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Annals of Biological Research, 2011, 2 (6):371-377
(http://scholarsresearchlibrary.com/archive.html)

Scholars Research Library
ISSN 0976-1233
CODEN (USA): ABRNBW

Queen's College Step Test Predicted VO_{2Max}: The Effect of Stature

Mahdieh Molanouri Shamsi[1], Hamid Agha Alinejad[2], Mohammad Ghaderi[3], Kamal Talebi Badrabadi[4]

[1]Department of Physical Education & Sport Science, Faculty of Humanity, Taft Branch, Islamic Azad University, Yazd,Taft, Iran
[2]Department of Exercise Physiology Physical Education and Sport Science Faculty, Tarbiat Modares University, Tehran, Iran
[3]Department of Physical Education & Sport Science, Mahabad Branch, Islamic Azad University, Mahabad, Iran
[4]Yazd Education Organization, Meybod Education Affair, Iran

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ABSTRACT

*The purpose of the present study was to evaluate the relation between stature and maximal oxygen uptake (VO_{2Max}). Fifty four active female university students with (Mean ± SD, ages: 23.22±1.93 yr, height: 162.13±8.59 cm, weight: 57.9 7±8.59 kg, body mass index (BMI): 22.03 ± 2.24 kg/m², fat free mass (FFM): 43.75 ± 5.97 kg, body fat percent (BF%): 24.24 ± 4.70)**,** were assessed applying Queen's College step test (QCT) and Cycle ergo meter test (CET). They were divided into three groups including short (153.22±3.11cm), medium (161.27±1.77cm) and high (171.91±3.17cm) stature. The results indicated that VO_{2Max} values measured by QCT and CET were significant different ($P \leq 0.05$). However, the differences between the VO_{2Max} values which were directly measured by CET and indirectly predicted by QCT within each three groups were statistically insignificant ($P>0.05$). Within each three groups QCT measured VO_{2Max} values were higher than the VO_{2Max} values measured by CET. In addition, there was no significant statistical correlation between stature and VO_{2Max} values in all the participants ($P>0.05$). It was concluded that, there was no relation between stature and maximal oxygen uptake (VO_{2Max}) measured by two different tests.*

Key words: Stature, Step test, Maximal oxygen consumption.

INTRODUCTION

VO_{2Max} is the primary indicator of aerobic fitness, cardiovascular health, and endurance performance [1-2-3]. The direct measurement of VO_{2Max} is the criterion measure, or "gold standard", of aerobic capacity where the participant undergoes a maximal exercise test on a cycle ergo meter or treadmill and oxygen consumption is measured directly [1-4-5]. Whilst this is the gold standard, the equipment is expensive, impractical in non-laboratory and field-test situation and also, it requires a high level of technical expertise and supervision. It is unsuitable for those individuals also for whom exhaustive exercise is not recommended.

As a result, many other tests have been developed for estimation of aerobic capacity. Some these tests are field tests requiring maximum effort, for example the 20-m multiple shuttle run [6], whilst others are submaximal treadmill, cycle ergo meter or bench-stepping tests with single stage or multistage protocols [7]. The basic premise of submaximal testing is that linear relationship exists between heart rate and oxygen consumption [8-9].

Step tests are one of the most widely used field tests for estimating VO_{2Max} [10]. Stepping requires no elaborate or expensive equipment, no calibration, and can be easily administered to large numbers of people [11-12-13]. Most commonly administered step tests are performed at a fixed cadence on a bench of a fixed height [14]. One such test is the Queens college step test (QCT) developed by Mc Ardle et al [15], and Molanouri Shamsi et al [5]. The investigators chose the bench height for convenience as most bleachers are approximately 41/3 cm [15].

