J. Phys. Ther. Sci.
27: 491–493, 2015

Original Article

# The influences of position and forced respiratory maneuvers on spinal stability muscles

Ji Won Park[1)], Migyoung Kweon[1)], Soonmi Hong[1)*]

[1)] *Department of Physical Therapy, College of Medical Science, Catholic University of Daegu: 13-13 Hayang-ro, Hayang-eup, Gyeongsan-si, Gyeongbuk 712-702, Republic of Korea*

**Abstract.** [Purpose] The purposes of this study were to investigate the influences of position on %MVIC of spinal stability muscles to establish for the most effective breathing pattern for activation of spinal stability muscles in order to provide an additional treatment method for use in spinal stability exercise programs. [Subjects and Methods] Thirty-three healthy subjects performed quiet breathing and four different forced respiratory maneuvers (FRM); [pursed lip breathing (PLB), diaphragmatic breathing (DB), combination breathing (CB) and respiration muscle endurance training (RMET)] in both standing and sitting positions. %MVIC of them (the multifidus (MF), erector spinae (ES), internal oblique/transversus abdominis (IO/TrA), external oblique (EO), rectus abdominis (RA) measured. [Results] IO/TrA, MF and EO showed greater activation in standing than in sitting, while RA and ES showed greater activation in sitting than in standing. RMET induced significantly greater activation of spinal stability muscles then other breathing patterns. %MVIC changes of muscle activities induced by FRM were independent of position with a few exceptions. [Conclusion] The increased respiratory demands of FRM induced greater activation of spinal stability muscles than QB. RMET was found to be the most effective breathing pattern for increasing the activation of the spinal stability muscles.

**Key words:** Spinal stability muscles, Position, Forced respiratory maneuvers

*(This article was submitted Aug. 1, 2014, and was accepted Sep. 2, 2014)*

## INTRODUCTION

Spinal stability and respiration are used similar muscles for each functions. The diaphragm, the primary respiratory muscle, has been reported to act as one of spinal stability muscles and other spinal stability muscles are also activated to increase respiratory capacity[1–7)]. The muscles used in both spinal stability and respiratory tasks include the diaphragm, transversus abdominis (TrA), intercostals muscles, internal oblique muscle (IO) and pelvic floor muscles (PFM)[1–3)], which are also known as core muscles. The spinal stability provided by these muscles is derived from their co-contraction which increases intra-abdominal pressure[4)]. These muscles function as respiratory muscles by increasing their activities when respiratory demand increases[1–3, 5–7)].

We speculated that increasing the strengths of the respiratory muscles would have positive effects on spinal stability. One way of strengthening the respiratory muscles was to breathe forcefully. The question was whether forced breathing pattern increased the spinal stability muscle activities enough to strengthen them. Bridging exercises was the commonly used methods to increase spinal stability muscle strengths[8, 9)] and prone position bridging exercise was the most effective among in other positions[10)]. The previous study showed %MVIC of these muscles with forced breathing patterns were as high as with bridging exercises. In addition, the synergy ratios of these muscles with forced breathing patterns were similar with those with bridging exercises[8, 9, 11–13)]. However, these previous studies were performed in the standing position and it is not clear whether the increased muscle activations were due to increased postural demand or increased respiratory demand or both. In addition, it is necessary to determine whether there are any interaction effects between position and breathing patterns to suggest forced breathing pattern as one way to strengthen spinal stability muscles.

## SUBJECTS AND METHODS

Thirty three subjects who had no history of low back pain within the last six months, musculoskeletal impairments of the lower limbs, or neurological or respiratory pathology were enrolled in this study. Subjects with a cold, or excessive abdominal fat or a current or previous swimming habit were excluded. The data of 33 subjects (16 males, 17 females, 20.33 ± 2.10 years old, height 1.66 ± 0.08 m, weight 59.83 ± 9.60 kg, BMI 21.57 ± 2.31 kg/$m^2$) were used for data analysis. Prior to their participation, all the participants read and signed an informed consent form, in accordance with the ethical principles of the Declaration of Helsinki. The protocol for this study was approved by the Ethics Committee of Catholic University of Daegu. Each participant performed

*Corresponding author. Soonmi Hong (E-mail: curtcult@hanmail.net)

