes to heart disease (Al-Mallah et al., 2018). Many of these diseases are among the top chronic conditions that affect people globally (World Health Organization, 2021). Physical activity therefore must be a part of students' weekly routine to help them tackle the difficulty of gaining higher education and maintaining their health at the same time.

With CRF playing such an important role in human health, it is necessary to be able to effectively determine an individual's CRF and whether it meets current recommendation guidelines. Maximal aerobic capacity (VO_2 max) is the maximal consumption, distribution, and utilization of oxygen during exhaustive exercise and is the gold standard for categorizing an individual's CRF (Kenney et al., 2019). While VO_2 max can be measured by a trained technician using laboratory equipment, most people do not have access to such tests on a regular basis and an easier method for determining their CRF is necessary. Fortunately, many field tests have been developed to allow people to estimate their CRF with little more than a stopwatch and a track to run on. The 1.5-mile run test has been reported as one of the most accurate and reliable tests to estimate a person's VO_2 max (Mayorga-Vega et al., 2016; ACSM, 2013). Using an established equation (Equation 1) and the average run speed for the 1.5-mile test, an accurate VO_2 max estimate can be produced (Larsen et al., 2002). Furthermore, in an unpublished thesis, Jackson found that 1.5-mile times did not differ significantly ($p = .122$) for either men or women when performed on a track versus a treadmill (Jackson, 2008).

To determine a person's level of CRF, an individual can compare their VO_2 max score to normative data for their age and sex (ACSM, 2013). Normative data come from cross-sectional studies in which a large group of subjects from a population takes a test. The results of each subject are used to determine percentile ranks that indicate the range of scores within the population. Thus, normative data provide a quick and simple way to assess performance and examine how an individual's score compares to a population (Hoffman, 2006).

The ACSM reports normative data for the 1.5-mile run test, however, this data was not established by sampling a population in a formal study but rather calculated using an adjusted 12-minute run test equation by the Cooper Institute (S. Farrell, personal communication, February 20th, 2021). The Cooper Institute's calculated normative data lack demographic parameters and the generalizability of the data is uncertain. The first purpose of this study was to fill the gap by establishing normative data for the 1.5-mile run test for university-aged adults. Due to the ease of use, all the 1.5 mile run tests were performed on treadmills. Secondarily, this study examined any differences between the Cooper Institute's calculations for the 1.5-mile test and completion times between male and female subjects. We hypothesized that there would not be a significant difference between the Cooper Institute's calculations and our measured findings. We hypothesized that male subjects would have a lower run time at any given percentile rank than female subjects. This study provides a convenient method for students to assess their CRF. When improvement is desired, an individual can routinely check progress by referencing the normative data chart as they improve their 1.5-mile time.

METHODS

Experimental Approach to the Problem

The normative data collected was obtained from a sample of 397 subjects (197 women; 200 men). All 1.5-mile run tests were completed on a motorized treadmill (Platinum Club Series Treadmill, Life Fitness, Rosemont, IL). A running distance of 1.5 miles was used to compare results to the normative data (1) because this distance has been previously identified as the minimum distance necessary to estimate cardiorespiratory fitness (Vickers, 2001). In addition, previous research has shown that the 1.5-mile run test had a positive correlation with $\dot{V}O_2$ max (Gleason et al., 2014, Larsen et al., 2002). Subjects were instructed to run until reaching 1.5-mile with their self-selected stride frequency. The University Institutional Review Board (IRB) approved this study, and each subject signed a written informed consent form before participating in the study.

Subjects

A total of 397 active, healthy volunteers (200 men; 197 women) between 19 and 29 years of age were recruited for participation in this research. Subjects were recruited and tested from December 2015 until May 2019. Subjects who were thoroughly familiar with treadmill ergometry and laboratory procedures, volunteered to participate in the study. Many subjects participated in a club or recreational sports (42.7% of men and

43.4% of women), but not college varsity sports such as soccer, track and field, etc. All subjects regularly participated in moderate or strenuous exercise for a minimum of 3 days per week for a period of at least 4 weeks prior to participation. Moderate physical activity was defined as any form of activity that takes 3.0-5.9 METs to complete, such as brisk walking, dancing, golf, tennis, and volleyball. Vigorous activity was defined as any activity that requires 6 or more METs to complete, such as jogging and running, bicycling, soccer, swimming, or performing heavy lifting (ACSM, 2013). Subjects were screened for cardiovascular and musculoskeletal disease using a medical history questionnaire, an activity questionnaire, and the Physical Activity Readiness Questionnaire (PAR-Q). Inclusion criteria were (a) classification as "Low Risk" according to ACSM's Cardiovascular Disease Risk Factor Assessment (ACSM, 2013), (b) not currently on any type of restricted diet or on any medication, (c) no musculoskeletal conditions or injuries, and no flu or illness during study, (d) non-smokers for at least the past 6 months, and (e) classification as non-obese (BMI < 30 and waist circumference < 102 cm). Based on inclusion criteria, subjects were considered healthy and active. Subjects participated in two separate sessions as part of the study procedures.