Several researchers have suggested that, if a step is too high, local muscular fatigue may ensue before a true assessment of aerobic capacity can be obtained, so the test may be more a measure of muscular endurance of the legs than of aerobic capacity [5-10-16]. Bench heights based on participants stature may improve the validity of the step test as a measure of aerobic capacity. A number of researchers have concluded that for step tests the height of step should be adjusted to the participants stature and have concluded that these tests may decrease the inter participant variability in oxygen cost and heart rate during a task and, as such, may produce a more valid prediction of VO_{2Max} [5-10-17-18].

Several researchers have indicated that a step height producing an angle of $73/3^0$ produces the largest correlation between aerobic capacity and heart rate [17-19]. Ashley et al [20], found no significant difference in aerobic capacity, during QCT using a bench height based on knee joint angle of 90^0 and the original QCT. Their results indicated a greater heart rate recovery and minutes 1,2,3 during the QCT than during the modified QCT [20].

Also Molanouri Shamsi et al [5], proved that modification of the step height based on the knee angle of 90° in NMST reduces muscle fatigue or pain and also may lessen the inter individual variability in oxygen cost during the task.

VO_{2Max} is directly proportional to stature and body surface area [21]. But effect of stature in the predicted VO_{2Max} by step tests is not quite clearly.

Stature is effected by race, heredity, environment and nutrition. Submaximal step tests such as QCT are often used to estimate VO_{2Max} as it is often difficult to be measured in the field. It is used to estimate VO_{2Max} in all individuals regardless of differences in their stature. The purpose of this study was to assess the effect of stature in the predicted VO_{2Max} by QCT.

MATERIALS AND METHODS

Participants

Fifty four active female university students with (Mean ± SD, ages: 23.22±1.93 yr, height: 162.13±8.59 cm, weight: 57.97±8.59 kg, body mass index (BMI): 22.03 ± 2.24 kg/m², fat free mass (FFM): 43.75 ± 5.97 kg, body fat percent (BF%): 24.24 ± 4.70). Volunteered as subjects and randomly chosen from faculty of physical education students. They were divided into three groups including short (153.22±3.11cm), medium (161.27±1.77cm) and tall (171.91±3.17cm) stature, based on stature norm of Iranian students [22]. The physical and body composition characteristics of participants are presented in Table 1. There are significant differences between body mass, stature and FFM in three groups.

Stature was measured to the nearest 0.5 cm and body mass determined to the nearest 0.1 kg using a SECA digital balance. The percentage fat was estimated from the average sum of the four skin folds; triceps, iliac crest, leg and abdominal [23]. All participants were informed of the purpose, procedures and possible risks of the investigation before they gave written informed consent to participate in the study.

Procedure and measurements

VO_{2Max} of each participant was determined by CET and QCT. VO_{2Max} was presented as per kg body mass (ml/kg/min) and FFM (ml/kgFFM/min). All participants had four days of rest between the two tests. The participants were all fully familiar with exercise testing procedures. They were instructed to arrive at the laboratory in a rested and fully hydrated state, at least 3-h postprandial and to avoid strenuous exercise in the 48 h preceding a test session.

Queen's College step test

QCT was performed on a stool of 41/3 cm (16/25 inches) height for a total duration of 3 min at the rate of 22 cycles /min which was set by metronome. After completion of the exercise, the participant was asked to remain standing and the carotid pulse rate was measured from 5 to 20 seconds of the recovery period [9].

CET incremental protocol

The VO_{2Max} test was concluded on a CET (ZAN-680, Ergo Spiro, Germany) using a standardized incremental protocol, in which participants started with a 3 min warm-up with out load. The initial exercise load of 25w was increased in a linear pattern with 25w every 2 minute until volitional exhaustion. Resistance designed to elicit exhaustion in 8-12 minutes. Gas exchange parameters were recorded breath-by-breath. The rating of perceived exertion (RPE) was additionally recorded every 2 min (Borg, scale 6-20). The pedal rate was set at 60 rpm.

