Changes in cardiopulmonary function according to posture during recovery after maximal exercise

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Abstract. [Purpose] This study was undertaken to measure cardiopulmonary function according to body position during the recovery period after maximal exercise and to identify an effective position after high-intensity exercise. [Subjects and Methods] Fifteen male university students in their twenties participated in the study. The subjects were randomly assigned to the supine position, the sitting position, or the trunk forward leaning position during the recovery period following maximal exercise. Oxygen uptake, minute ventilation volume, respiration rate, and heart rate according to posture were measured in a stable state, at maximal exercise loading, and at 1, 3, and 5 minutes after maximal exercise. [Results] Changes of cardiopulmonary function according to posture during the recovery period after maximal exercise showed that minute ventilation volume was smaller in the trunk forward leaning position than in the sitting or supine positions, and oxygen uptake also declined. [Conclusion] The trunk forward leaning position has a more positive effect on pulmonary ventilation after high-intensity exercise.

Key words: Cardiopulmonary function, Trunk forward leaning position, Maximal exercise

INTRODUCTION

The graded exercise test is a non-invasive procedure that can be performed easily for the diagnosis of cardiopulmonary diseases. The test has been used extensively to evaluate the cardiopulmonary functions of patients with cardiopulmonary disease and healthy individuals and to analyze risk factors, and is also used to assess exercise performance before prescribing exercise or to evaluate exercise safety before conducting high-intensity exercise programs1, 2. The physiological parameters involved in cardiopulmonary function in terms of exercise physiology include maximal oxygen uptake, pulmonary ventilation, oxygen-carrying and carbon dioxide-carrying capacities of blood, and cardiac output3. Maximal oxygen uptake is defined as maximal ability to consume oxygen per unit time, and is used as an objective assessment tool for cardiovascular endurance assessment4, though it is most commonly to provide data for assessing maximal exercise performance and cardiopulmonary function through aerobic processes. Changes in body posture affect cardiopulmonary function, and the effect of gravity depends on the position of the human body5, 6. Moreover, it has been reported that rapid changes in cardiopulmonary function occur during the initial recovery period after maximal exercise7–9. Despite reports that cardiopulmonary function is significantly affected by body position, no established guidelines have been issued regarding the stationary position adopted for the exercise test or regarding recovery period after high-intensity exercise. Thus, this study was undertaken to measure cardiopulmonary function according to body position during the recovery period after maximal exercise and to identify an effective position after high-intensity exercise.

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SUBJECTS AND METHODS

The subjects of this study were 15 male university students in their twenties attending a university located in Daegu Metropolitan City, and who voluntarily agreed to participate in the study. These 15 study subjects had no evidence of any orthopedic disease, visual impairment, visual field defect, a congenital thoracic deformity, rib fracture or any pulmonary, renal, endocrine system, orthopedic or rheumatic disease that may have prevented proper functioning of the respiratory system. Furthermore, they had no history of thoracic or abdominal surgery, and did not have a cardiovascular disease, such as, arrhythmia. All subjects meeting the inclusion criteria were given verbal and written information on the purpose of this study and provided written informed consent. In addition, the human rights of subjects were protected. After subjects had been provided with an explanation about the intent and purpose of this study, those who signed a research agreement were randomly assigned to the supine position, the sitting position, or the trunk forward leaning position during the recovery period following maximal exercise. The anteversion angle of the trunk forward leaning position was set at 60°. In order to reduce the effect of fatigue, general characteristics were examined and body mass indices (BMI) were measured after they had rested for one day. The Bruce protocol was used for the graded exercise test, and the setting criteria of the maximal exercise were considered as follows: (1) maximal heart rates of the subjects reached over 90% of age-predicted heart rates, (2) the Borg ratings of perceived exertion of the subjects were above 17. The exercise test was conducted in a laboratory at 18 ± 1 °C and RH 50 ± 5%, after a 4 to 5 hours fast and a 30 minute stabilization period. Oxygen uptake, minute ventilation volume, respiration rate, and heart rate according to posture were measured in a stable state, at maximal exercise loading, and at 1, 3, and 5 minutes after maximal exercise, and the means and standard deviations of measured values were calculated. In order to prevent fatigue caused by exercise during the experiment from affecting measured values in other positions, measurements were made over 3 days, and each item was remeasured by the same measurer. The mean values were then calculated for statistical analysis, which was conducted using SPSS Ver. 20.0 for Windows. One-way repeated measures ANOVA was used to determine the changes between measurement points, and to determine the significance of differences in measured values in different postures at each time point. The LSD method was used as a post hoc test. Statistical significance was accepted for p values<0.05.

