The Trunk Rotation may Differentially Affect Lung Volume and Respiratory Muscle Strength in Males and Females

Miki Takahata (✉ d.miki.takahata@yachts.ac.jp)  
Yamagata Prefectural university of Health Sciences

Miho Osawa  
Yamagata Prefectural University of Health Sciences

Mizuki Hoshina  
Yamagata Prefectural University of Health Sciences

Michiyasu Yamaki  
Yamagata Prefectural university of Health Sciences

Toshiaki Sato  
Yamagata Prefectural university of Health Sciences

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Abstract

It is known that gender affect pulmonary function, associated with anatomical differences between male and female. However, the effects of trunk rotation on respiratory variables and its differences between males and females remain unclear. We examined the effects of gender and physical characteristics on postural changes in healthy young people. In this study, 9 males and 11 females (22 ± 1 year old for both males and females) were enrolled. We measure the vital capacity (VC), inspiratory capacity (IC), tidal volume (VT), expiratory reserve volume (ERV), inspiratory reserve volume (IRV), and force vital capacity (FVC) and respiratory muscle (PImax and PEmax) with rest posture in the sitting position (rest posture) in sitting position and 30° trunk rotation both genders in the sitting position (rotational posture). The value of VC, IC, ERV, IRV, FVC, or FEV1.0 for males were significantly higher than that for females in both postures. Further, PEmax was more affected by rotational posture in male than in female. On the other hand, PImax showed a significant decrease in the rotational posture only in females.

This study indicated that the effect of rotational posture on PImax and PEmax, a measure of respiratory muscle strength, may be different between males and females. These finding may provide important insights on gender differences in respiration in daily living.

Introduction

It is known that there are significant differences in pulmonary function between male and females. Females are characterized by a smaller-sized rib cage and airways relative to lung size (1)·(2)·(3)·(4) and a greater contribution of inspiratory rib cage muscles than males (5). These anatomical differences between males and females may affect performance in activities of daily living (ADL).

Posture also affects pulmonary function and the contribution of the rib cage and abdomen. Previous studies have investigated posture effect on chest wall kinematics (Craig 1960). Verschakelen et al. have showed the effect of gender on chest wall kinematics (7). There are differences in the composition of thoracic dimensions and configuration between genders (8)·(9). However, few studies have examined the effects of gender and physical characteristics on respiratory changes relative to posture.

In this study, we attempt to elucidate the effects of gender and physical characteristics on respiratory variables during rotational posture in healthy people.

Methods

Subjects

There were 20 healthy young people (22 ± 1 year old for both genders) were enrolled in this study. The inclusion criteria were nonsmoker and with no cardiac and pulmonary diseases.

Pulmonary function
Pulmonary function was assessed using a spirometer (H-801, CHEST, Japan), according to ATS/ERS statement on pulmonary function test (10). The variables such as vital capacity (VC), inspiratory capacity (IC), tidal volume (VT), expiratory reserve volume (ERV), inspiratory reserve volume (IRV), force vital capacity (FVC), forces expiratory volume in one second (FEV1.0), or forces expiratory volume % in one second (FEV1.0%), were measured. Respiratory muscle strength was determined by measuring the maximal inspiratory pressure (PImax) and maximal expiratory pressure (PEmax) using a mouth pressure meter (IOP-01, Kobata, Japan), following ATS/ERS statement on respiratory muscle testing (11). The maximum value of the three maneuvers varying by less than 20% was recorded. These variables were measured in the resting or 30° trunk rotation in the sitting position. Participants performed a test in two sitting postures with rest period.

**Statistical analysis**

Respiratory variables are expressed as mean ± standard deviation. The data were analyzed using the IBM SPSS Statistics software version 24.0 (IBM Corporation, Armonk, NY, USA). Two-way ANOVA with repeated measures was used to compare the effects across posture and gender on each variable. Bonferroni’s correction was used for the post-hoc analysis. The level of significance was set at p < 0.05 for all statistical comparisons.

**Ethical approval and consent to participate**

This study’s ethical approval was granted by the Ethics Review Board of Yamagata Prefectural University of Health Sciences, Yamagata, Japan (#1801-23). This study was carried out in accordance with the recommendations of the Ethics Review Board of Yamagata Prefectural University of Health Sciences. All participants gave written informed consent in accordance with the Declaration of Helsinki.