Procedures

All testing took place in the Cal Poly Humboldt Human Performance Lab (HPL). To ensure inter-rater reliability issues, all anthropometric data was collected by the same proctor. During the first session, all subjects completed a consent form, health history form, and had initial measurements taken (i.e., weight, height, and anthropometrics). Weight (437 Physician's Scale, Detecto, Webb City, MO) and height (Seca 216, Chino, CA) measurements were taken as part of the subject assessments. Body mass index (BMI) was calculated from height and weight measurements to determine if subjects met inclusion criterion (e). Body density was determined using the 3-site formula using skinfold (Lange Skinfold Calipers, Beta Technology, Santa Cruz, CA) measures at the triceps, suprailiac, and thigh for women and chest, abdominal, and thigh for men (Jackson et al., 1980); ethnic and sex-specific equations were used to calculate the percentage of body fat from body density. Prior to the data collection days, subjects participated in one familiarization session to help them get accustomed to the testing procedures and protocols (i.e., some practices in pacing).

Procedures for the 1.5-Mile Run Test

Prior to each experimental session, subjects performed a warm-up, which included running for five minutes at their self-selected speed, followed by a dynamic stretching, such as leg swing, high knees, etc. Subjects completed 1.5 miles as fast as possible on a motorized treadmill (Platinum Club Series Treadmill, Life Fitness, Rosemont, IL) with a 0% percent grade of incline. Subjects were instructed to run until reaching 1.5-miles with their self-selected stride frequency. Upon test completion, a mandatory cool-down period was enforced. Subjects walked slowly (80 m/min) for about 5 minutes immediately after the run to prevent venous pooling.

Normative Data and Statistical Analyses

The Shapiro-Wilk's test was used to examine the data for normal distribution. Q-Q plot graphs were used to determine outliers. Anthropometric data, completion time and speed were reported as mean ± standard deviation (SD). All data was analyzed separately to provide percentile values for men and women. Percentile norms were created using the percentile function in Microsoft Office Excel for Windows 2016 and GraphPad Prism 9.0 (GraphPad Software, Inc., San Diego, CA). Normative data run speed was imputed into the ACSM's equation for estimating VO_2 max for running (Equation 1) to produce VO_2 max normative values (ACSM 2013). Further VO_2 max normative data expressed relative to mass, lean body mass, body mass to -0.67 power, body mass to -0.75 power, and BMI were created. A t-test for independent means was used to examine differences between sexes and between Copper Institute reference values and the current study's norms. Significance for all the statistical tests was set at an alpha level of 0.01.

Equation 1. Metabolic Calculation for the Estimation of Energy Expenditure

$$3.5 + 0.2(\text{speed}) + 0.9(\text{speed})(\text{grade}) = VO_2 \text{ max (ml kg-1 min-1)}$$

RESULTS

A total of 397 university students between the ages of 19-29 completed the 1.5-mile test protocol. Q-Q plot graphs determined that there were no outliers. The 1.5-mile run times were normally distributed ($p = 0.90$ for men and $p = 0.34$ for women) as assessed by Shapiro-Wilk's test of normality on the studentized residual. Table 1 shows racial demographics of the study subjects. The majority of the subjects reported their racial background as either white (43.5%) or Hispanic or Latino (37.2%). Table 2 shows anthropometrics, average 1.5-mile run speed and time, and calculated average absolute and relative VO_2 max values for both sexes using the ACSM metabolic equation (ACSM 2013). There was a significant difference between sexes for all categories except for VO_2 max BMI^{-1} (ml• m^2 •kg^{-2}•min^{-1}) ($p = 0.61$). Table 3 presents normative data and maximum and minimum values for both sexes for 1.5-mile test speed and time. Table 4 presents both relative (ml•kg^{-1}•min^{-1}) and absolute (L•min^{-1}) VO_2 max normative values for both sexes calculated from the 1.5-mile run time norms using the ACSM metabolic equation (ACSM 2013). Table 5 represents VO_2 max normative data relative to lean body mass, body mass to the -0.67, and body mass to the -0.75. Table 6 represents absolute and relative VO2 max divided by BMI.

