Original Article

Effects of increased functional residual capacity on finger-floor distance in healthy young adults

YOSHIKI TAKEUCHI, RPT, MS¹⁾, HIROTAKA KATO, RPT^{1, 2)}, MASAHIRO ISHIZAKA, RPT, PhD³⁾, AKIRA KUBO, RPT, PhD³⁾*

¹⁾ Shioya Hospital, International University of Health and Welfare, Japan

²⁾ Department of Physical Therapy, Graduate School of Health and Welfare Science, International University of Health and Welfare, Japan

³⁾ Department of Physical Therapy, School of Health Sciences, International University of Health and Welfare: 2600-1 Kitakanemaru, Ohtawara-shi, Tochigi 324-8501, Japan

Abstract. [Purpose] To investigate the effect of increased functional residual capacity on the finger-floor distance and to assess spinal curvature in the sagittal plane using the Spinal Mouse in healthy young participants. [Participants and Methods] Thirty-nine healthy volunteers (age=21.2 ± 0.8 years) participated in this study. The finger-floor distance was used to measure trunk flexion and was recorded at the resting expiration level and at 2 different functional residual capacity levels: 1,000 and 2,000 ml air inhaled at the resting expiration level. Spinal curvature morphology was evaluated using the Spinal Mouse in the sagittal plane when flexion was completed under the 2 increased functional residual capacity and resting expiration level conditions during finger-floor distance measurement. Finger-floor distance and spinal curvature were assessed according to functional residual capacity using one-way repeated measures analysis of variance and post-hoc analysis. [Results] Significant effects and differences were found for the finger-floor distance under all conditions. No significant effect was found for spinal curvature. [Conclusion] An increase in functional residual capacity may decrease trunk flexion. This correlation might also be observed in patients with chronic obstructive pulmonary disease.

Key words: Functional residual capacity, Finger-floor distance, COPD

(This article was submitted Jul. 31, 2018, and was accepted Oct. 7, 2018)

INTRODUCTION

According to statistics of the Ministry of Health, Labor, and Welfare in 2017, the mortality rate tends to increase in patients with chronic obstructive pulmonary disease (COPD)¹⁾. The elasticity of the lung and rib cage decreases, and the functional residual capacity (FRC) increases in patients with COPD. In addition to the complaint of shortness of breath, poor trunk mobility is also one of the major disabilities in patients with COPD.

Our previous study²⁾ demonstrate that an increase in FRC might decrease an active range of thoracic axial rotation in healthy young participants. The causes and mechanisms for poor thoracic mobility in these patients are complicated.

The purpose of this study was threefold: to evaluate the change in thoracic circumference in increased FRC conditions (P1); to investigate the change in sagittal mobility by measuring the finger-floor distance (FFD) in increased FRC conditions (P2); to assess the spinal curvature (SC) in the sagittal plane using the Spinal Mouse (P3) in healthy young participants. The reason for recruiting young and healthy participants was to exclude the bias due to general health status such as malnutrition, systemic inflammation, physical activity level, quality of life, and age-related changes in physical conditions.

*Corresponding author. Akira Kubo (E-mail: akubo@iuhw.ac.jp)

©2019 The Society of Physical Therapy Science. Published by IPEC Inc.

This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial No Derivatives (by-nc-nd) License. (CC-BY-NC-ND 4.0: <https://creativecommons.org/licenses/by-nc-nd/4.0/>)

PARTICIPANTS AND METHODS

In P1, twenty-nine healthy male volunteers, recruited from the university (age=20.6 ± 1.1 years, height=170.0 ± 10.0 cm, mass=60.0 ± 8.5 kg, body mass index=21.1 ± 2.8 kg/m²; mean ± standard deviation), participated in this study. The exclusion criteria were any pathologic condition of the spine, rib, shoulder, hip, or knee in the past 6 months, a history of scoliosis, the presence of spinal deformation, or a rheumatologic or respiratory condition at the time of study.

A degree of chest expansion, which represents the circumference magnitude of the thoracic cage, was examined by using a chest expansion measurement device (T.K.K.3345, Takei Equipment Industry Co., Ltd., Japan). The participants were made to stand with uncovered upper body, and were equipped with the device. The chest expansion measure was to assess the effect of increased FRC efficiency at the level of the axilla and the 10th rib (Fig. 1). Nishigaki et al.³⁾ previously reported that this device has high intra- and inter-evaluator reliabilities and validity for evaluating the measurement result with reference to the traditional tape measure result. Therefore, the number of measurements was set to once at each FRC condition in this study.

The degree of chest expansion was based on the resting expiration level (REL). The chest expansion was recorded at REL and at two different FRC levels, that is, 1,000 and 2,000 ml air inhaled at REL from a 2,000-ml capacity rounded cylinder (ACA105, Minato Medical Science Co., Ltd., Japan) (Fig. 2). The chest expansion at the maximum inspiration timing was also recorded. All measurements were performed in a randomized order.