RESULTS

Demographic characteristics of the subjects were shown in Table 1. The oxygen uptake according to body position during recovery after maximal exercise was observed to decrease in the order trunk forward leaning > sitting > supine, but differences between postures were not statistically significant (Table 2). Minute ventilation volume decreased in the order

### Table 1. General characteristics of the subjects

| Subjects | Age (years) | Height (cm) | Weight (kg) | BMI (kg/m²) |
|----------|-------------|-------------|-------------|-------------|
| n=15     | 24.6 ± 1.0  | 174.6 ± 5.7 | 78.5 ± 10.3 | 20.5 ± 2.3  |

BMI: body mass index

### Table 2. Change in oxygen uptake according to positions each time (ml/min)

|        | Rest | ME    | R1     | R3     | R5     |
|--------|------|-------|--------|--------|--------|
| Supine | 485.9 ± 103.9 | 2,691.5 ± 366.6 | 1,793.2 ± 493.2 | 756.0 ± 248.9 | 542.7 ± 90.5 |
| Sitting | 454.5 ± 81.2 | 2,730.8 ± 472.8 | 1,502.6 ± 380.4 | 655.8 ± 162.3 | 525.9 ± 121.5 |
| TFL    | 466.7 ± 88.8* | 2,484.0 ± 517.7* | 1,275.5 ± 526.7* | 635.5 ± 115.5* | 518.9 ± 96.1* |

TFL: trunk forward leaning; ME: maximal exercise; R1: at 1-min recovery period; R3: at 3-min recovery period; R5: at 5-min recovery period

Statistically significant (p<0.05).

### Table 3. Changes in minute ventilation volume according to positions each time (l/min)

|        | Rest | ME    | R1     | R3     | R5     |
|--------|------|-------|--------|--------|--------|
| Supine | 15.0 ± 3.5  | 99.7 ± 17.4 | 73.9 ± 19.7 | 45.6 ± 16.7 | 32.4 ± 13.5* |
| Sitting | 13.7 ± 4.3  | 100.5 ± 21.8 | 68.5 ± 18.2 | 42.0 ± 10.6 | 29.9 ± 7.0* |
| TFL    | 13.4 ± 2.7* | 89.8 ± 14.8* | 55.0 ± 13.5* | 32.3 ± 9.0* | 20.0 ± 2.8* |

TFL: trunk forward leaning; ME: maximal exercise; R1: at 1-min recovery period; R3: at 3-min recovery period; R5: at 5-min recovery period

Statistically significant (p<0.05).
trunk forward leaning > sitting > supine, and was significantly lower in the trunk forward leaning posture than in the sitting or supine posture at the 5-minute time point during the recovery period (Table 3). No significant difference in respiratory rate according to body position was observed during the recovery period after maximal exercise (Table 4), and similarly no significant difference was observed in heart rate according to posture, but significant changes in heart rate were observed with respect to time in each posture (Table 5).