Figure 1 shows a significant difference ($p < 0.01$) between female and male run time distributions. Figure 2 shows completion time across percentile norms for both sexes. There was a significantly higher average completion time for women than men ($p < 0.01$). Figures 3 and 4 show a comparison of both men and women percentile norms from the current study to the normative values created by the Cooper Institute (the Cooper Institute, 2009). No significant differences were found between the Cooper Institute's normative values and the current study's norms (p = 0.47 for men and p = 0.37 for women).

Table 1. Self-reported race identification of study sample

Race	All	Male	Female
White	43.5%	43.7%	43.4%
Hispanic or Latino	37.2%	38.7%	35.7%
Black or African American	2.8%	3.0%	2.6%
Asian	3.8%	3.5%	4.1%
Native American or Alaska Native	2.3%	1.5%	3.1%
Unknown or no response	10.4%	9.5%	11.2%

Note, n = males 200, females 197

Table 2. Characteristics of the study sample by sex (mean ± *SD*)

Characteristics	All (n = 397)	Male (n = 200)	Female (n = 197)	Difference and p for sex
Age	22.4 ± 2.3	22.9 ± 2.3	21.9 ± 2.3	4.6%, $p < 0.01$
Body mass (kg)	75.7 ± 15.4	83.2 ± 15.6	67.6 ± 10.6	18.7%, $p < 0.01$
Height (cm)	172.3 ± 9.3	178.3 ± 7.1	166.1 ± 6.8	6.8%, $p < 0.01$
Body mass index (kg•m^{-2})	25.3 ± 4.2	26.1 ± 4.3	24.6 ± 4.6	5.9%, $p < 0.01$
Body fat (%)	21.2 ± 5.5	18.5 ± 4.8	24.0 ± 4.8	29.8%, $p < 0.01$
Lean body mass (kg)	59.2 ± 11.2	67.2 ± 8.9	51.1 ± 6.6	23.9%, $p < 0.01$
1.5 Mile Run Speed (km•h^{-1})	11.8 ± 2.2	12.6 ± 2.2	11.0 ± 1.9	12.3%, $p < 0.01$
1.5 Mile Run Time (min:sec)	12:45 ± 02:30	11:55 ± 2:12	13:35 ± 2:31	13.9%, $p < 0.01$
VO2max BM^{-1} (ml•kg^{-1}•min^{-1})	42.8 ± 7.4	45.3 ± 7.5	40.2 ± 6.3	11.4%, $p < 0.01$
VO2max (L•min^{-1})	3.2 ± 0.8	3.7 ± 0.6	2.7 ± 0.5	28.5%, $p < 0.01$
VO2max LBM^{-1} (ml•kg^{-1}•min^{-1})	54.2 ± 8.0	55.5 ± 8.0	52.8 ± 7.7	4.8%, $p < 0.01$
VO2max BM$^{-0.67}$ (ml•kg^{-1}•min^{-1})	177.1 ± 30.9	193.3 ± 28.2	160.6 ± 23.9	16.9%, $p < 0.01$
VO2max BM$^{-0.75}$ (ml•kg^{-1}•min^{-1})	125.4 ± 21.6	136.0 ± 20.2	114.7 ± 17.2	5.6%, $p < 0.01$
VO2max BMI^{-1} (ml• m^{2} •kg^{-2}•min^{-1})	2.20 ± 0.50	2.19 ± 0.5	2.21 ± 0.5	1.2%, $p = 0.61$
VO2max BMI^{-1} (L• m^{2} •kg^{-1}•min^{-1})	0.128 ± 0.029	0.144 ± 0.025	0.111 ± 0.022	21.7%, $p < 0.01$

VO2max: maximal oxygen uptake, BM: body mass, BF: body fat, LBM: lean body mass, BMI: Body mass index

Table 3. Percentile norms and descriptive statistics for speed and time of the 1.5-mile run test

