Effects of Posture on Cardiorespiratory Responses during Mild Exercise

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Abstract. In order to determine the effect of exercise posture on the cardiovascular and respiratory systems during mild exercise, nine healthy young males participated in this study. Cycle exercise was performed at 50 W and 150 W in both sitting and supine postures. The relative work intensity was on average 25%VO2 max for 50 W and 50%VO2 max for 150 W. Cardiac output and stroke volume were larger in the supine than in the sitting posture. The lower arteriovenous oxygen difference in the supine posture indicated a relative ineffectiveness of oxygen supply by the blood flow in the exercising muscles. Blood pressure and total peripheral resistance posture were lower in the supine than in the sitting posture, despite lower perfusion pressure in the exercising muscles, suggesting the relief of sympathetic nervous activity by the loading of arterial and cardiopulmonary baroreceptors. Heart rate was higher in the supine posture, suggesting a contribution from the cardiac depressor reflex in mild exercise. We concluded that despite the absence of metaboreflex during mild exercise, the cardiorespiratory responses in the different postures were at least apparently similar to those during moderate and heavy exercises.

Key words: Cardiac output, Oxygen uptake, Postural change.

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INTRODUCTION

Work load and exercise posture are of importance to physical therapy. Appropriate knowledge of cardiorespiratory responses during exercise in different postures is a basic requirement for deciding whether supine or sitting postures should be adopted. Our previous study1) showed exercise posture did not affect oxygen uptake during incremental exercise below 50% of maximal oxygen uptake (50%VO2 max), although beyond that level oxygen uptake was significantly larger in the sitting posture than in the supine posture. The effect of posture on other cardiorespiratory variables, such as cardiac output, however, remained to be clarified.

The great impact of muscle pump as a “second heart” on the circulatory system during exercise is well recognized2). Cardiac output and stroke volume are influenced not only by cardiac pump but also to a large extent by muscle pump. In the supine position, compared to sitting one, the filling pressure to the muscle pump decreases, although that to the cardiac pump increases. In moderate and heavy exercise cardiac output has been reported to be larger in the supine position than in sitting position3), however, mild exercise may be different from exercise of higher intensity because of the absence of metaboreflex, which predominantly regulates the cardiorespiratory system during moderate and heavy exercises4).
Most physical therapy is within the range of mild exercise, and although many research has been conducted on the effects of posture during exercise\textsuperscript{3,5}, research on mild exercise, below 50%VO\textsubscript{2}max, is fairly rare. The purpose of the present study is therefore to determine the effect of exercise posture on the cardiovascular and respiratory systems during mild exercise.

SUBJECTS AND METHODS

Subjects
Nine healthy males (age: 24.8 ± 3.5 yrs; mean ± SD) participated in this study after giving their written informed consent. The study protocol followed the standards of the Ethics Committee of the University of Tokyo.

Posture and exercise
All the measurements were made on a special bicycle ergometer (Ergo SSR, TS Health Systems, Tokyo, Japan), which has a seat with a back rest. In the sitting position, the back rest was set vertical, and the legs were thrown down forward. In the supine position, the back rest and the legs were reclined horizontally.

The resting measurements were made in both the sitting and supine positions after at least for five minutes in each position. After the resting measurements, the subjects began submaximal exercise in the sitting position at 50 watts (W) of work load and 60 rpm of cycling frequency. After five minutes, the posture was changed to the supine. After supine exercise for another five minutes, the posture was returned to the sitting position and the work load was changed to 150 W, and the same postural changes were repeated.

Maximal oxygen uptake (VO\textsubscript{2}max) was determined in the sitting posture by incremental work load protocol (25 W/min from 150 W) immediately after the submaximal exercise. All-out was determined when rated perceived exertion\textsuperscript{6} (RPE) reached 19 or above, or if HR exceeded the level of 220 - age (yrs). VO\textsubscript{2}max was decided as the peak value of oxygen uptake reached during the exercise test. The testing protocol followed the procedure of the American College of Sports Medicine\textsuperscript{7}.

Measurements
Respiratory fractions of oxygen and carbon dioxide were determined by a mass spectrometer (WSMR-1400, Westron, Chiba, Japan), and expiratory flow was measured breath-by-breath by a pneumotachometer (PNEUMOTACHO, Westron). Online determinations of oxygen uptake, carbon dioxide elimination, respiratory quotient, and ventilatory volume were performed through an interface unit (WLCS-5700MR), described by Nishi\textsuperscript{8}, and a personal computer (PC-9800, NEC, Tokyo, Japan). The heart rate (HR) was calculated from electrocardiogram recordings from chest electrodes which were transmitted by a telemetric system (ECO-10, Fukuda Denshi, Tokyo, Japan), and blood pressure was measured by a finger cuff method\textsuperscript{9} using Finapres (Ohmeda, CO, USA) at the level of the 4th intercostal space in the sitting posture, or in the center of the chest in the supine posture. The cardiac output was determined by an acetylene-argon rebreathing method\textsuperscript{10} with modified calculation procedures\textsuperscript{11} using a mass spectrometer.

