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EXPLANATION OF VARIANCE IN VO_2max FOR TRAINED AND UNTRAINED MALE SUBJECTS.

B ZHOU[1], M. P. ERNST[1], AND Y. T. WANG[2]

[1]Department of Physical Education and Recreation, California State University Dominguez Hills, Carson, CA;

[2]Department of Physical Therapy, Georgia State University, Atlanta, GA

ABSTRACT

EXPLANATION OF VARIANCE IN VO_2max FOR TRAINED AND UNTRAINED MALE SUBJECTS. **Zhou B, Ernst MP, And Wang YT**. **JEP**online. 2004;7(2):1-5. To identify the variables that best explained the variance in VO_2max for untrained and trained males, ten college students (untrained = UT) and ten collegiate distance runners (trained = TR) were recruited and volunteered to participate in this study. VO_2max, Qmax, and HRmax were measured during a graded exercise test. No differences existed in HRmax and a-vO_2 diffmax between the two groups. TR had the greater values for VO_2max (72.1?6.28 vs. 48.9?5.21 ml/kg/min, $p < 0.01$), Qmax (26.3?1.73 vs. 21.3?1.58 L/min, $p < 0.01$), and SVmax (145.0?7.79 vs. 127.9?14.0 ml/beat, $p < 0.01$). VO_2max was not correlated to Qmax, SVmax, a-vO_2 diffmax, HRmax, and body mass for UT, but positively correlated to Qmax, a-vO_2 diffmax, negatively correlated to HRmax and body mass for TR. Further analysis yielded a model for TR; VO_2max = 1.245 a-vO_2 diffmax + 0.769 Qmax – 0.603 Wt. – 0.0004 ($R = 0.99$, $R^2 = 0.98$, SEE = 0.12, $p < 0.01$). To compare trained with untrained, the larger VO_2max in the TR was due to larger values in Qmax and SVmax. Using the correlation and regression approaches, both the a-vO_2 diffmax and Qmax were critical for VO_2max in TR. According to the model, VO_2max was best predicted by a-vO_2 diffmax, Qmax, and body mass in the TR. Of the three, the a-vO_2 diffmax had greatest contribution to VO_2max.in TR. In addition, the regression model with both trained and untrained subjects demonstrated that VO_2max = – 0.603 Wt. + 0.457 a-vO_2 diffmax ($R = 0.77$, $R^2 = 0.60$, SEE = 0.65, $p < 0.01$), which confirmed that the peripheral factors played a dominant role for the variance of VO_2max in male subjects.

Key words: Acetylene Rebreathing Procedure, Cardiac Output, Stroke Volume, Regression Model

INTRODUCTION

Maximal Oxygen consumption (VO_2max) varies among individuals in a same population, such as trained runners (1,7,8,10,11,22). The variables that are related to the variance in VO_2max within a group of subjects include, but are not limited to, training status, genetic predisposition, body mass, body composition, maximal arteriovenous oxygen content difference (a-vO_2 diffmax), maximal heart rate (HRmax), and maximal stroke volume (SVmax) (2,3,4,6,13,23,25). The purpose of this study was to investigate the variables that best explain the variance in VO_2max for collegiate male runners, with independent variables limited to HRmax, SVmax, a-vO_2 diffmax, maximal cardiac output (Qmax), and body mass.

METHODS

Subjects

Ten male physical education students (UT) and ten male university distance runners (TR) participated in this study. The study was approved by the Institutional Review Boards at Brigham Young University and LDS Hospital (Salt Lake City, Utah). All subjects signed a written informed consent form and were asked to familiarize with the treadmill and the acetylene rebreathing procedure prior to testing.