Percentile Rank	Speed ($km \cdot h^{-1}$)			Time (min:sec)		
	All	Male	Female	All	Male	Female
99	17.5	18.2	14.5	08:17.1	07:57.8	09:58.6
95	15.4	17.0	13.8	09:22.5	08:30.3	10:27.9
90	14.5	15.4	13.4	10:00.0	09:23.6	10:47.5
85	13.8	14.7	13.0	10:27.9	09:49.9	11:08.7
80	13.6	14.2	12.7	10:39.8	10:13.5	11:24.6
75	13.4	13.8	12.5	10:50.6	10:27.9	11:34.1
70	13.0	13.7	12.2	11:10.6	10:33.4	11:50.5
65	12.6	13.4	12.0	11:30.5	10:43.4	12:05.6
60	12.3	13.1	11.6	11:46.3	11:03.4	12:29.7
55	12.1	12.8	11.4	12:00.0	11:10.8	12:39.9
50	11.9	12.5	11.3	12:10.7	11:32.7	12:51.4
45	11.5	12.1	10.9	12:32.5	11:54.8	13:14.1
40	11.3	11.9	10.6	12:49.3	12:09.7	13:38.9
35	10.9	11.6	10.1	13:14.1	12:21.5	14:17.1
30	10.6	11.4	9.7	13:37.2	12:40.6	14:54.0
25	10.1	11.0	9.7	14:16.5	13:05.2	14:58.5
20	9.7	10.6	9.1	14:55.5	13:36.9	15:57.6
15	9.4	10.2	8.7	15:20.9	14:05.4	16:40.0
10	8.8	9.6	8.2	16:25.7	15:02.0	17:35.5
5	8.1	9.0	7.8	17:51.9	16:04.3	18:36.2
1	7.7	8.2	7.2	18:51.5	17:39.2	20:00.2
Maximum	18.3	18.3	15.3	7:53.7	7:53.7	9:28.4
Minimum	7.1	7.7	7.1	20:16.2	18:45.0	20:16.2

Note, n = males 200, females 197

Table 4. Percentile norms and descriptive statistics for calculated VO_2max values (VO_2max BM^{-1} and absolute VO_2max) of the 1.5-mile run test

Percentile Rank	VO_2max BM^{-1} ($ml•kg^{-1}•min^{-1}$)			Absolute VO_2max ($L•min^{-1}$)		
	All	Male	Female	All	Male	Female
99	61.7	64.1	51.8	5.1	5.2	4.0
95	55.0	60.2	49.6	4.6	4.7	3.5
90	51.7	54.9	48.2	4.3	4.5	3.2
85	49.6	52.4	46.8	4.1	4.4	3.1
80	48.7	50.7	45.8	4.0	4.3	3.0
75	48.0	49.6	45.2	3.8	4.2	3.0
70	46.7	49.2	44.2	3.6	4.1	2.9
65	45.4	48.3	43.4	3.4	4.0	2.9
60	44.5	47.1	42.1	3.3	3.9	2.8
55	43.7	46.3	41.6	3.2	3.8	2.8
50	43.1	45.3	41.0	3.1	3.7	2.7
45	41.9	43.7	39.9	3.0	3.6	2.6
40	41.1	43.2	38.8	2.9	3.5	2.6
35	39.9	42.3	37.3	2.9	3.4	2.5
30	38.9	41.6	35.9	2.8	3.4	2.4
25	37.3	40.0	35.7	2.6	3.2	2.4
20	35.8	38.9	33.7	2.5	3.2	2.3
15	34.9	37.4	32.4	2.4	3.1	2.3
10	32.9	35.6	30.9	2.3	2.9	2.2
5	30.5	33.5	29.4	2.2	2.6	1.9
1	29.1	30.8	27.6	1.6	2.3	1.6
Maximum	64.6	64.6	54.4	3.2	5.4	4.3
Minimum	21.3	29.2	27.3	0.8	2.2	1.5

Note, *n* = males 200, females 197

Table 5. Percentile norms and descriptive statistics for calculated VO_2max values ($VO_2max\ LBM^{-1}$, $VO_2max\ BM^{-0.67}$, and $VO_2max\ BM^{-0.75}$) of the 1.5-mile run test

Percentile Rank	$VO_2max\ LBM^{-1}$ ($ml•kg^{-1}•min^{-1}$)			$VO_2max\ BM^{-0.67}$ ($ml•kg^{-1}•min^{-1}$)			$VO_2max\ BM^{-0.75}$ ($ml•kg^{-1}•min^{-1}$)		
	All	Male	Female	All	Male	Female	All	Male	Female
99	72.8	74.8	68.6	260.1	262.4	206.2	183.4	185.5	144.6
95	67.2	69.8	65.0	232.3	238.2	197.8	163.1	170.6	142.0
90	64.1	65.5	62.6	213.5	231.8	190.2	150.1	162.3	136.9
85	61.7	62.9	61.1	207.2	221.5	186.3	146.0	155.4	133.3
80	60.7	61.3	60.1	202.6	212.7	182.0	142.9	149.3	130.3
75	59.5	60.1	58.5	197.5	209.3	178.9	140.3	147.4	127.9
70	58.5	59.2	57.2	193.2	206.5	174.6	137.5	145.4	125.1
65	57.5	58.4	56.5	188.2	204.3	171.5	133.5	143.9	122.5
60	56.8	57.8	55.2	183.1	201.3	168.1	130.1	141.0	120.9
55	55.4	57.1	54.3	179.8	197.1	165.7	127.9	140.0	118.2
50	54.3	55.8	53.4	176.2	194.0	160.5	124.9	137.4	115.7
45	53.1	54.1	52.5	173.4	190.6	156.7	122.5	133.2	112.3
40	52.4	52.9	51.8	169.9	186.9	155.4	120.6	129.8	110.7
35	51.4	52.1	49.3	165.8	181.8	152.3	117.1	127.6	109.1
30	50.2	51.3	48.0	160.1	177.8	147.8	113.8	124.7	105.8
25	48.7	50.7	47.0	155.5	175.0	143.0	111.0	122.3	101.9
20	47.3	49.5	45.5	150.4	172.6	140.3	106.6	120.3	99.7
15	45.4	47.9	44.4	143.1	165.7	136.1	101.9	115.4	95.8
10	43.5	45.0	42.3	137.4	158.1	128.6	96.9	111.1	91.2
5	40.4	41.4	40.1	129.0	144.0	117.7	91.2	100.5	84.3
1	37.5	38.3	37.5	112.5	135.5	112.1	81.6	94.1	81.0
Maximum	76.0	76.0	72.4	271.0	271.0	219.0	191.1	191.1	156.3
Minimum	35.2	36.9	35.2	107.5	130.9	107.5	77.1	92.2	77.1