**Results**

Twenty healthy young people participated in this study. The characteristics of participants are shown in Table 1. The participants performed pulmonary function test in the resting or 30° trunk rotation in the sitting position. Respiratory variables (VC, IC, VT, ERV, IRV, FVC, FEV1.0, and FEV1.0%) and respiratory muscle strength variables (PImax and PEmax) were measured in each posture.
Table 1
Physiological characteristics of participants

|                      | All (n=20) | Male (n=9) | Female (n=11) |
|----------------------|------------|------------|--------------|
| Age (year)           | 22 ±1      | 22 ± 1     | 22 ± 1       |
| Height (cm)          | 163.5 ± 8.4 | 170.8 ± 5.8 | 157.5 ± 4.6*** |
| Weight (kg)          | 57.4 ± 12.9 | 68.6 ± 11.1 | 48.3 ± 3.6*** |
| BMI (kg/m²)          | 21.3 ± 3.4 | 23.5 ± 3.6 | 19.4 ± 1.5** |
| SMI (kg/m²)          | 6.7 ± 1.3  | 7.9 ± 0.8  | 5.6 ± 0.4*** |

Data are presented as mean ± standard deviations. BMI: body mass index SMI: skeletal muscle mass index. **: p<0.01, ***: p<0.001.

The value of VC, IC, ERV, IRV, FVC, or FEV1.0 for males were significantly higher than that for females in both postures (Table 2).

Table 2
Differences in respiratory and respiratory muscle variables during the rest or rotational posture in sitting position between male and female

Figure 1 shows the results of the two-way ANOVA with repeated measures and post-hoc analysis. There was significant main effect of gender on FVC, FEV1.0, VC, ERV, PImax, and PEmax (FVC: F₁,₁₈=45.8, p<0.001, VC: F₁,₁₈=44.6, p<0.001, ERV: F₁,₁₈=25.0, p<0.001, PImax: F₁,₁₈=5.3, p<0.05, PEmax: F₁,₁₈=13.6, p<0.01). In these variables, males showed greater value than females in rest posture and rotational posture.

There was significant main effect of posture on FVC, FEV1.0, VC, ERV, PImax, and PEmax (FVC: F₁,₁₈=45.8, p<0.001, VC: F₁,₁₈=44.6, p<0.001, ERV: F₁,₁₈=25.0, p<0.001, PImax: F₁,₁₈=7.3, p<0.05, PEmax: F₁,₁₈=32.1, p<0.001). For males and females, the rotational posture significantly decreased these values.

A significant interaction between gender and posture was observed in PEmax (F₁,₁₈=7.5, p<0.05). In PEmax, the rotational posture decreased the male value more in males than in females.

Discussion

In the present study, we examined the effects of trunk rotation posture in the sitting position for respiratory variables, such as vital capacity (VC), inspiratory capacity (IC), tidal volume (VT), expiratory
|       | Male                | Female               | t-value | Male vs Female |
|-------|--------------------|----------------------|---------|----------------|
| VC    | Rest               | 4.7 ±0.6             | 3.0 ± 0.4 | 7.0            | p<0.001       |
| (L)   | Rotation           | 4.3 ± 0.7            | 2.7 ± 0.5 | 6.1            | p<0.001       |
| IC    | Rest               | 2.6 ±0.4             | 1.7 ± 0.4 | 5.3            | p<0.001       |
| (L)   | Rotation           | 2.6 ±0.4             | 1.7 ± 0.4 | 4.5            | p<0.001       |
| TV    | Rest               | 0.8 ±0.3             | 0.7 ± 0.4 | 0.6            | n.s.          |
| (L)   | Rotation           | 0.8 ±0.3             | 0.7 ± 0.3 | 0.6            | n.s.          |
| ERV   | Rest               | 2.0 ±0.4             | 1.3 ± 0.4 | 4.2            | p<0.001       |
| (L)   | Rotation           | 1.7 ±0.3             | 1.0 ± 0.3 | 4.8            | p<0.001       |
| IRV   | Rest               | 1.8 ±0.4             | 1.0 ± 0.3 | 5.5            | p<0.001       |
| (L)   | Rotation           | 1.8 ±0.4             | 1.0 ± 0.3 | 5.8            | p<0.001       |
| FVC   | Rest               | 4.7 ±0.6             | 3.1 ± 0.4 | 7.1            | p<0.001       |
| (L)   | Rotation           | 4.4 ±0.7             | 2.7 ± 0.5 | 6.4            | p<0.001       |
| FEV1.0| Rest               | 4.1 ±0.5             | 2.8 ± 0.4 | 6.5            | p<0.001       |
| (L)   | Rotation           | 3.8 ±0.6             | 2.5 ± 0.5 | 5.9            | p<0.001       |
| FEV1.0%| Rest              | 87.2 ± 4.6           | 90.4 ± 4.7 | 1.5          | n.s.          |
| (%)   | Rotation           | 87.1 ± 4.4           | 89.9 ± 4.6 | 1.4          | n.s.          |
| Plmax (cmH₂O) | Rest          | 89.5 ± 32.1          | 65.6 ± 21.5 | 2.0          | n.s.          |
|       | Rotation           | 86.1 ± 28.9          | 59.4 ± 16.4 | 2.6          | p<0.05       |
| PEmax (cmH₂O) | Rest       | 101.5 ± 25.9         | 62.7 ± 14.8 | 4.2          | p<0.01       |
|       | Rotation           | 89.1 ± 29.0          | 58.5 ± 13.8 | 3.1          | p<0.01       |

All data are presented as mean ± standard deviations.