VO_{2Max} was defined as the highest VO2 measured during any 30-s period. A test was approved as being maximal when at least four of the following five criteria was met: a plateau in VO2 despite increased work rate (increase by< 150 ml/min or <2/1 ml/kg/min (2) R-value $\geq$ 1/15 (3) ventilatory equivalent for oxygen > 30, (4) RPE greater than 17 and (5) end HR within 10 beats.min^{-1} of age predicted HR_{max}. The HR_{max} was predicted from age using the formula of Tanaka et al [24], HR_{max}=208-·/7.age in years.

Data analysis

Data are presented as mean ± standard deviation. For statistical analyses SPSS 13.0 was used. A P value<0.05 was considered statistically significant. Paired t-test were used to determine the significance of differences between VO_{2Max} on the QCT and CET. A one-way analysis of variance (ANOVA) was used to determine the significance of differences between groups in two tests. Whenever necessary, the means were compared by the Tukey test. Also, Pearson-s coefficient of correlation (r) was used to describe the relationship between VO_{2Max} per kg body mass as well as the VO_{2Max} per FFM and starure.

RESULTS

The results showed that tall participants revealed greater VO_{2Max} in ml/kg/min on the both CET and QCT than short and medium participants (Table 2).While short participants revealed greater VO_{2Max} in ml/kgFFM/min on the both CET and QCT than tall and medium participants. Results of ANOVA to compare VO_{2Max} of three groups revealed no significant differences in VO_{2Max} in ml/kg/min means obtained by CET and QCT. However, results of VO_{2Max} in ml/kgFFM/min comparisons showed significant difference between medium and short participants. Short participants revealed greater VO_{2Max} per FFM than medium participants, there was not significant difference between short and tall participants (Table 2).

Results displayed in Table 2 reveal, significant differences in the mean VO_{2Max} obtained with CET and QCT. Mean VO_{2Max} of individuals in each of groups was greater in the QCT than in the CET. Therefore, it can be said that in comparison with the CET method, the estimation of VO_{2Max} with QCT exceeds true levels in groups.

Significant correlations were not found between measured VO_{2Max} and the stature. Correlation coefficients for VO_{2Max} in ml/kg/min are -0.04 and -0.06 for CET and QCT ($P>0.05$; see Fig. 1) and for VO_{2Max} in ml/ kgFFM/min are -0.1 and -0.14 for CET and QCT ($P>0.05$; see Fig. 1,respectively).

DISCUSSION

Most commonly administered step tests are performed on a bench of a fixed height [14]. As stepping efficiency may be influenced by step height [20], it is difficult to measure VO_{2Max} accurately, unless the height of the step is adjusted.

Results of present study showed no significant differences in the VO_{2Max} means obtained with the CET in three groups. However, tall participants revealed greater VO_{2Max} in ml/kg/min on the both CET and QCT. It appears that VO_{2Max} of tall participants were due to greater body surface area, cardiac output and lungs size than shorter counterparts, which provide a larger area for the exchange of oxygen. A number of researchers have found an relationship between aerobic capacity and stature [2-5-10-25]. But short participants revealed greater VO_{2Max} in ml/ kg FFM/ min in two tests. VO_{2Max} calculation per FFM revealed a higher physical activity level for short participants. Present study also, reveal no significant differences in the VO2Max in ml/kg/min means obtained with QCT. These results suggest that stature has not influence on participants VO_{2Max} resulted from QCT. Therefore, it seems that adjusting the step to the stature of participants for optimizing the estimation of VO_{2Max} is not necessary.

Ashley, et al [20], indicated no difference in the measure of VO_{2Max} in both original QCT and QCT using a bench height based on knee joint angle of 90^0 in non active women (18-37 years old) [20].

Shahnavaz [18], concluded that the relationship between oxygen demand and step height was negligible between 50^0 and 90^0 of hip angl. It appears that step height usually dose not effect the estimate of VO_{2Max}. But several researchers have concluded accommodation of step height to a person stature may provide a better estimation of VO_{2Max} enhancing the validity of the step test. Adjusting the step height account for difference in biomechanical efficiency of stepping and ultimately oxygen consumption during the step test [10-12-26].