Note, *n* = males 200, females 197

Table 6. Percentile norms and descriptive statistics for calculated VO_2max values (Relative $VO_2max\ BMI^{-1}$ and Absolute $VO_2max\ BMI^{-1}$) of the 1.5-mile run test

Percentile Rank	Relative $VO_2max\ BMI^{-1}$ ($ml \bullet m^2 \bullet kg^{-2} \bullet min^{-1}$)			Absolute $VO_2max\ BMI^{-1}$ ($L \bullet m^2 \bullet kg^{-1} \bullet min^{-1}$)		
	All	Male	Female	All	Male	Female
99	3.37	3.44	3.09	0.202	0.207	0.158
95	3.00	3.09	2.97	0.178	0.185	0.146
90	2.85	2.76	2.88	0.166	0.176	0.141
85	2.74	2.68	2.77	0.157	0.173	0.136
80	2.64	2.58	2.66	0.150	0.165	0.133
75	2.56	2.53	2.59	0.145	0.159	0.127
70	2.51	2.43	2.55	0.141	0.156	0.123
65	2.43	2.37	2.48	0.139	0.151	0.120
60	2.37	2.29	2.43	0.136	0.148	0.117
55	2.26	2.18	2.36	0.131	0.144	0.115
50	2.16	2.13	2.23	0.127	0.141	0.112
45	2.08	2.07	2.11	0.123	0.140	0.108
40	2.02	2.03	2.02	0.120	0.137	0.105
35	1.97	1.98	1.97	0.116	0.135	0.099
30	1.90	1.92	1.89	0.112	0.130	0.097
25	1.83	1.80	1.85	0.108	0.126	0.095
20	1.76	1.76	1.76	0.102	0.123	0.091
15	1.66	1.65	1.67	0.097	0.120	0.088
10	1.55	1.56	1.53	0.091	0.113	0.085
5	1.40	1.43	1.39	0.085	0.107	0.078
1	1.21	1.21	1.23	0.070	0.093	0.067
Maximum	3.66	3.66	3.18	0.226	0.226	0.172
Minimum	1.13	1.20	1.13	0.066	0.084	0.066

Note, *n* = males 200, females 197

Figure 1. 1.5-mile run time for the 10th to 90th percentile ranks by sex. * Significantly different, $p < 0.01$

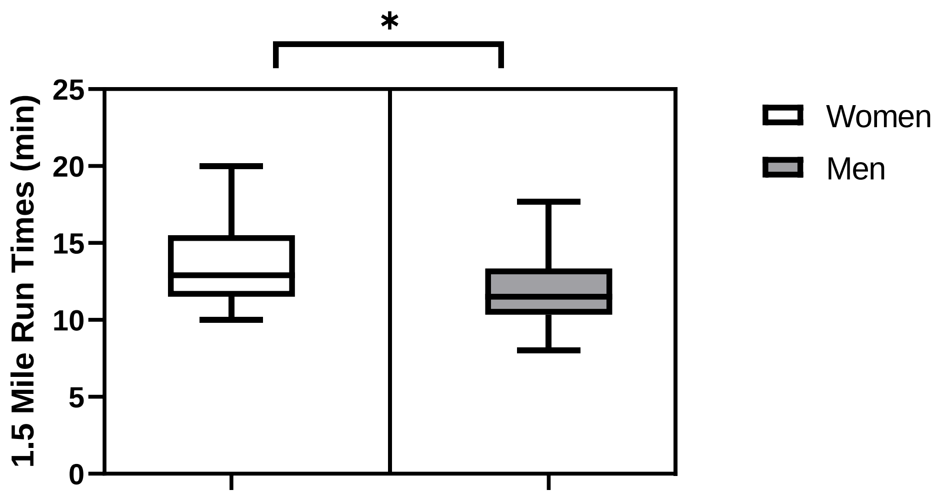


Figure 2. 1.5-mile run time for 1st to 99th percentile ranks by sex. * Significantly different, $p < 0.01$