VC: vital capacity, IC: inspiratory capacity, VT: tidal volume, ERV: expiratory reserve volume, IRV: inspiratory reserve volume, FVC: force vital capacity, FEV1.0: forces expiratory volume in one second, FEV1.0%: forces expiratory volume % in one second, Plmax: maximal inspiratory pressure, and PEmax: maximal expiratory pressure. n.s.: not significant.

It is known that posture and gender differences effects on pulmonary function. However, how trunk rotation affects respiratory variable in healthy young people remains unclear. This study's main
results were the rotational posture decrease in respiratory variables: FVC, FEV1.0, VC, ERV, PEmax, and Plmax.

The results showed significant decrease in VC and FVC during respiration in trunk rotation posture than that in the rest sitting posture. Lee et al. reported a reduced motion at the axilla of the rib cage during respiration with spinal rotation (12). The rotational posture causes a range of motion decrease in the rib cage, changing its articulations and intercostal muscle activities. This posture requires increased abdominal motion. It is suggested that this thoracoabdominal motion change induced the VC and FVC decreases.

The results indicated significant decrease in ERV and FEV1.0 during respiration in the rotational posture compared to that in the rest sitting posture. Moreover, PEmax was more affected by rotational posture in male than in female. According to a previous study, obesity and external pressure on the rib cage reduced ERV (13). The muscle strength variables for forced expiration were significantly decreased in the rotational posture. The agonist muscle for trunk rotation includes the external and internal oblique abdominal muscles, which are the most active during forced expiration. Therefore, this result suggests that rotational posture limits the activity of the forced expiratory muscles. It is known that chest wall kinematics is significantly influenced by gender (8), (9). There are differences in the relative contribution of the rib cage and abdomen during respiration. Bellemare et al. reported that the differences in the composition of thoracic dimensions and configuration between males and females produce differences in the contribution of the rib cage and abdomen during ventilation (5). The significant interaction between posture and gender for PEmax suggested that males may be more affected by the limitation of trunk rotation during forced expiration due to the higher contribution of the abdomen during respiration.

Plmax was significantly decreased in the rotational posture compared with that in the rest posture in females, although it did not change in males. Females have smaller airways relative to their lung size (1). We deduced that the rotational posture, restricting the range of motion of the rib cage, affected the inspiratory muscle strength for female.

This study exhibited that respiratory variables were significantly decreased by rotational posture even in healthy young people with average muscle strength. The effect of rotational posture on Plmax and PEmax, a measure of respiratory muscle strength, may be different between males and females. Therefore, the elderly or chronically ill patients speculated cause further affected by posture.

**Abbreviations**

ADL: activities of daily living

ERV: expiratory reserve volume

FEV1.0: forces expiratory volume in one second

FEV1.0%: forces expiratory volume % in one second
FVC: force vital capacity
IC: inspiratory capacity
IRV: inspiratory reserve volume
PEmax: maximal expiratory pressure
Plmax: maximal inspiratory pressure
VC: vital capacity
VT: tidal volume

Declarations

Ethics approval and consent to participate
This study's ethical approval was granted by the Ethics Review Board of Yamagata Prefectural University of Health Sciences, Yamagata, Japan (#1801-23).

Consent for publication
Not applicable

Availability of data and materials
The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests
The authors declare that they have no competing interests.

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Authors' contributions
M.T. is the guarantor of the article and takes responsibility for the integrity of the work as a whole. All author contributed to study conception and design. M.O. and M.H. recruited participants. M.T., M.O., and M.H. performed assessments. M.T., M.O., M.Y., and T.S. contributed to data analysis. M.T., M.O., and M.Y. contributed to interpretation of data, and writing the manuscript.

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Figures
Figure 1

Differences in respiratory variables during the resting or 30°rotation of thoracic in sitting position. a: vital capacity (VC), b: inspiratory capacity (IC), c: tidal volume (VT), d: expiratory reserve volume (ERV), e: inspiratory reserve volume (IRV), f: force vital capacity (FVC), g: forces expiratory volume in one second (FEV1.0), h: maximal inspiratory pressure (Plmax), i: maximal expiratory pressure (PEmax). *: p<0.05, **: p<0.01, ***: p<0.001.