The circumference magnitude of the four thoracic cage conditions at each FRC level, including REL and maximum inspiration level and at the heights of the two levels were analyzed using a two-way repeated measure of ANOVA, and post-hoc analysis was carried out using the Bonferroni's method.

In P2, thirty-nine healthy volunteers, recruited from the university (male=24, female=15, age=21.2 ± 0.8 years, height=170.0 ± 10.0 cm, mass=59.0 ± 10.1 kg, body mass index=21.1 ± 2.4 kg/m²), participated in this study, with exclusion criteria same as P1.

The influences of the increased FRC conditions (both 1,000 ml and 2,000 ml) including the REL condition on FFD were investigated in this study. All measurements were performed in a randomized order. The FFD was measured by using flexion-D (T.K.K.5403, Takei Equipment Industry Co., Ltd., Japan) (Fig. 3).

The FFDs of the three conditions at each FRC level, including REL, were analyzed using a one-way repeated measure of ANOVA, and post-hoc analysis was carried out using the Bonferroni's method.

In P3, twenty male healthy volunteers, also recruited from the university (age=19.9 ± 2.1 years, height=170.0 ± 10.0 cm, mass=63.8 ± 7.8 kg, body mass index=21.0 ± 2.0 kg/m²), participated in this study with exclusion criteria same as P1.

The spinal curvature morphology evaluation was obtained using the Spinal Mouse (Idiag A G, Switzerland) in sagittal planes, when the flexion was completed in both the previously described increased FRC and REL conditions for FFD measurement. The measurements were performed in a randomized order. The thoracic kyphosis angle (Thsp), lumbar lordosis angle (Lsp), and sacral inclination angle (Sac/Hip) were compared using the measured values from the Spinal Mouse.

The angles of the three conditions at each FRC level, including REL, were analyzed using a one-way repeated measure of ANOVA, and post-hoc analysis was carried out using the Bonferroni's method.

Statistical analysis of these results was carried out using SPSS for Windows 23.0 (IBM Corporation). Descriptive data was expressed as mean ± standard deviation, where p<0.05 indicated statistical significance.

All volunteers signed an informed consent form that was approved by the Institutional Review Board at the University of the corresponding author (Approval No. 2016-10-128).

Fig. 1. Chest expansion measure at the level of the axilla and that of 10th rib height.

Fig. 2. 1,000 and 2,000 ml air inhaled at the resting expiration level from a 2,000-ml capacity rounded cylinder.

Fig. 3. Measurement of finger floor distance.

Table 1. Chest expansion at the level of the axilla and that of 10th rib height

	REL	Forced inspiration		Maximum inspiration
		1,000 ml	2,000 ml	
Axilla (cm)	0.4 ± 0.3	1.6 ± 0.6	2.4 ± 0.9	2.5 ± 1.0
Th10 (cm)	0.7 ± 0.4	1.9 ± 0.8	3.0 ± 1.2	3.4 ± 1.8

p<0.05: REL vs. 1,000 ml, 2,000 ml, maximum inspiration.

1,000 ml vs. 2,000 ml, maximum inspiration.

REL: resting expiration level; Th10: 10th rib height.

Table 2. Finger floor distance in each condition

	REL	Forced inspiration	
		1,000 ml	2,000 ml
FFD (cm)	2.2 ± 8.7	1.8 ± 9.0	0.5 ± 8.9

p<0.05: REL vs. 1,000 ml, 2,000 ml.

1,000 ml vs. 2,000 ml.

REL: resting expiration level; FFD: finger floor distance.

Table 3. Spinal curvature flexion angle in each condition

	REL	Forced inspiration	
		1,000 ml	2,000 ml
Thsp (°)	48.2 ± 16.0	47.1 ± 14.0	42.6 ± 14.4
Lsp (°)	39.5 ± 11.3	38.2 ± 10.5	39.8 ± 11.5
Sac/hip (°)	71.5 ± 11.9	73.5 ± 9.1	71.2 ± 11.0

REL: resting expiration level; Thsp: thoracic kyphosis angle; Lsp: lumbar lordosis angle; Sac/hip: sacral inclination angle.

RESULTS

The result of P1 is shown in Table 1. A significant effect was found in the FRC and rib cage height factors, but there was no significant interaction. In the post-hoc analysis, the expansion significantly increased in FRCs of 1,000, 2,000, and in maximum inspiration as compared to REL, as well as in 2,000 and maximum inspiration as compared to 1,000. However, no significant difference was found between 2,000 and maximum inspiration.