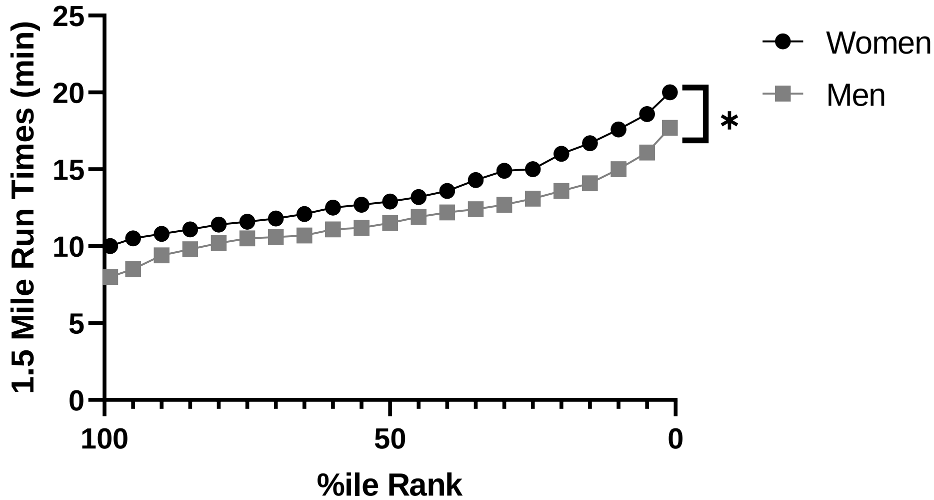


Figure 3. Comparison of the 10th to 90th percentile rank for 1.5-mile run time between Cooper Institute and the present study's norms. A) Men B) Women