The values obtained at the fourth minute of each position and each work load were adopted as representatives except for cardiac output, which was measured during the fourth minute of each position and each work load.

Calculations
The other parameters were calculated as follows:
Stroke volume=cardiac output/HR;
Arteriaovenous oxygen difference (a-v O\textsubscript{2} differ)=oxygen uptake/cardiac output;
Pulse pressure=systolic pressure-diastolic pressure;
Mean arterial pressure (MAP)=diastolic pressure + (pulse pressure)/3;
Total peripheral resistance (TPR)=MAP/cardiac output.

Statistics
Three-way ANOVA was performed with work loads (resting, 50 W, and 150 W) and postures (sitting and supine) as experimental factors, and subjects as a block factor. When a significant difference was detected, a paired t-test was performed. The statistical significance level was set at p<0.05.

RESULTS

Relative workloads
The average VO\textsubscript{2}max of the subjects was 41.8 ±
6.9 (mean ± SD). The oxygen uptake, and the calculated relative workload for each work load and each posture are shown in Table 1. The oxygen uptake did not differ significantly between the sitting and supine postures.

### Cardiorespiratory responses

As shown in Table 1, HR did not differ significantly between the sitting and supine postures. The cardiac output and stroke volume were larger in the supine posture than in the sitting posture at each work load, and the difference was statistically significant at 150 W. The a-v O₂ differ and TPR were larger in the sitting posture. Systolic and diastolic pressures were also higher in the sitting posture.

### DISCUSSION

The present exercise was within the range of mild exercise, since the relative work intensity was on average 25%VO₂max for 50 W and 50%VO₂max for 150 W. The same oxygen uptake regardless of posture was in agreement with our previous study

The larger cardiac output and stroke volume in the supine posture indicated the relative importance of cardiac pump, compared to muscle pump, during mild exercise. Although the effects of posture were apparently the same as those during moderate and heavy exercises, the present research on mild exercise was needed because of the absence of metaboreflex during mild exercise, which predominantly regulates the cardiorespiratory system during moderate and heavy exercises. The much larger capacity of cardiac pump than that of muscle pump in ordinary persons would explain the present result.

The lower a-v O₂ differ, in the supine posture indicates a relative ineffectiveness of oxygen supply by the blood flow in the exercising muscles. The lack of gravitational hydrostatical gradient along the body trunk in the supine posture when compared to that of the sitting posture might cause
a decrease in the perfusion pressure in the exercising legs as well as an increase in the cardiac filling pressure\(^{12}\). In the supine posture, the ineffective oxygen supply caused by a decrease in perfusion pressure would therefore be compensated by an abundant blood flow in the exercising legs.

Blood pressure was reported to be increased by metaboreflex, when metaboreceptors in exercising muscles were activated by a decrease in its perfusion pressure\(^{4, 12}\). The blood pressure in the present supine posture was, however, lower than in the sitting posture despite a lower perfusion pressure in the exercising muscles. A lack of production of metabolites during low intensity exercise may explain this observation. The lower blood pressure in the supine posture could be a result of relief of sympathetic nervous activity by loading of arterial and cardiopulmonary baroreceptors\(^{5}\), as usually observed in a resting condition. The lower TPR in the supine position agrees with this explanation, since the TPR is largely influenced by sympathetic nervous activity\(^{2}\). The higher HR in the supine posture may suggest a lower vagal activity during the sitting exercise, and a unique reflex is known that suppresses vagal activity in the face of an increase in cardiac filling pressure\(^{13, 14}\), although the existence of the reflex in humans is still controversial\(^{15}\). Further investigation is needed. Another explanation may simply be that the supine position always followed the sitting posture, although this is unlikely since the period of four minutes is usually enough for HR to reach steady state during even moderate exercise\(^{16}\).

The larger pulse pressure in the sitting posture may appear to contradict the lower stroke volume in that posture, since in many cases changes in pulse pressure are related to changes in stroke volume\(^{17}\). This could however be explained as a higher heart contraction force in the sitting position induced by activation of the sympathetic nervous system in that posture, as suggested by the higher TPR.

**CONCLUSION**

We investigated the effects of posture on cardiorespiratory responses during mild exercise, within which range most physical therapy is performed. Despite the absence of metaboreflex during mild exercise, the cardiorespiratory responses in the different postures were at least apparently similar to those during moderate and heavy exercises. The cardiac output and stroke volume were larger, and the oxygen supply in the exercising muscles was relatively ineffective in the supine posture, however, the lower blood pressure and total peripheral resistance may be a result of the absence of metaboreflex during mild exercise. The effects of posture and intensity of exercise should be taken into account in risk management and prescriptions for physical therapy.

**REFERENCES**


