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Impact of Height on the Prediction of Maximum Oxygen Consumption in Active Young Men

Marefat Siahkouhian
University of Mohaghegh Ardabili, Ardabil, Iran

Abstract: Aim of this study was to determine the impact of height on the prediction of the maximum oxygen consumption in active young men. The subjects of this study were 20 active young men who were selected and assigned to two groups of short (n = 10, age (year) = 20±2.5, height (cm) = 159.62±4.16, weight (kg) = 61.2±4.38) and tall (n = 10, age (year) = 21.45±3.161, height (cm) = 183.20±3.19, weight (kg) = 80.33±5.12). To explore the impact of height in the prediction of maximum oxygen consumption, the Queen's step test and the incremental maximal treadmill test were used. Respiratory exchange was measured continuously throughout the test by an automated open-circuit gas analysis system. The results of the study revealed that tall active young men showed higher maximum oxygen consumption on the Queen's step test than short ones (61±2.94 vs. 52.80±1.81 mL/kg/min). Furthermore findings indicated that on the incremental maximal treadmill test too, tall active young men had higher maximum oxygen consumption than shorter subjects (48.50±3.06 vs. 42.10±2.02 mL/kg/min). According to this study results, we concluded that (1) Queen's step test overestimates the prediction of maximum oxygen consumption both in tall and short active young men and (2) the higher maximum oxygen consumption observed in tall active young men on the Queen's step test can not be due to their height alone; therefore, it seems that the higher maximum oxygen consumption in the tall subjects may be due to large amounts of lungs capacity, however, incorporated physiological factors involvement will be require for future studies.

Key words: Queen's step test, maximum oxygen consumption, height adjustable steps

INTRODUCTION

Determination of cardio-respiratory fitness is restricted to within the laboratory because of its exhausting and difficult experimental protocol. It is therefore desirable to find a simple procedure for evaluation of maximum oxygen consumption in population studies, especially in the field and in the absence of a well equipped laboratory. Among various indirect protocols, the Queen's College step Test (QCT) is the simplest one, which is frequently used to determine the cardio-respiratory fitness in terms of maximum oxygen uptake (D'Alanzo *et al*., 2006; Bandyopadhyay, 2008).

Recently, we reported that the VO_{2max} seen in tall girls on the both Queen's step test and maximal treadmill test, may be due to their physiological and physical properties (Bolboli *et al*., 2008).

Chatterjee *et al*. (2005) reported that the QCT has been standardized among Indians, who can easily perform this test without any premature exhaustion probably for its simple experimental protocol with lower stool height and slower cadence (Chatterjee *et al*., 2005, 2004). Bandyopadhyay (2008) indicated that QCT can be considered as an alternative step test of Harvard Step Test (HST) in Indian population provided it is properly validated and recommended. The application of QCT as an alternative of HST for determination of Physical Fitness Index (PFI) in Indian males has been already been established and recommended.

Researchers designed and developed steps adjustable to the height of subjects in order to optimizing the prediction of maximum oxygen consumption by the means of the Queen's step test (Howley and Turner, 2004; Welch *et al*., 2002; Mazic *et al*., 2001). During stepping, the biomechanical and work rate is determined by the step height (Francis and Brasher, 1992). Welch *et al*. (2002) studied the reliability of the three minute step test in order to prediction of maximum oxygen consumption with a specific stepping frequency. Their results showed that the three minute rate-specific and height-adjusted step test, predicts maximum oxygen consumption more accurately than fixed height step tests (Welch *et al*., 2002). In addition, Culpepper and Francis (1987) showed that a 73.3 degree angle in the thigh joint is the most suitable angle for the prediction of maximum oxygen consumption in the step test. Shepherd (1966) claims that estimation of maximum oxygen consumption regardless of the effect of height is a precise and reliable test.

On the other hand, Keren *et al*. (1980) indicated that physical properties such as weight and height do not affect the prediction of maximum oxygen consumption in the step test. In other word, maximum oxygen consumption is independent of weight and height.

Furthermore, Ashley *et al.* (1997) reported that step tests based on subject's stature do not more accurately predict the aerobic capacity than those using a standardized bench height. Willmore and Costill (1994) demonstrated that due to inverse relationship between stepping heart rate immediately after physical activity and maximum oxygen consumption, heart rate is regarded as the criterion to prediction of maximum oxygen consumption.

According to this literature, as the Queen's step test with a fixed height is used to predict maximum oxygen consumption in all individuals regardless of height differences, the aim of this study was to explore the impact of active young men height on the estimation of maximum oxygen consumption.