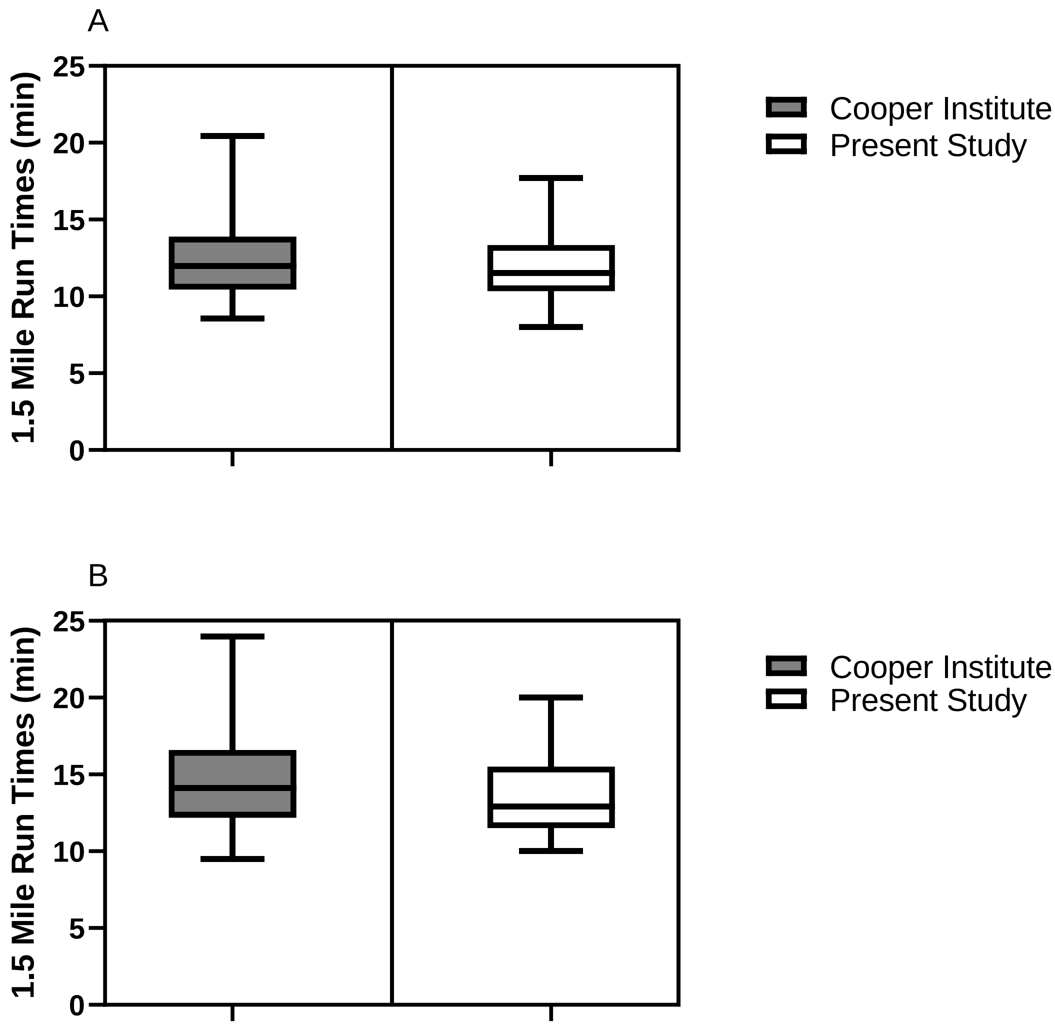
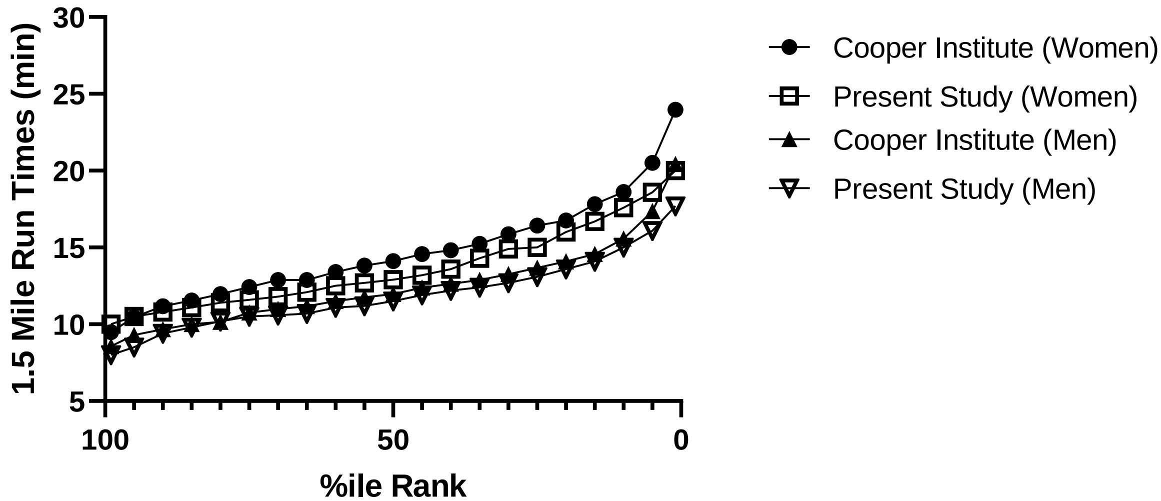


Figure 4. Comparison of the 1st to 99th percentile ranks for 1.5-mile run time between the Cooper Institute and present study's norms categorized by sex.



DISCUSSION

Determining cardiorespiratory fitness can inform an individual about the quality of their exercise patterns, their ability to perform athletically, and the degree of risk they face of developing different metabolic diseases (Al-Mallah et al., 2018). Regular testing can help individuals track their body health and inform them when adjustments to exercise routines are needed. The 1.5-mile run test provides a simple and accessible method for routinely testing CRF (Mayorga-Vega et al. 2016). A person can interpret, evaluate, and compare their results from a 1.5-mile test a normative data chart. The main purpose of this study was to develop normative values for moderately active college-aged women and men for the 1.5-mile test on a treadmill. To the extent of the authors' knowledge, this is the first study to establish such normative values for both men and women. Table 3 depicts percentile ranks for both sexes for 1.5-mile run time and speed. One limitation of the study was that subjects' VO_2 max was not directly measured, and thus the normative data is meant to provide an accurate sense of an individual's CRF but not an exact value. Run speed was, however, converted into VO_2 max ((ml• m^2 •kg^{-2}•min^{-1}) to provide norms that factor in body mass and allow comparison relative to body size. Tables 4, 5, and 6 show VO_2 max values relative to body mass, lean body mass, and BMI at each percentile rank.