The result in P2 was shown in Table 2. Both a significant effect and significant difference was found in all conditions.

The result in P3 was shown in Table 3. No significant effect was found.

DISCUSSION

In this study, the purpose was to clarify the change in the trunk flexion range of motion in increased FRC states using FFD, which is generally recognized as sagittal trunk mobility (P2). Prior to this study, we needed to investigate the relationship between increased FRC and chest expansion (P1). We also needed to examine the association of the spinal curvature morphology evaluation in the sagittal plane because of the elucidation of the mechanism (P3).

In P1, the degree of chest expansion depended on the amount of inhaled air. The chest expansion increased by 2.4 ± 0.9 cm at the level of the axilla and by 3.0 ± 1.2 cm at that of the 10th rib, in the condition of inhaled 2,000 ml. However, no significant difference was observed between the 2,000 ml inhaled condition and maximum inspiration. Therefore, the chest expansion with 2,000 ml inhaled air was comparable to a voluntary deep inspiration.

In P2, a significant effect as well as significant difference was found in all conditions. The change in FFD also depended on the amount of inhaled air. An expansion of the thorax with an increase in the FRC led to decreased mobility of trunk rotation as per our previous study^{2, 4)}. In this study, we could demonstrate decreased active trunk flexion with a quantitative increase in FRC, in addition to trunk rotation.

In P3, no significant effect was found in Thsp, Lsp, or Sac/Hip. Mannion et al.⁵⁾ carried out studies to examine the reliability of measures of spinal curvature and range of motion, made with the Spinal Mouse. The Spinal Mouse delivered reliable results both within, between days, and between investigators. This suggested that this device could be used with confidence for such measurements. Suehiro et al.⁶⁾ reported that the minimum detectable changes for Thsp, Lsp, and Sac/Hip

in the prone position with the Spinal Mouse in healthy young males were greater than 7.5, 4.0, and 4.8°, respectively. The data of this study fell below the acceptance criteria. The 1,000 ml and 2,000 ml inhaled air conditions indicated an increase in rib cage volume, and showed a significant change in trunk flexion using FFD. However, the change depended on factors other than spinal alignment. Ito et al.⁷⁾ reported that the median sternotomy in patients who underwent scheduled surgery, could alter the thoracic alignment and mobility within twenty postoperative days using the Spinal Mouse. Our study speculated that the spinal alignment did not lead to change in these angles, because a transient increased FRC condition was conducted in healthy young participants. However, it is suggested that the change in the spinal alignment may occur in COPD patients who have chronically and progressively increasing FRC.

This study has some limitations. The participants were different for each setting of the purpose. The Spinal Mouse data was focused only on male participants. The measurement of inspiratory capacity and total lung capacity by using spirometry was not conducted in our study. These limitations related to the participants and measurements might have influenced the results of the present study. Therefore, our results should be interpreted carefully.

Conflict of interest

The authors report no conflicts of interest in this work.

REFERENCES

- 1) Ministry of Health, Labor and Welfare: Male/female death and mortality rate simplicity classified from disease (for 100,000 people) http://www.mhlw.go.jp/toukei/saikin/hw/jinkou/kakutei16/dl/11_h7.pdf (Accessed Feb. 27, 2018) (In Japanese)
- 2) Kubo A, Ishizaka M, Takeuchi Y, et al.: Effect of increased functional residual capacity on the active range of thoracic axial rotation in healthy young men. *J Phys Ther Sci*, 2018, 30: 282–285. [Medline] [CrossRef]
- 3) Nishigaki Y, Mizuguchi H, Takeda E, et al.: Development of new measurement system of thoracic excursion with biofeedback: reliability and validity. *J Neuroeng Rehabil*, 2013, 10: 45. [Medline] [CrossRef]
- 4) Takeuchi Y, Kudou T, Fujita T, et al.: Effect of functional residual capacity increase on trunk rotation of healthy adults. *Rigakuryoho Kagaku*, 2017, 32: 473–476 (In Japanese). [CrossRef]
- 5) Mannion AF, Knecht K, Balaban G, et al.: A new skin-surface device for measuring the curvature and global and segmental ranges of motion of the spine: reliability of measurements and comparison with data reviewed from the literature. *Eur Spine J*, 2004, 13: 122–136. [Medline] [CrossRef]
- 6) Suehiro T, Mizutani M, Watanabe S, et al.: The reliability and minimum detectable change of spinal curvature measurements in the prone position with a spinal mouse. *Rigakuryoho Kagaku*, 2013, 28: 761–765 (In Japanese). [CrossRef]
- 7) Ito A, Irie H, Ueda K, et al.: Alteration of spinal column alignment and mobility after cardiac surgery by median sternotomy. *Rigakuryohogaku*, 2018, 45: 82–89 (In Japanese).