Cardiac output (Q), stroke volume (SV), and heart rate (HR) measurement

All variables were assessed during a graded exercise test (GXT) as described previously (29). Q was measured at rest and during the last 30 s of each stage of the GXT by using the acetylene rebreathing method initiated by Triebwasser et al. (27) and redeveloped into the computerized rebreathing system by Jensen et al. (14). The estimated coefficient of variation for this technique was 6.8% (14). Test-retest correlation coefficients for resting and maximal values were 0.99 and 0.93 respectively (29). The acetylene rebreathing technique is highly reproducible in determining cardiac output (28). A modification of the equipment and technique was made so that both Q and VO_2 could be measured during the GXT (9). A pneumatic switch kept the bag system closed for the first 2 minutes of each stage during the GXT to allow subjects to breathe room air. After 2 minutes of each stage, subjects were instructed to open the pneumatic valve at end expiration and breathed in and out through a pre-filled mix gas in a bag. The mixture of gas in the bag was 1% acetylene, 9.18% helium, 40% oxygen, and 48.82% nitrogen. This mixture was breathed for eight complete breathes at rest and six breathes during each stage of exercise (29).

An electronic HR monitor was used to record HR at rest and during each stage of exercise while Q was measured. Stroke volume of each subject at rest and during each stage of the GXT was obtained by the equation: $SV = Q / HR$ (15,18,19).

Oxygen consumption (VO_2) measurement

VO_2 was determined using a standard open-circuit system in which expired volumes were measured by a Fleish Pneumotach (Hans Rudolph, Model 3813, Kansas City, MO), and the concentrations of oxygen and carbon dioxide were quantified by a medical gas analyzer (Marquette 1100 Mass Spectrometer) (29). Data from the pneumotachometer and mass spectrometer were transferred to a computer. VO_2 was calculated by the software developed by Consensus Technologies (Salt Lake City, UT). Maximal oxygen consumption was considered to be reached when two of three criteria were satisfied: VO_2 leveling off despite an increase in work rate, heart rate greater than 90% of the age-predicted maximal value (220 – age), and a respiratory exchange ratio (RER) greater than 1.10 (4,12).

The maximal arteriovenous oxygen content difference (a-vO_2 diffmax) was calculated based on the Fick equation: $VO_2max = (HRmax \times SVmax) \times a\text{-}vO_2\ diffmax$ (15).

Statistical analysis

Independent t-tests were used to exam the differences of age, body mass, HRmax, VO_2max, Qmax, SVmax, and a-vO_2 diffmax between the two groups. Partial Correlation was employed to analyze the relationship between VO_2max and independent variables including the body mass, HRmax, Qmax, SVmax, and a-vO_2 diffmax for each group. Stepwise Linear Regression was used to yield a model if the correlation coefficients reach the significant level (24). To be eligible to conduct the multiple regressions, all variable data were standardized to z-scores before the regression procedure was executed. The probability of the F-ratio to enter or remove a variable into or from the regression model was set at p ? 0.05 and ? 0.10 respectively. Statistical significance was set at $p < 0.05$ (26).

RESULTS

There were no differences in age, maximal heart rate (HRmax), and maximal arteriovenous oxygen content difference (a-vO_2 diffmax) between the two groups. TR had greater VO_2max ($p < 0.01$), maximal cardiac output (Qmax) ($p < 0.01$), and maximal stroke volume (SVmax) ($p < 0.01$), but smaller body mass ($p < 0.05$), than that of UT (Table 1).

The correlation coefficients indicated that Qmax, SVmax, HRmax, a-vO_2 diffmax, and body mass were not correlated to the relative term of VO_2max for UT ($p > 0.05$). Whereas, Qmax and a-vO_2 diffmax were positively, HRmax and body mass were negatively correlated to the relative term of VO_2max for TR (Table 2). Further analysis using Stepwise Linear Regression yielded a model for the TR, $VO_2\text{max} = (1.245 * \text{a-}vO_2\text{ diffmax}) + (0.769 * \text{Qmax}) - (0.603 * \text{Wt}) - 0.0004$ ($R = 0.99$, $R^2 = 0.98$, $SEE = 0.12$, ? < 0.01). The model indicated that the variables that best explained the variance in VO_2max for TR were the a-vO_2 diffmax, Qmax, and body mass. Regarding the power of the model, the analysis of the linear regression was also conducted with both groups. The model with both TR and UT subjects showed that $VO_2\text{max} = (-0.603 * \text{Wt}) + (0.457 * \text{a-}vO_2\text{ diffmax})$ ($R = 0.77$, $R^2 = 0.60$, $SEE = 0.65$, $p < 0.01$), which suggested that the peripheral factors were the critical variables to explain the variance in VO_2max.

