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EXPLANATION OF VARIANCE IN VO_2max FOR TRAINED AND UNTRAINED FEMALE COLLEGE STUDENTS.

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ABSTRACT

EXPLANATION OF VARIANCE IN VO_2max FOR TRAINED AND UNTRAINED FEMALE COLLEGE STUDENTS. **Zhou B**. **JEP**online 2004;69-74. To follow up our previous study in which the male subjects were investigated, the attempt of the current study was to find out the variables that best explained the variance in VO_2max for the trained and untrained college female students. Ten college female students (untrained = UT) and ten collegiate female 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 (GXT). No differences existed in HRmax, a-$\bar{v}O_2$ diffmax and body weight (Wt) between two groups (p>0.05). TR had the greater values for VO_2max (59.4±4.18 vs. 43.5±3.33 ml/kg/min, p<0.01), Qmax (21.1±2.52 vs. 17.7±2.13 L/min, p<0.01), and SVmax (118.0±13.05 vs. 97.0±11.99 ml/beat, p<0.01). The relative term of VO_2max was not correlated to Qmax, SVmax, a-$\bar{v}O_2$ diffmax, HRmax, and body mass for UT (p>0.05), but VO_2max = 2.49 +2.735 Qmax – 0.987 Wt + 0.344 a-$\bar{v}O_2$ diffmax for TR (R=0.998, R^2=0.996, SEE=0.31, p<0.01). To compare trained with untrained, the larger VO_2max in TR was due to greater values in Qmax and SVmax. The regression model indicated that the Qmax, a-$\bar{v}O_2$ diffmax and body weight were the critical variables that best explained the variance in VO_2max for TR. Of the three, the Qmax was the most critical variable for VO_2max. In addition, the regression model that combined the trained and untrained females demonstrated that VO_2max = 2.605 Qmax – 0.777 Wt. + 0.324 a-$\bar{v}O_2$ diffmax – 3.678 (R=0.998, R^2=0.995, SEE=0.68, p<0.01). It confirmed that the central factor, Qmax, was the most critical variable to determine VO_2max, which might play a dominant role for variance of VO_2max in the female college students.

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 the trained runners or untrained individuals (1,8,9,11,12,23). The variables that can be used to explain the variance in VO_2max include, but not limited to, training status, genetic predisposition, body mass, body composition, maximal arteriovenous oxygen content difference (a-$\bar{v}O_2$ diffmax), maximal heart rate (HRmax), maximal cardiac output (Qmax), and maximal stroke volume (SVmax) (2,3,4,7,14,24,26). To follow up our previous study (31) in which the male subjects were investigated, the attempt of the current study was to find out the variables that best explain the variance in VO_2max for the trained and untrained college female students, and the gender difference in the variables associated with the variance in VO_2max. The independent variables were HRmax, SVmax, a-$\bar{v}O_2$ diffmax, Qmax, and body mass.

METHODS

Subjects

Ten female physical education students (UT) and ten female 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.

Oxygen consumption (VO_2) measurement

All variables were assessed during a graded exercise test (GXT) as described previously (30). VO_2 was tested 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). 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, 13).

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

Q was measured using the acetylene rebreathing method initiated by Triebwasser et al. (28) and redeveloped into the computerized rebreathing system by Jensen et al. (15). A modification of the equipment and technique was made so that both Q and VO_2 could be measured during GXT (10). A pneumatic switch kept the bag system closed for the first 2 min of each stage during GXT to allow subjects to breathe room air. After 2 minutes of each stage, subjects were instructed to open the pneumatic valve at the end of expiration and then breathed in and out through a pre-filled mixed 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 re-breathed for eight complete breathes at rest and six breathes during each stage of exercise (30). Q was measured at rest and during the last 30 s of each stage of the GXT.

The changes in concentration of acetylene and helium during rebreathing were measured by a mass spectrometer and digitized at 100 Hz by a computer for storage and processing of the data. Typically, the concentration of helium did not change after the second breath, but the concentration of acetylene continued to decline after each sequential expiration due to the uptake of acetylene by the capillary blood. Thus, Q was calculated from the exponential disappearance rate of acetylene relative to helium during the rebreathing procedure. The slope of the acetylene concentration curve relative to the helium concentration curve is proportional to the rate of blood flow through the lungs or Q. Blood flow, in turn, depends on the work rate; thus the steeper the $[C_2H_2]$ slope, the greater the Q as calculated by the equations used by Cander and Forster (5). This technique is highly reproducible in determining cardiac output (29). The estimated coefficient of variation for this technique was 6.8 % (15). Test-retest correlation coefficients for resting and maximal values were 0.99 and 0.93 respectively (30).

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: $SV = Q \div HR$ (16,19,20).

The maximal arteriovenous oxygen content difference ($a\text{-}\bar{v}O_2$ diffmax) was calculated based on the Fick equation: VO_2max = (HRmax * SVmax) * $a\text{-}\bar{v}O_2$ diffmax (16).

Statistical Analyses

ANOVA were used to exam the differences of age, body mass, HRmax, VO_2max, Qmax, SVmax, and $a\text{-}\bar{v}O_2$ 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 $a\text{-}\bar{v}O_2$ diffmax. Stepwise Linear Regression was used to yield a model if the correlation coefficients reached the significant level (25). The probability of the F-ratio to enter or remove a variable into or from the regression model was set at $p \leq 0.05$ and ≥ 0.10 respectively. The independence of predictor variables was estimated by the Collinearity Statistics including the tolerance statistic and the variance inflation factor. Statistical significance was set at $p<0.05$ (27).

