The Trunk Rotation May Reduce Lung Volume and Respiratory Muscle Strength Prominently in Female Than Male

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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 (P_Imax and P_Emax) 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. In both genders, the VC, ERV, FVC, FEV1.0, and P_Emax values in the rotational posture were significantly lower than that in the rest posture. Further, in females, there was a significant decrease in P_Imax in the rotational posture compared with the resting posture.

This study indicated that trunk rotation may limit pulmonary function prominently in female than in male. 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 males⁵. 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 kinematics⁷. 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 (P_Imax) and maximal expiratory pressure (P_Emax) 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 $\pm$ standard deviation. The data were analyzed using the IBM SPSS Statistics software version 24.0 (IBM Corporation, Armonk, NY, USA). The differences between males and females, and the two sitting postures in each variable were analyzed using Student's t-test, with a significance level 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 (P_Imax and P_Emax) were measured in each posture.

The differences between male and female for each respiratory and muscle strength variable during the two sitting postures were shown in Table 2. In the respiratory variables, the value of VC, IC, ERV, IRV, FVC, and FEV1.0 for males were significantly greater than that for females in both postures. In the muscle strength variables, P_Imax in the rotational posture and P_Emax in the both postures for males were significantly greater than that for females. P_Imax in the rest sitting position showed no significant difference between male and female.

The differences between the rest and rotational sitting postures for each variable were shown in Fig. 1. The VC, ERV, FVC, FEV1.0, and P_Emax values of males and females in the rotational posture were

significantly less than that in the rest sitting posture. The rotational posture affects the respiratory function, especially expiratory volume.

There was a significant decrease in P_Imax in the rotational posture compared with that in the resting posture in females, as opposed to P_Imax in males showing no significant change. Thus, rotational posture could limit inspiratory muscle strength, especially for 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 reserve volume (ERV), inspiratory reserve volume (IRV), force vital capacity (FVC), forced expiratory volume in one second (FEV_{1.0}), or forced expiratory volume % in one second (FEV_{1.0}%), and respiratory muscles. 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: VC, FVC, ERV, P_Emax, and P_Imax.

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.

Furthermore, the results indicated significant decrease in ERV and FEV_{1.0} during respiration in the rotational posture compared to that in the rest sitting posture. 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.

P_Imax was significantly decreased in the rotational posture compared with that in the rest posture in females, although it did not change in males. 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. 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. Therefore, the elderly or chronically ill patients

speculated cause further affected by posture.

Conclusion

The present study revealed that posture and gender differences affect the lung volume and respiratory muscle strength. These findings may provide important insights on gender differences in respiration in daily living activities.

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

PImax: maximal inspiratory pressure

VC: vital capacity

VT: tidal volume

Declarations

Funding

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Conflicts of interest/Competing interests

The authors declare no conflicts of interest associated with this manuscript.

Author 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.

Ethics approval

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

Consent to participate

Informed consent was obtained from all individual participants included in this study.

Consent for publication

Participants signed informed consent regarding publishing their data.

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Author 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.

References

1. Mead, J. Dysanapsia in normal lungs assessed by the relationship between maximal flow, static recoil, and vital capacity. *Am. Rev. Respir. Dis.* **121**, 339–342 (1980).
2. McClaran, S. R., Harms, C. A., Pegelow, D. F. & Dempsey, J. A. Smaller lungs in women affect exercise hyperpnea. *J. Appl. Physiol.* **84**, 1872–1881 (1998).
3. Sheel, A. W. & Guenette, J. A. Mechanics of breathing during exercise in men and women: Sex versus body size differences? *Exerc. Sport Sci. Rev.* **36**, 128–134 (2008).
4. Dominelli, P. B. *et al.* Sex differences in large conducting airway anatomy. *J. Appl. Physiol.* **125**, 960–965 (2018).
5. Bellemare, F., Jeanneret, A. & Couture, J. Sex differences in thoracic dimensions and configuration. *Am. J. Respir. Crit. Care Med.* **168**, 305–312 (2003).