Table 1. Comparisons of characteristics between male college students and male collegiate distance runners.

Variables	*Students*	*Runners*
Age (years)	**28.1? 7.49**	**25.5? 4.33**
Body Mass (kg)	**76.5? 11.5 ***	**66.8? 3.70**
VO_2max *(L/min)*	**3.58? 0.43**	**4.80? 0.33****
VO_2max *(ml/kg/min)*	**48.9? 5.21**	**72.1? 6.28****
Qmax *(L/min)*	**21.3? 1.58**	**26.3? 1.73****
SVmax *(ml/beat)*	**127.9? 14.0**	**145.0? 7.79****
a-vO_2diffmax *(ml/L)*	**168.7? 22.0**	**183.3? 20.6**
HRmax (beats/min)	**185.8? 8.01**	**186.9? 8.61**

Values are means ? SD. n = 20, ** ? < 0.01, * ? < 0.05.

Table 2. Relationships between maximal oxygen consumption and its related variables in male collegiate distance runners versus male college students.

Variables	*Students*	*Runners*
VO_2max (ml/kg/min) ***Qmax (L/min)***	**-0.349**	**0.993****
VO_2max (ml/kg/min) **a-vO_2 diffmax (ml/L)**	**0.093**	**0.998****
VO_2max (ml/kg/min) ***HRmax (beats/min)***	**0.324**	**-0.898***
VO_2max (ml/kg/min) ***SVmax (ml/beat)***	**0.505**	**0.499**
VO_2max (ml/kg/min) ***Body mass (kg)***	**-0.580**	**-0.994****

Values are r, correlation coefficient. n = 20, ** ? < 0.01, * ? < 0.05.

DISCUSSION

To compare the trained with the untrained, our study had similar results with previous observations (1,4,7,8,22,23), which suggested that the central factors influencing O_2 transport capacity were critical in response to the difference in VO_2max between the TR and UT. The greater value of VO_2max in TR was due to the greater values in the Qmax and SVmax, but not the a-vO_2 diffmax (2,3).

Using the Correlation and Regression approaches in this study, it demonstrated that, both the a-vO_2 diffmax and Qmax were the critical variables that best explained the variance in VO_2max for the TR. As shown in the model, the a-vO_2 diffmax was the most critical variable to explain the variance in VO_2max for TR according to the weights of the variables. This may suggest that muscle O_2 utilization plays a dominant role in VO_2max for the TR (5,16,17,20,21)

Regarding the power of the model, a further analysis using the Stepwise Linear Regression was conducted with both TR and UT subjects. The analysis yielded another model that confirmed that the peripheral factors, body mass and a-vO_2 diffmax, were the critical variables to explain the variance in VO_2max for both trained and untrained male subjects. Nevertheless, we recognize that ideally more subjects per independent variables are needed in multiple regression research. Our results do indicate that further research is needed to better understand the causal factors that contribute to VO_2max in individuals of different training and endurance fitness status.

In summary, the finding of the present study suggested that the a-vO_2 diffmax, Qmax, and body mass were the critical variables that best explained the variance in VO_2max for the TR. Off the three, the a-vO_2 diffmax was the most critical variable to determine VO_2max for the trained collegiate male runners. A further regression analysis with both trained and untrained subjects indicated that the peripheral factors such as the a-vO_2 diffmax and body mass play a dominant role for variance of VO_2max.

Address for corresponance. Ben Zhou, Department of Physical Education and Recreation, California State University Dominguez Hills, 1000 E Victoria Street, Carson, CA 90747, Tel: (310) 243-2223, Fax: (310) 217-6946, E-mail: bzhou@csudh.edu.

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