Santo and Golding [26], conducted a study to determine whether adjusting the step height could effect the concurrent validity of the YMCA step test and maximal treadmill test. They concluded that the step test, when adjusted for stature, is moderately correlated to VO_{2Max}.

Selig et al [12], introduced a multi-stage step test protocol that accounts for differences in stature and is suitable, valid and reliable for people with low tolerance to exercise.

Ashley et al [20], have suggested that modification of step height may have effect stepping economy. This is suggested by the higher heart rates during minutes 1,2,3 as well as during recovery of the QCT. Modification of step height in multi-stage step tests such as protocol introduced by Selig et al [12], may decrease heart rate during stages and produce a more valid prediction of VO_{2Max}. Modification of step height in single-stage step tests such as QCT probably does not produce a significant change in VO_{2Max}. The result of our study and Ashley et al [15], confirm this issue. QCT is a reliable and valid predictor of VO_{2Max} in college-aged women. The participants of our study and Ashley et al [15], were college-aged women. Moreover, researchers used different cadence and step height in their investigations that would influence in the results.

The stature of participants show significant differences, furthermore VO_{2Max} in ml/kg/min was not significant different in three groups, so we can conclude that stature has not influence in the VO_{2Max} estimated by the QCT.

A comparison of predicted VO_{2Max} by the CET and QCT revealed that QCT overestimates the VO_{2Max} in the participants. In female participants, the reported validity with maximal testing ranged from r=0.7-0.8 [15-20].

In the present study, VO_{2Max} per FFM revealed significant difference between short and medium participants in the QCT; While no significant difference was shown in three groups in the CET. The level of aerobic capacity is related to percentage of FFM and level of training [28]. The step tests which were employed in the present study have recruited greater amount of muscle mass than cycling [29,30]. Our results have confirmed the influence of FFM and weight on the VO_{2Max} estimated by step tests.

Table 1- Physical and body composition characteristics of participants

Participants	N	Age (year)	Body mass (kg)*	stature (cm)*	BMI (kg/m^2)	FFM(Kg)*	Body fat (%)
Short	18	23.88 (1.36)	53.68 (8.72)	153.22 (3.11)	22.85 (3.47)	39.3 (5.45)	26.46 (3.33)
Medium	18	23.00 (2.22)	55.95 (6.23)	161.27 (1.77)	21.26 (2.37)	43.48 (3.94)	21.95 (5.46)
Tall	18	22.77 (2.04)	64.27 (7.02)	171.91 (3.17)	21.73 (2.13)	48.49(4.60)	24.31 (4.47)

Descriptive statistics: mean (±S.D.)

