A Preliminary Study of Ventilatory Responses during Maximal Exercise in Healthy Thais

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Background and objectives: Cardiopulmonary exercise testing (CPET) evaluates the ability of cardiovascular and respiratory systems in maximal exercise. It is used for the diagnosis and prognosis of cardiovascular and pulmonary disease patients. Assessment of the breathing pattern at maximal exercise in patients is limited because the range of ventilatory responses at maximal exercise in healthy Thai is unknown. This study aimed to evaluate the ventilatory response to maximal exercise and to compare the differences in these responses between genders.

Methods: The maximal cardiopulmonary responses were performed in 30 healthy Thai subjects (15 males; aged 27±5 years and 15 females; aged 27±3 years) who underwent the CPET using a ramp protocol until reaching symptom limitation.

Results: All subjects had normal ranges of clinical characteristics except that weight and height in males were higher than in females (p<0.001). Maximal work rate (WRmax), maximal voluntary ventilation (MVV), maximal expired total ventilation (VE max) and maximal tidal volume (VTmax) in males were significantly higher than in females (205 vs 111 W, 149.5 vs 107.2 L/min, 96.1 vs 54.8 L/min; p<0.001 and 2.0 vs 1.3 L; p<0.01).

Nevertheless, the breathing reserve was not significantly different between genders.
Introduction

It has been well known that the CPET is generally used to evaluate responses of various organs including cardiovascular, pulmonary, circulatory, neural and musculoskeletal systems to sub-maximal and maximal exercise. In addition, it is being used for diagnosis and prognosis patients with cardiovascular and pulmonary diseases. These responses are then compared to previously established “normal” values in order that judgment regarding limitation of exercise by cardiac, respiratory, or other factors could be offered. Ventilatory responses to exercise up to a maximal level have been found to be useful in assessing the presence and severity of both heart and lung diseases. Most studies of “normal” responses have focused on the prediction of power and oxygen uptake at maximal exercise, as well as the ventilatory and heart rate responses to exercise. The general pattern of the expected changes in ventilatory responses, namely $V_{E}$, VT and Rf are well known, but the range of individual responses that may occur at maximal exercise have not been studied thoroughly in Thai subjects. This lack of information limits the physicians to draw conclusions from ventilatory data at maximal exercise.

$V_{E}$ max is similar for leg cycling, treadmill walking and running but is less for arm cycling because the maximal metabolic rate is lower when smaller muscle groups are used. Moreover, several studies have reported $V_{E}$ max in males being higher than in females. The difference between the measured maximal voluntary ventilation (MVV) and $V_{E}$ max during exercise is used as a measure of the ventilatory or breathing reserve (BR). The BR is usually reduced in patients with moderate to severe restrictive or obstructive lung disease. A comparison between males and females reveals that males have higher BR than females. On the contrary, Mohammad and coworkers found that BR was not different between genders.

Therefore, the aims of this study were to evaluate the ventilatory responses to maximal exercise in healthy Thais and to compare differences in those responses between genders.

Methods

Study design and Population

In this study, the design was analytical and descriptive. The subjects in the present study were recruited from the healthy population in the Khon Kaen province of Thailand. Thirty of them (15 males and 15 females) aged between 20-40 years were participated. Number of subjects was calculated according to a previous study done by Fairbarn et al. They were
healthy with BMI between 18.5 to 24.9 kg/m\(^2\). Those having history of regular alcohol drinking, smoking, cardiovascular, neuromuscular, arthritic, pulmonary diseases, severe microvascular diseases, diabetes mellitus, hypertension or other debilitating diseases were not included in this study. Physical examination and health questionnaires regarding health were obtained. Additionally, a written informed consent was obtained from all subjects after a full explanation of the procedures and risks. This study was approved by the Human Research Ethics Committee, Khon Kaen University (HE561453).

**Clinical and Anthropometric Characteristics**

Height and weight were measured for each participant according to the WHO guidelines\(^ {21} \). Participants wore light clothing without shoes. Weight was determined using a digital scale to the nearest tenth. Height was measured standing with feet together and arms relaxed at the sides. The BMI was calculated as weight (kg) divided by height (m\(^2\)).