6. CRAIG, A. B. Effects of position on expiratory reserve volume of the lungs. *Journal of applied physiology* **15**, 59–61 (1960).
7. Verschakelen, J. A. & Demedts, M. G. Normal thoracoabdominal motions. Influence of sex, age, posture, and breath size. *Am. J. Respir. Crit. Care Med.* **151**, 399–405 (1995).
8. Fugl Meyer, A. R. Relative respiratory contribution of the rib cage and the abdomen in males and females with special regard to posture. *Respiration* **31**, 240–251 (1974).
9. Mendes, L. P. D. S. *et al.* Influence of posture, sex, and age on breathing pattern and chest wall motion in healthy subjects. *Brazilian J. Phys. Ther.* **24**, 240–248 (2020).
10. Graham, B. L. *et al.* Standardization of Spirometry 2019 Update. An Official American Thoracic Society and European Respiratory Society Technical Statement. *Am. J. Respir. Crit. Care Med.* **200**, e70–e88 (2019).
11. Gibson, G. J. *et al.* ATS/ERS Statement on Respiratory Muscle Testing. *Am. J. Respir. Crit. Care Med.* **166**, 518–624 (2002).
12. Lee, L. J., Chang, A. T., Coppieters, M. W. & Hodges, P. W. Changes in sitting posture induce multiplanar changes in chest wall shape and motion with breathing. *Respir. Physiol. Neurobiol.* **170**, 236–245 (2010).
13. Steier, J., Lunt, A., Hart, N., Polkey, M. I. & Moxham, J. Observational study of the effect of obesity on lung volumes. *Thorax* **69**, 752–759 (2014).

Tables

Table 1
Physiological characteristics of participant

	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/m ²)	21.3 ± 3.4	23.5 ± 3.6	19.4 ± 1.5**
SMI (kg/m ²)	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.			

Table 2

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

		Male	Female	t-value	Male vs Female
VC (L)	Rest	4.7 ± 0.6	3.0 ± 0.4	7.0	p < 0.001
	Rotation	4.3 ± 0.7	2.7 ± 0.5	6.1	p < 0.001
IC (L)	Rest	2.6 ± 0.4	1.7 ± 0.4	5.3	p < 0.001
	Rotation	2.6 ± 0.4	1.7 ± 0.4	4.5	p < 0.001
TV (L)	Rest	0.8 ± 0.3	0.7 ± 0.4	0.6	n.s.
	Rotation	0.8 ± 0.3	0.7 ± 0.3	0.6	n.s.
ERV (L)	Rest	2.0 ± 0.4	1.3 ± 0.4	4.2	p < 0.001
	Rotation	1.7 ± 0.3	1.0 ± 0.3	4.8	p < 0.001
IRV (L)	Rest	1.8 ± 0.4	1.0 ± 0.3	5.5	p < 0.001
	Rotation	1.8 ± 0.4	1.0 ± 0.3	5.8	p < 0.001
FVC (L)	Rest	4.7 ± 0.6	3.1 ± 0.4	7.1	p < 0.001
	Rotation	4.4 ± 0.7	2.7 ± 0.5	6.4	p < 0.001
FEV1.0 (L)	Rest	4.1 ± 0.5	2.8 ± 0.4	6.5	p < 0.001
	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.
PImax (cmH ₂ O)	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 (cmH ₂ O)	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, PImax: maximal inspiratory pressure, and PEmax: maximal expiratory pressure. n.s.: not significant.					

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 (TV), 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 (PImax), i: maximal expiratory pressure (PEmax). *: p<0.05, **: p<0.01, ***: p<0.001. The VC, ERV, FVC, FEV1.0, and PEmax values of males and females in the rotational

posture were significantly less than that in the rest sitting posture. The Plmax of females in the rotational posture were significantly less than that in the rest sitting posture.