RESULTS

There were no differences in maximal heart rate (HRmax), maximal arteriovenous oxygen content difference ($a\text{-}\bar{v}O_2$ diffmax) and body mass (Wt.) between the two groups ($p>0.05$). RT had greater VO_2max ($p<0.01$), maximal cardiac output (Qmax) ($p<0.01$), and maximal stroke volume (SVmax) ($p<0.01$), but younger age ($p<0.01$) to compare with the UT (Table 1).

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

Variables	*Students*	*Runners*
Age (years)	**22.6±1.58**	**19.9±1.79****
Body Mass (kg)	**62.8±10.87**	**56.8±4.38**
VO_2max *(L/min)*	**2.73±0.40**	**3.38±0.42****
VO_2max *(ml/kg/min)*	**43.5±3.33**	**59.4±4.18****
Qmax *(L/min)*	**17.7±2.13**	**21.1±2.52****
SVmax *(ml/beat)*	**97.0±11.99**	**118.0±13.05****
$a\text{-}\bar{v}O_2$diffmax *(ml/L)*	**153.7±12.45**	**160.6±11.19**
HRmax (beats/min)	**188.2±4.76**	**187.0±6.51**

Values are means± SD. n = 20, ** ρ<0.01.

Table 2. Relationships between maximal oxygen consumption and related variables in female college students and distance runners.

Variables	*Students*	*Runners*
VO_2max (ml/kg/min) ***Qmax (L/min)***	**-0.312**	**0.659***
VO_2max (ml/kg/min) **$a\text{-}\bar{v}O_2$ diffmax (ml/L)**	**0.136**	**0.382**
VO_2max (ml/kg/min) ***HRmax (beats/min)***	**0.165**	**-0.247**
VO_2max (ml/kg/min) ***SVmax (ml/beat)***	**-0.394**	**0.546***
VO_2max (ml/kg/min) ***Body mass (kg)***	**-0.573***	**0.429**

r=correlation coefficient; n=20, * ρ<0.05.

The correlation coefficients indicated that Qmax, SVmax, HRmax, and $a\text{-}\bar{v}O_2$ diffmax, were not correlated to the relative term of VO_2max for UT ($p>0.05$) except body mass that was negatively correlated to VO_2max ($p<0.05$). Whereas, Qmax and SVmax were positively correlated to the relative term of VO_2max for TR ($p<0.05$) (Table 2). Further analysis using Stepwise Linear Regression yielded a model for TR, which was VO_2max = 2.49 +2.735 Qmax – 0.987 Wt + 0.344 $a\text{-}\bar{v}O_2$ diffmax. (R=0.998, R^2=0.996, SEE=0.31, $p<0.01$). The model indicated that the variables that best explained the variance in VO_2max for TR were the Qmax, body mass, and $a\text{-}\bar{v}O_2$ diffmax. VO_2max was best predicted by Qmax. Regarding the power of the model, a further analysis was conducted with both TR and UT subjects. The analysis with a larger sample yielded a similar model, which was VO_2max = 2.605 Qmax – 0.777 Wt. + 0.324 $a\text{-}\bar{v}O_2$ diffmax – 3.678 (R=0.998, R^2=0.995, SEE=0.68, $p<0.01$). This confirmed that the central factor, Qmax, best explained the variance in VO_2max to compare with peripheral factors, body weight and $a\text{-}\bar{v}O_2$ diffmax, for both trained and untrained female college students.

DISCUSSION

To compare the trained with the untrained female students, our study had similar results with previous observations (1,4,8,9,23,24,30,31), which suggested that the central factors were critical in response to the difference in VO_2max. The greater value of VO_2max in TR was due to the greater values in the Qmax and SVmax, but not a-$\bar{v}O_2$ diffmax (2,3).

The TR's model demonstrated that the variables that best explained the variance in VO_2max for trained college females were Qmax, a-$\bar{v}O_2$ diffmax, and body mass. Of the three, the Qmax was most critical according to the weights of the variables. This may suggest that the central factor related to the capacity of O_2 transport might play a dominant role for the variance in VO_2max for female TR (1,2,3,4,8,9). To compare with our previous study, it was interesting to find out that there was a gender difference in the most critical variable to explain the variance in VO_2max. In the previous study, we found that a-vO_2 diffmax was the most critical variable to determine VO_2max, which suggested that muscle O_2 utilization might play a dominant role in VO_2max for the male TR (6,17,18,21,22,31).

From our study, it is unclear whether this gender difference is due to training status, body composition, a consequence of genetics, or a combination of the influences. Because this was a cross-sectional study with a limitation, we could not quantify the differences in training and body composition. Regardless of whether the differences are due to genetics, training, or body composition, the mechanisms responsible for the gender difference in the most critical variable that explain the variance in VO_2max for the female or male TR are not apparent from the present study.

Similarly as the previous study, the linear regression analysis was conducted with both TR and UT subjects in regarding the predicted power of the model in the current study. The analysis yielded another similar model that confirmed that the Qmax, body mass, and a-vO_2 diffmax were the variables that best explain the variance in VO_2max, and the Qmax was the most critical one. This analysis suggested that more subjects per independent variables were needed in multiple regression approach. Our results do warrant that further research is needed to better understand the factors in response to the variance of VO_2max in individuals who differ from gender, training, and endurance fitness status.

In summary, the finding of the present study suggested that the Qmax, body mass, and a-$\bar{v}O_2$ diffmax, were the variables that best explained the variance in VO_2max for the trained and untrained female college students. Off the three, the Qmax was the most critical variable to determine VO_2max, which might play a dominant role for variance of VO_2max in the female college students.

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