MATERIALS AND METHODS

Participants: Twenty healthy active young men volunteered to participate as subjects after all procedures were explained; a medical history questionnaire completed and informed consent signed. The University of Mohaghegh Ardabili Human Subjects Committee approved all experimental procedures. The medical history questionnaire screened potential volunteers for any health-related problems that might affect the parameters measured. All subjects were randomly allocated into two groups of short and tall. They did not drink alcohol on a regular basis and had not any programmed physical activity for at least 72 h before experiment were studied. They did not take any drugs which may be affects the heart rate throughout the study. Subjects' physical characteristics and skin fold measurement taken from three sites (midaxillary, abdominal and suprailiac) are presented in Table 1.

Experimental design and procedures: All subjects, prior to enrollment into the study, completed one preliminary visits to the laboratory before undertaking the main exercise trails. In this day, subject mass (model 712; seca, Germany) and height (Portable Stadiometer; Holtain, UK) were recorded; then all subjects completed a body composition assessment. In addition, the subjects were instructed to abstain from strenuous exercise for 3 day before main trial. On the day of the main trails, the subjects reported to the laboratory at approximately the same time of day (±1 h) during 3 subsequent days and completed the Queen's step test and maximal treadmill tests, respectively.

Table 1: Physical and body composition characteristics of subjects

	Groups		
	Short	Tall	
Variables	---------- (n = 10) ----------		p-value
No.	10	10	-
Age (years)	20.22±2.5	21.45±3.61	$p \geq 0.05$
Height (cm)	159.62±4.16	183.20±3.19	$p \leq 0.001$
Weight (kg)	61.20±4.38	80.33±5.12	$p \leq 0.05$
Body fat (%)	18.52±3.38	17.25±5.27	$p \geq 0.05$
Lean body mass (kg)	49.71±4.92	66.47±5.18	$p \leq 0.05$

Data are expressed as Mean±SD

Maximal treadmill test: Following a 10 min warm-up consisting of running at 50% VO_{2max} (5 min) and stretching (5 min), subjects run on treadmill until volitional exhaustion. The maximal treadmill test consisted of increases in treadmill speed every minute until subject's volitional exhaustion. Respiratory exchange was measured continuously throughout the test by an automated open-circuit gas analysis system. The highest averaged 30 sec oxygen uptake VO_{2max} value was defined as maximum oxygen consumption.

Queen's step test: As the queen's step test is a submaximal exercise test, all subjects after 5 min warm-up, stepped up and down on the 41.7 cm platform at a rate of 24 steps per minute, for a total of 3 min. Subjects were instructed to maintain their determined stepping rhythm during Queen's step test. The subject immediately stopped on completion of the test and the heart rates are counted for 15 sec from 5-20 sec of recovery (Nieman, 1999). HR was continuously monitored using short-range telemetry (Polar S610; Polar Electro, Finland). Maximum oxygen consumption calculated using the following equation:

$$\text{Maximum oxygen consumption (mL/kg/min)} = 111.33\text{-}0.42 \times \text{heart rate (beat min}^{-1}\text{)}$$

Body fat percent evaluation: Mechanical harpenden caliper was used to measurement of skinfold thickness and three point Jackson-Pollack equation for prediction of body fat. Measurements were taken when the skin is dry and not overheated (Nieman, 1999).

Statistical analysis: All data are presented as Mean±SD. Statistical significance was set at the $p<0.05$ level. Subject physical characteristics were compared under two groups using independent samples t-tests (Table 1). Maximal oxygen consumption data obtained by the means of Queen's step test and maximal treadmill test were compared with using paired samples t-tests. For statistical analysis of data inferential (paired t-test), were used. Graphs and figures were drawn using Excel software and data analysis was performed using SPSS 10.05 software under windows.

RESULTS

Findings of this study showed that tall young active men revealed greater maximum oxygen consumption on

the Queen's step and maximal treadmill tests than short ones (Table 2). In fact, mean maximum oxygen consumption of both groups was greater in the Queen's step test than in the maximal treadmill test.

Comparison of maximum oxygen consumption of both groups in the two treadmill and the Queen's step tests revealed significant differences in the mean maximum oxygen consumption. Predicted maximum oxygen consumption in both groups was greater in the Queen's step test than in the treadmill test (Table 3).

An association between aerobic capacity and height of active young men also shown in Fig. 1 and 2. The results also, revealed a significant correlation between height and predicted maximum oxygen consumption in the Queen's step ($R = 0.780$; $p \leq 0.01$) and treadmill ($R = 0.739$; $p \leq 0.01$) tests (Fig. 1, 2).