**Cardiopulmonary Exercise Testing**

Each subject performed an incremental exercise test on a treadmill (Stationary CPET, Cosmed, Quark CPET). The protocol for CPET was calculated based on age, weight, height, gender and WR according to the formula of Porszasz and colleagues\(^ {22} \). Furthermore, they had to spend a few hours to familiarize with equipments and the CPET protocol in advance. The protocol included a 2-min rest period in the standing position on a treadmill, 3-min warm-up by beginning to walk at 0.9 km/h, followed by increases in speed rate and inclination every 1 min until exhaustion and, finally, 3-min recovery at a speed of 0.9 km/h. All tests were performed in room air (25°C) according to current guidelines for exercise testing, with continuous monitoring of ECG, blood pressure and oxygen saturation\(^ {2} \). The test could be interrupted either by the subjects, because of dyspnea, leg fatigue or disabling symptoms, or by the investigator, for safety reasons.

The criteria for reaching maximal exercise were three or more of the followings: reaching a plateau in \(\text{VO}_2\), maximum heart rate (HR) more than 90% of the predicted value for that age (220-age), RER more than 1.15 (although RER values are not exactly indicative of maximum capacity), subject requested stopping because of severe fatigue or dyspnea, and reaching 18 points or more of the RPE scales (Borg’s scales)\(^ {23} \).

**Statistical Analysis**

Data were expressed as mean(SD). The Stata 10 Statistical software was used to perform the statistical analysis. Unpaired t-test was used to compare differences in characteristics, lung function and all parameters between male and female. Two-sample Wilcoxon rank-sum (Mann-Whitney) test was used when data deviate from normality. A value of \(p<0.05\) was taken to be the threshold of statistical significance.

**Results**

The average age was 27 ± 5 in females and 27 ± 3 years in males. Weight and height were significantly higher in males comparing to those of females (64.6 ± 8 vs. 53.0 ± 5.5 kg. and 174.0 ± 6.6 vs. 159.2 ± 6.6 cm.; \(p<0.001\)). Nonetheless, BMI were comparable (21.3 ± 2.0 vs. 20.9 ± 2.0 kg/m\(^2\)). SBP, DBP, MAP, HR and Rf in males and females were within normal ranges (Data not shown).

We observed normal pulmonary function expressed as %predicted in both males and females. Furthermore, there were no significant differences in pulmonary function between genders (Table 1).

Table 2 and Fig. 1 summarize ventilatory responses during the cardiopulmonary exercise testing. WRmax was 91.5% predicted in males and slightly lower, e.g. 84.7%
predicted in females (p<0.001). Besides, VE and VT but not RF at the AT and at maximal exercise of males were higher than those of females, e.g. VE 1.5 and 1.75 folds; VT 1.7 and 1.5 folds (p<0.001) (Table 2). MVV in males were significantly 1.39 folds higher than in females (p<0.001). The mean BR of males and females were similar, 53.4 and 52.4 L/min. There was no difference in BR between male and female (Table 2). The WRmax was significantly higher in males than in females (p<0.001) (Fig. 1A).

Fig. 1B, 1C and 1D depict the relationships between ventilatory responses and WR in both genders. It was found that RF, VT and VE has positive correlations with WR (males, r = 0.8138, r = 0.6745 and r = 0.8524, p<0.001; females, r = 0.6230, r = 0.7196 and r = 0.8647; p<0.001). Similarly, Fig. 1E, 1F and 1G show positive relationships between RF, VT and VE to VO2 in both genders (males, r = 0.7508, r = 0.8696 and r = 0.9358, p<0.001; females, r = 0.5551, r = 0.8222 and r = 0.8945; p<0.001).

Besides, at a given WR, RF (30 vs 22 /min) and VE (28 vs 23 L/min) responses to WR up to 150 watts in females were greater while VT (0.9 vs 1.2 L) lower than those of males (p<0.001).