A second goal of this study was to examine differences, if any, between the Cooper Institute's (2009) calculated norms for the 1.5-mile run test, as well as completion times between male and female subjects within this study. No significant differences were found between the Cooper Institute's calculated percentile rank normative data for the 1.5-mile test and the current study's [(for men, $p = 0.47$, for women, $p = 0.30$), Figures 3 and 4]. This finding supports the accuracy of the ACSM's equation to reasonably estimate CRF when used for a population similar to the one sampled in this study.

On average, men completed the 1.5-mile test in a time 13.9% sooner than women ($p < .01$), at a speed 12.3% faster ($p < .01$) (Table 1, and Figures 1 and 2). Men also had a 27.5% higher absolute VO_2 max (L•min^{-1}) than women ($p < .01$). However, this difference between women and men narrowed when VO_2 max was calculated relative to body mass (11.4%, $p < .01$) and even further declined when calculated relative to lean body mass (4.8%, $p < .01$). Performance differences between sexes found in this study appear to be largely due to mass and body composition differences between men and women (Table 2). On average, the women in this study had 29.8% ($p < .01$) more fat mass than men ($p < .01$), and men had 18.7% more overall mass than women ($p < .01$). The energy cost of running (C_r) is defined as the energy demand per unit distance normalized to body mass and is one of three factors that affect aerobic performance (Lacour and Bourdin, 2015). Body mass has been shown to be inversely proportional with C_r, resulting in greater energy efficiency per gram of body mass for larger runners compared to smaller runners (Anderson, 1996). This trend may explain the performance difference between sexes found in this study; males having more mass on average than females benefited from greater energy efficiency when running. Maud and Shultz (1986) examined sex differences in anaerobic power and anaerobic capacity and found a similar trend with performance difference between sexes narrowing when anaerobic power was reported relative to mass, and no differences between sexes when results were expressed relative to fat-free mass. The small difference in calculated VO_2 max relative to lean body mass between sexes in this study is likely due to further differences in physiology between sexes, such as a 5%-10% lower hemoglobin concentration in women than men (Joyner 1993; Cheuvront et al., 2005).

Alternatively, there was a significant difference in height between female and male subjects with males being 6.8% taller than females (p <.01), which might explain the difference found in 1.5-mile performance between the sexes. Running economy is a measure of how much oxygen is needed to run a particular pace and is a major factor in determining distance running performance (Moore 2016). In a review of biomechanics and running economy, Anderson (1996) found that anthropometric dimensions that could positively affect running economy include shorter than average height for men, taller than average height for women, ectomorphic physique, leg morphology that distributes mass closer to hip joint and smaller than average feet. Moore (2016) reported in a review on the modifiable biomechanical factors affecting running economy that using a natural stride length, greater leg stiffness, less leg extensions at toe-off, and alignment of ground reaction force and leg axis during propulsion are among the most important factors in improving running economy. These two reviews propose a large number of variables that affect running economy, indicating that height alone would likely not be the cause of differences seen in running performance between men and women in this study. Anderson also states that shorter than average height in men may be beneficial for running economy, which suggests that increasing height would not result in shorter run completion times.

The study population was limited to only recreationally active subjects, and both competitive college athletes and sedentary individuals were excluded from the study. Thus, the normative data does not represent the overall fitness of the university population, but rather allows an individual to compare themselves to people meeting the U.S. Department of Health and Human Services recommendations for physical activity (150 min/week at an intensity level of 3-6 METs) (Gibson and Heyward 2019). Information on physical activity trends in the overall university population can be found elsewhere (Keating et al., 2005; Lopez et al., 2021).

Subjects in this study were chosen within the age range of 19 to 29 years old. VO_2 max generally declines with age (Betik and Hepple, 2008), and therefore, the normative data tables developed in this study are useful for individuals between the ages of 19 and 29 but would not be applicable for older adults. Future studies could establish normative data for age classes extending beyond the 19 to 29 age range examined in this study.

PRACTICAL APPLICATION

The normative data tables developed in this study provide a tool for college-aged women and men to gain insight into their physical fitness. By comparing an individual's 1.5-mile test run time and speed to the values depicted in Table 3, the individual can quickly discover how they compare to other physically active university students. Tables 4, 5, and 6 require an individual to factor in their body mass or lean body mass, resulting in a more personalized score. Individuals can use these tables to not only determine their fitness level but also to track progress of an exercise regime or to assess effectiveness of an exercise program. Furthermore, college coaches and health professionals can use these tables in conjunction with a 1.5-mile test protocol to easily estimate the CRF of many students in a relatively short period of time.

Individuals who do not identify with the binary sex system used in this study may wonder how to use the normative data presented here. The purpose of splitting the normative reference values into male and female was to address physiological differences between people. Thus, an individual should compare themselves to the sex that best fits their physiology, generally the sex they were assigned at birth or based on whether they take hormones that alter their physiology.

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