Table 2: Predicted maximum oxygen consumption of tall and short subjects by the means of Queen's and maximal treadmill tests

Test	Tall	Short	Significance
Queen's step test	61.00±2.94	52.80±1.81	$p \leq 0.001$
Maximal treadmill test	48.50±3.06	42.10±2.02	$p \leq 0.001$

Table 3: Results of the paired samples t-test in the treadmill and Queen's step tests

Method	Group	Mean difference	t-values	df	Significance
Treadmill	Short	6.4	8.23	9	0.000*
Queen's step	Tall	8.2	6.83	9	0.000*

*Difference is significant at 0.001 ($p<0.001$)

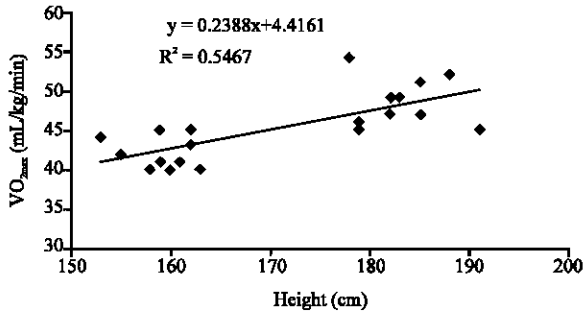

Fig. 1: Correlation between subject's height and maximum oxygen consumption in the treadmill test

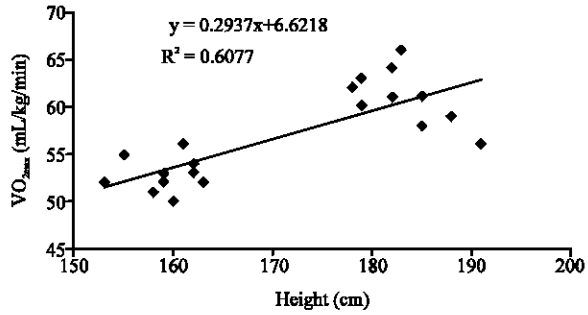

Fig. 2: Correlation between subject's height and maximum oxygen consumption in the Queen's step test

DISCUSSION

Bolboli *et al.* (2008) reported that taller sedentary girls had greater VO_{2max} than short ones in the Queen's step and treadmill tests. Accordingly, we studied in this study the impact of height on the estimation of maximum oxygen consumption among the active young men. Results of this study revealed that tall young active men showed greater maximum oxygen consumption on the Queen's step test than short ones. Associations between aerobic capacity and height and weight of young footballers, female swimmers and 15-25 years old individuals (men and women) have been reported by Culpepper and Francis (1987), Chen (1985) and Montoye *et al.* (1977).

This results indicated that comparing treadmill test; Queen's step test overestimates the maximum oxygen consumption in the both tall and short subjects. On the other hand, literature indicated that Queen's step is a reliable test for the prediction of maximum oxygen consumption. Bandyopadhyay (2008), D'Alanzo *et al.* (2006) and Chatterjee *et al.* (2005) have shown the Queen's step test to be reliable for the estimation of maximum oxygen consumption. In addition, researchers have shown that height-adjusted step test is a valid and reliable measure of maximum oxygen consumption in field conditions (Welch *et al.*, 2002; Mazic *et al.*, 2001; Gosling and Carlson, 2000; University of Alabama and Birmangam, 1992; Francis and Fenstein, 1991).

On the other hand, concurrent with the earlier (Bolboli *et al.*, 2008) and this study results, Ashley *et al.* (1997) showed that step tests based on subject's stature do not more accurately predict the maximum oxygen consumption comparing with standard steps. A brief review of literature indicates that studies due to different methodology has been shown different results regarding the influence of height on the estimation of maximum oxygen consumption by the Queen's step test.

As maximum oxygen consumption among the tall subjects comparing with short ones was similar in the both tests, it appears that long leg length and easy administration of the test by the tall subjects during Queen's step test may not a only affecting factor for predicting of maximum oxygen consumption. Hence, tall subjects due to greater lean body mass (Table 1) and larger lungs size than in their shorter counterparts, may be had higher maximum oxygen consumption. Thus, according to earlier (Bolboli *et al.*, 2008) and this study results it seems that height adjustable steps which designed for optimizing the estimation of maximum oxygen consumption, may not a unique determinant for validating of predicted VO_{2max} values. It should be noted that other physiological factors such as lungs capacities and

variables and movement pattern may be involved, which require further investigation.

CONCLUSION

Generally, based on findings of this study, we concluded that taller subjects had greater maximum oxygen consumption than short ones in the treadmill and Queen's step tests. In addition, maximum oxygen consumption overestimated by the Queen's step test in the both tall and short subjects.

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