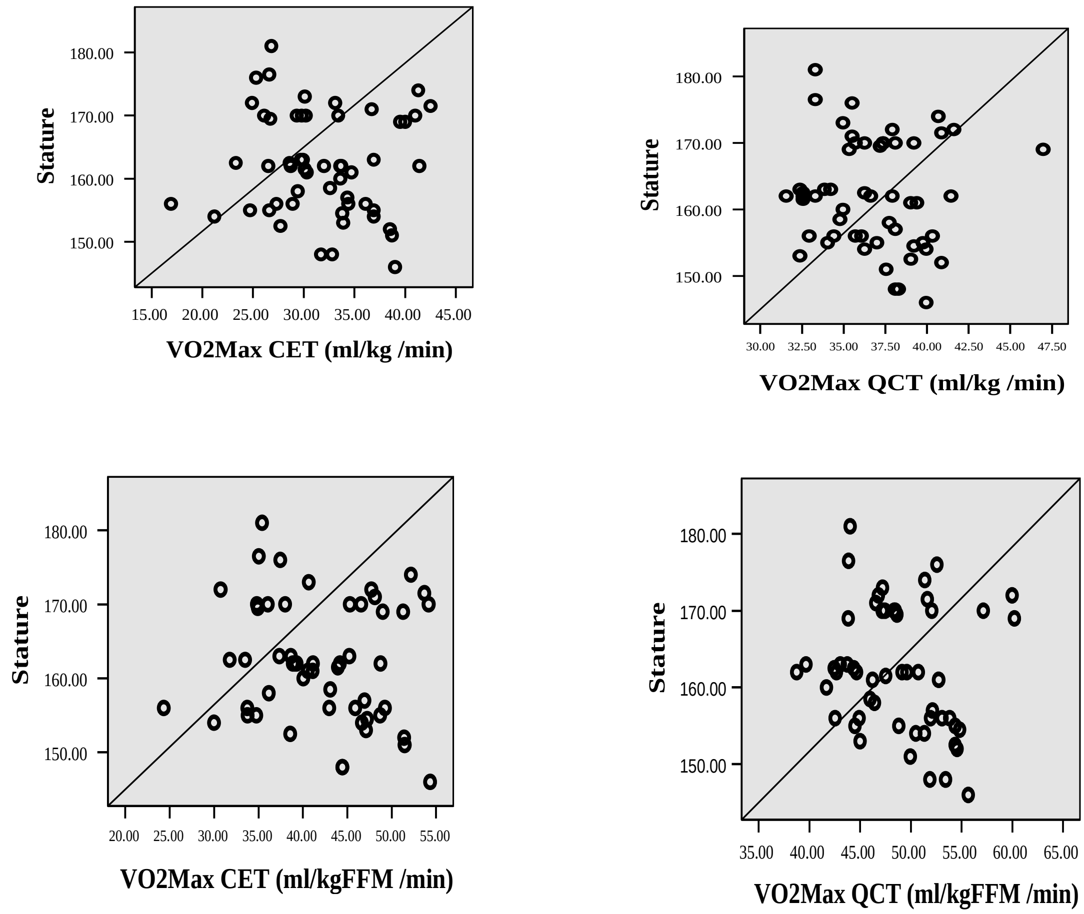
Table 2- ANOVA and Paired t-test results in the QCT and CET

Subjects	VO_{2Max} QCT (ml/kg /min)	VO_{2Max} CET (ml/kg /min)	P	VO_{2Max} QCT (ml/kgFFM /min)	VO_{2Max} CET (ml/kgFFM /min)	P
Short	37.32 (2.63)	31.44 (6.35)	*0.001	50.48 (4.08)	44.37 (5.96)	*0.001
Medium	35.51 (2.9)	31.62 (4.07)	*0.001	46.23 (3.09)	42.54 (5.35)	*0.001
Tall	37.61 (3.34)	32.4 (6. 2)	*0.001	49.99 (5.27)	41.55 (7.75)	*0.001
P	0.08	0.98		*0.002	0.54	

Descriptive statistics: mean (±S.D.)

In this study insignificant correlation was found between stature and VO_{2Max} in two tests. Our participants were physical education students with same level of fitness. However, short participants showed greater VO_{2Max} in ml/ kgFFM/ min than two other groups. Thus, the tall participants do not exhibit the effect of greater body surface area and stature.

Figure 1. The correlation between stature and VO_{2Max} in ml/kg/min and ml/kgFFM/min for CET and QCT



DISCUSSION

In summary, Sub maximal tests such as QCT are often used to estimate VO_{2Max} as it is often difficult to measure in the field. Our results suggest that in the female participants, their stature did not seem to influence stepping. Furthermore QCT overestimate VO_{2Max} in all of participants. Accordingly, stature is not considered as influential in the estimation of VO2Max using the QCT and CET. Researchers should involve a different age sample of female and men samples to examine more fully the utility of step tests based on subject stature.

Acknowledgment

We most appreciate all the participants of this research. The study was supported by the Sport Science Research Center (SSRC).

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