**DISCUSSION**

The purpose of this study was to propose a body posture for the recovery period after exercise to improve exercise performance by investigating changes in cardiopulmonary function according to posture during the recovery period following maximal exercise. In this study, analysis showed that minute ventilation volume and oxygen uptake decreased in the trunk forward leaning posture during the recovery period. In particular, a significant decrease in minute ventilation volume was observed at the 5-minute time point during the recovery period after maximal exercise. These results suggest that the trunk forward leaning posture improves ventilatory capacity during the recovery period after maximal exercise, and thus, enables rapid recovery of the respiratory system after high-intensity exercise\(^{10, 11}\). Previous studies have also been conducted on the relation between pulmonary function and posture. Bullock stated that when a person lies in the supine position blood flow in the pulmonary circulation is increased, and that this decreases the volume of gas inhaled into the thoracic cavity and contents of the abdomen pressurize the diaphragm, which reduces inhalation and results in reduced pulmonary function\(^{12}\). Takeshi et al. reported that measurements of respiration according to activity of the rectus abdominis showed that since abdominal contents pressurized the diaphragm in the supine posture, lung function was significantly better in the sitting than in the supine posture\(^{13}\). In the present study, no significant differences in oxygen uptake were observed in different postures when measurements were made in a stable state, at the point of maximal exercise loading, or at 1, 3, and 5 minutes into the recovery period after maximal exercise. However, during the recovery period, oxygen uptake decreased in the order trunk forward leaning > sitting > supine posture, and the highest oxygen uptake was observed in the supine posture, as has been shown previously\(^{14}\). The main limitation of this study is that since 15 students in their twenties were enrolled, caution should be exercised when generalizing our results. Furthermore, personal dietary habits, nutrition, and genetic characteristics of subjects were not taken into account, and although measures were taken to minimize psychological agitation before the experiment, no formal psychological treatment was applied to evaluate the effects of psychological state. Finally, although personal exercise during the experimental period was controlled, individual exercise ability was not considered. Taken together, our results about changes of cardiopulmonary function according to posture during the recovery period after maximal exercise showed that minute ventilation volume was smaller in the trunk forward leaning position than in the sitting or supine positions, and oxygen uptake also declined, though not significantly. Therefore, we conclude the trunk forward leaning position has a more positive effect on pulmonary ventilation after high-intensity exercise. By applying this position, patients with ventilatory difficulties can quickly restore the cardiopulmonary function after trainings or exercises to improve their ventilatory capacity.

In order to perform various exercise tests or help to restore the efficiency of cardiopulmonary function to a stable state quickly after intense exercise by applying this position, further studies are required of various interventions and on patients with ventilatory difficulties.

### Table 4. Changes in respiratory rate according to positions each time (bpm)

|        | Rest | ME     | R1   | R3   | R5   |
|--------|------|--------|------|------|------|
| Supine | 19.0 ± 4.3 | 44.6 ± 8.9 | 36.9 ± 12.0 | 27.5 ± 4.6 | 25.7 ± 3.4 |
| Sitting | 18.6 ± 2.4 | 41.3 ± 6.2 | 31.5 ± 7.1 | 28.5 ± 4.2 | 26.1 ± 5.2 |
| TFL    | 18.2 ± 3.1* | 40.4 ± 5.5* | 33.5 ± 10.0* | 28.5 ± 4.5* | 25.4 ± 3.7* |

TFL: trunk forward leaning; ME: maximal exercise; R1: at 1-min recovery period; R3: at 3-min recovery period; R5: at 5-min recovery period

Statistically significant (p<0.05).

### Table 5. Changes in heart rate according to positions each time (bpm)

|        | Rest | ME     | R1   | R3   | R5   |
|--------|------|--------|------|------|------|
| Supine | 106.5 ± 15.8 | 170.7 ± 7.0 | 153.7 ± 10.5 | 130.8 ± 7.7 | 122.5 ± 7.3 |
| Sitting | 94.9 ± 11.4 | 171.4 ± 9.7 | 143.8 ± 16.3 | 126.4 ± 9.4 | 117.7 ± 8.0 |
| TFL    | 99.7 ± 13.1* | 171.3 ± 6.9* | 145.9 ± 12.2* | 128.4 ± 8.9* | 122.5 ± 9.4* |

TFL: trunk forward leaning; ME: maximal exercise; R1: at 1-min recovery period; R3: at 3-min recovery period; R5: at 5-min recovery period

Statistically significant (p<0.05).
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