Discussion

This study presents preliminary normative values for ventilatory responses to incremental exercise testing on a treadmill. The pulmonary function (Table 1) of our population sample was within the reported normal ranges, suggesting that the samples used in the present study are healthy population.

To our knowledge, the present study is the first to report higher WRmax, max, VTmax and MVV in males compared to females, and ventilatory responses were closely related to the amount of exercise (WR and VO2) in healthy Thai population. Apparently, RF and VE responses to WR in females were greater but VT lower than those of males. In addition, this study observed no significant difference in BR between genders.

In both genders, WRmax were similar to estimates of the Chinese but approximately 9% (males) and 15% (females) less than those of Caucasians17, 22. Previous studies have demonstrated that the WRmax of exercise depend on gender, age, body size and ethnicity10, 23-25. Thai population differs from the Caucasians, in their body structure, nutrition, physical activity, environment, and socioeconomic factors23. Thus, the difference in WRmax between Thais and Caucasians could be due to differences in those factors mentioned above.

The previous study suggests that VTmax could be used to speculate the ventilatory capacity and other resting pulmonary function measurements. Obviously, the VTmax depend on height, age, and gender18. The findings that VTmax and VE max in males were higher than in females are in agreement with several studies reported earlier3, 5, 16, 17. Several studies have demonstrated that age, gender, body size, physical activities, and exercise mode influence ventilatory efficiency6, 16, 22. It is likely that a body size, lung volumes, muscle mass and physical activities are attributable to higher VTmax and VE max in males3, 5, 16, 17.

The values for assessing VE at the end of exercise have been suggested. The first method is to calculate “breathing reserve” at the end of exercise (BR = MVV - VE max). Any values less than 11 L/min are considered to be abnormal26. We used the same method to calculate the BR in our population. Regardless of genders, all subjects had BR of higher than 11 L/min at the end of exercise. The observation that no influence of genders on BR is consistent with studies in Iranian3. In their study there were 20 males and 14 females recruited. On the contrary, studies in larger population by Ong et al.17 and Blackie et al.5 have demonstrated that the BR at the end of exercise in males was higher than that of females. We suggest that our study had small number of sample population. A further study in a greater sample size is crucial so that a concrete conclusion could be made.

MVV provides an estimate of the ventilatory reserves available to meet the physiologic demands of exercise27. Wasserman and colleagues have recommended that the indirect MVV (FEV1 x 40) is used in calculating BR18. Normal values of MVV depend on gender, lung size, height, age and race28. This is consistent with our study
Figure 1: A: Relationship between oxygen uptake ($\text{VO}_2$) and work rate (WR). B-D: Relationships between respiratory frequency (Rf), tidal volume (VT), expired total ventilation (VE) and WR. E-G: Relationships between respiratory frequency (Rf), tidal volume (VT), expired total ventilation (VE) and $\text{VO}_2$. 
which found that MVV in males were higher than in females. Similarly, former studies have shown that MVV in males was greater than in females25, 27. Hey et al.13 have recommended that VT related to VE is used to analyze the breathing pattern. We found that at low exercise intensity, the increase in VE is accomplished primarily by an increase VT whereas at high exercise intensity further increases in VE are accomplished primarily by increasing Rf. This is in line with the study of Wasserman et al.18.

We demonstrate the positive correlations of ventilatory responses and intensity of exercise in our study. Our finding that increases in ventilatory responses were linearly correlated with the increasing WR and VO2 in both males and females are consistent with studies reported previously5, 6. It is reasonable that ventilation should be more closely related to WR and VO2 as ventilation is primarily driven by metabolic needs5. We also observed that Rf and VE responses to WR up to 150 watts in females were relatively greater while VT was lower than those of males. The mechanisms responsible for this observation need to be explored in the future.

Conclusions

The present study derives ventilatory responses for CPET in healthy Thai population. Thai males have ventilatory responses to incremental exercise higher than those of females being consistent with other ethnics; Chinese, Brazil, British and Iranian. A further study in a large population is required before normal values for CPET is established.

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References


