Assessing Maximal Oxygen Uptake: Influence of Leg Length in the Harvard Step Test and Queen's College Step Test

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최대 산소 섭취량 평가: 하버드 스텝 테스트와 퀸스 칼리지 스텝 테스트에서 다리 길이의 영향

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Abstract

Purpose: This study aimed to investigate the influence of leg length on maximal oxygen uptake (VO_2 max), a key indicator of cardiovascular endurance and overall health.
Methods: The study involved 20 healthy male participants in their 20s, who performed VO_2 max measurements using Cardiopulmonary Exercise Testing (CPX) equipment and the Harvard Step Test and Queen's College Step Test for predicted VO_2 max (pVO_2 max).
Results: The study found a significant positive correlation between CPX VO_2 max and lower leg length. However, no significant correlations were observed with upper leg length and height. Simple linear regression analysis indicated that lower leg length significantly influenced exercise intensity using both the Harvard Step Test and the Queen's College Step Test. As lower leg length increases, exercise intensity using these step tests decreases.
Conclusions: These findings suggest that leg length, specifically lower leg length, plays a significant role in the measurement of VO_2 max. Customizing the step height based on individual body size is recommended when estimating exercise difficulty or VO_2 max through stepping exercises. Future research should address the limitations of this study to conduct more comprehensive studies related to VO_2 max

1. Introduction

VO_2 max is a crucial indicator of cardiovascular endurance and overall health, reflecting the body's maximum capacity to consume oxygen during intense exercise [1]. However, the high cost of the most accurate VO_2 max measurement method, CPX, has led to a demand for simpler methods [2, 3]. The Harvard Step Test and the Queen's College Step Test are examples of such methods.

These tests can be influenced by various factors, including walking habits, stride length, gait, and leg length [4]. The height of the step box and comfort level can also affect pVO_2 max measurements [5].

The Modified Queen's College Step Test, which customizes the step height based on individual body size, has been proposed to address these issues [6]. This study aims to investigate the influence of leg length on pVO_2 max measured using the Harvard Step Test and the Queen's College Step Test.

2. Subjerct and methods

2.1 Subject

The study involved 20 healthy male participants in their 20s, all of whom were students at S University in Chung-cheongnam-do.

2.2 Study Procedure

Before the experiments, participants were briefed on the procedures and measurements of height, age, weight, and leg lengths were taken. They performed VO_2 max measurements using CPX equipment while running on a treadmill. Predicted VO_2 max (pVO_2 max) was measured using the Harvard Step Test and the Queen's College Step Test, both performed using steps. Participants were given thorough explanations and practice opportunities before the experiments. A 24-hour break was provided after each examination to ensure adequate rest.

The laboratory environment was controlled at a temperature of 23 degrees Celsius and a humidity level of 50%. The research was conducted in a calm environment to minimize the influence of the sympathetic nervous system. Each measurement was conducted three times, and the average value was used.

Before commencing the step tests, participants practiced stepping to the rhythm of each step test's metronome for 20 seconds, then rested for 5 minutes. After the rest period, the test was conducted, and heart rate was measured immediately after the test to calculate pVO_2 max. For the Harvard Step Test, participants performed the stepping movement on a step box for a maximum of 5 minutes at a rate of 120 steps/min. In the Queen's College Step Test, the step box was set at a height of 41.27 cm, and participants repeated the stepping movement for 3 minutes at a metronome rate of 22 steps/min.

CPX VO_2 max was measured using the Bruce protocol on a motorized treadmill. Participants were equipped with a standard 12-lead electrocardiogram and a mask covering both their nose and mouth. Oxygen consumption was measured using a metabolic cart, and heart rate was continuously monitored through an electronic monitor. The protocol was deemed complete when participants met certain conditions, indicating maximum exercise capacity. All measurement results are presented as mean ± standard deviation.

2.3 Statistical Analysis

In this study, SPSS was used for data analysis. Descriptive statistics were used to understand the participants' characteristics. The Pearson correlation coefficient was used to investigate the correlation between height, leg lengths, and VO_2 max. Simple linear regression analysis was used to understand the impact of these variables on static balance ability. The statistical significance level was set at α = .05.

3 result

The study found a significant positive correlation between CPX VO_2 max and lower leg length. However, no significant correlations were observed with upper leg length and height. Simple linear regression analysis indicated that lower leg length significantly influenced exercise intensity using both the Harvard Step Test and the Queen's College Step Test. As lower leg length increases, exercise intensity using these step tests decreases. The regression equations for the Harvard Step Test and the Queen's College Step Test are Y = 0.935X + 84.88 and Y = 0.836X + 79.05, respectively.

[Table 1] General characteristics of subjects

Variable	N=18
Age(year)	22.17±2.66a
Height(㎝)	173.89±5.41
Weight(㎏)	69.59±5.80
upper leg length(cm)	38.28±3.32
lower leg length(cm)	40.22±3.20

Mean ± SD

[Table 2] Correlation between Exercise Intensity Using CPX VO_2max and Upper Leg Length, Lower Leg Length, and Height

	Height	upper leg length	lower leg length
	173.47± 5.41	38.28± 3.32	40.22± 3.20
CPX VO_2 max	0.376	0.060	0.595**
(p)	0.124	0.814	0.009

Mean±SD, *p<.05, **p<.01

[Table 3] Simple linear regression analysis results of Tibia length on exercise intensity using the Harvard Step Test's pVO_2max

	R2	B	Significance (p)
Constant	0.354	84.88	0.000**
Lower leg length		0.935	0.009**
Regression equation	Y= 0.935 X + 84.88		

Mean±SD, *p<0.05,** p<0.01

[Table 4] Simple linear regression analysis results of Tibia length on exercise intensity using Queen's college step test's pVO_2max.

	R2	B	Significance (p)
Constant	0.300	79.05	0.000**
lower leg length		0.836	0.019*
Regression equation	Y= 0.836 X + 79.05		

Mean±SD, *p<0.05, **p<0.01

4. conclusion

It is evident that methods using a fixed step height to estimate exercise difficulty or VO_2 max are highly influenced by individual body sizes. For individuals with significant differences in body size, it is recommended to use methods that involve adjusting the step height to accommodate these variations. In conclusion, customizing the step height based on individual body size is recommended when estimating exercise difficulty or VO_2 max through stepping exercises. Because step height varies among individuals, it is important to develop new methodologies to estimate cardiorespiratory capacity that are not affected by the step box. This allows for a more personalized and accurate assessment of cardiopulmonary function.

This study has several limitations. It only explored methods utilizing steps to assess the impact of individual body size on exercise load differences, and the sample size of the participants is limited. Future research should address these limitations to conduct more comprehensive studies related to VO_2 max.

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