**Table 1.** Results of the tests for the significant main effect of breathing patterns Unit (%MVIC)

| | IO/TrA | EO | RA | ES | MF |
|---|---|---|---|---|---|
| QB | 5.81±6.12* | 2.81±1.25* | 2.36±1.13* | 3.40±1.70* | 2.89±1.37* |
| CB | 8.31±8.40 | 4.00±2.01* | 2.76±1.29 | 3.84±1.86* | 3.46±1.61 |
| DB | 9.38±8.83 | 4.29±2.26*,*** | 2.79±1.24 | 3.85±1.87* | 3.27±1.56 |
| PLB | 6.77±6.27* | 3.23±1.52* | 2.51±1.19* | 3.61±1.89* | 3.00±1.31** |
| RMET | 12.91±10.33 | 6.12±3.73 | 3.44±1.56 | 5.52±2.71 | 4.01±1.86 |

*p< 0.001 different from RMET, **p=0.003 different from RMET, ***p=0.002 different from QB

five different breathing patterns in two positions, sitting and standing. The five different breathing patterns were quiet breathing (QB) and forced respiratory maneuvers (FRM): combination breathing (CB), diaphragmatic breathing (DB), pulsed lip breathing (PLB) and respiratory muscle endurance training (RMET). The details of FRM were described in the previous study[13]. %MVIC of internal oblique abdominis/transversus abdominis (IO/TrA)[14], external oblique abdominis (EO)[15], rectus abdominis (RA)[15], erector spinae (ES)[16] and multifidus (MF)[8] were measured for comparison of muscle activities. Muscle activations were measured using surface electromyography. The breathing tasks were performed in a random order. Measurements and data collection were performed following the procedures described in a previous study[13]. Two-way repeated ANOVA was used to determine the main effects of breathing pattern and position as well as interaction effects between them. Statistical significance for all tests was accepted for values of $p < 0.05$.

## RESULTS

Two-way repeated ANOVA was performed in order to evaluate the effects of position and breathing pattern on five spinal stability muscle activities. The dependent variable was %MVIC. The within-subjects factors were position (two levels: sitting and standing) and breathing patterns (five levels: QB, CB, DB, PLB and RMET). The main effects of position on %MVIC of IO/TrA, EO, RA, ES and MF were significant [$F(1,32)=24.794$, $p<0.001$; $F(1,32)=48.049$, $p<0.001$; $F(1,32)=16.069$, $p<0.001$; $F(1,32)=17.398$, $p<0.001$; $F(1,32)=6.971$, $p=0.013$; respectively]. In addition, the main effects of breathing patterns on %MVIC of IO/TrA, EO, RA, ES and MF were significant [$F(4,128)=25.150$, $p<0.001$; $F(4,128)=29.943$, $p<0.001$; $F(4,128)=28.974$, $p<0.001$; $F(4,128)=61.043$, $p<0.001$; $F(4,128)=22.487$, $p<0.001$; respectively]. The interaction effects were tested and were significant on only IO/TrA, EO and MF, [$F(4,128)=3.054$, $p=0.034$; $F(4,128)=3.281$, $p=0.040$; $F(4,128)=4.037$, $p=0.013$; respectively]. The paired t-tests was performed to examine the significant main effects of position after controlling for the family-wise error rate across these tests using Holm's sequential Bonferroni approach. Differences in mean %MVIC of IO/TrA, EO, RA, ES and MF between the two positions were significant: $t(164)= -9.61$, $p<0.001$; $t(164)= -10.06$, $p<0.001$; $t(164)=5.53$, $p<0.001$; $t(164)= 8.82$, $p<0.001$; $t(164)= -5.27$, $p<0.001$; respectively. Of particular interest, mean %MVIC of IO/TrA, EO and MF were higher in standing than in sitting, whereas %MVIC of RA and ES were lower in standing than sitting.

One-way ANOVA was performed to examine the significant main effects of breathing patterns after controlling for the family-wise error rate cross these tests using Holm's sequential Bonferroni approach (Table 1). For IO/TrA, RA and MF, RMET induced significantly greater activation of muscles than QB ($p< 0.001$) and PLB ($p<0.001$, $p< 0.001$, $p=0.002$, respectively). EO and ES in RMET showed significantly higher %MVIC than in CB, DB, PLB and QB ($p<0.001$). In addition, EO in DB showed significantly higher activation than in QB ($p=0.003$).

Finally, the paired t-test was performed to examine differences among breathing patterns in each position, controlling for the family-wise error rate using Holms sequential Bonferroni approach. The mean %MVIC of IO/TrA in PLB and RMET showed a significantly greater increase in standing than sitting compared to QB ($p=0.002$, $p=0.004$, respectively). The mean %MVIC of MF in CB showed a significantly greater increase in standing than in sitting compared to DB and PLB ($p=0.003$, $p=0.002$, respectively), however the mean %MVIC of MF in QB showed a significantly greater increase in standing than in sitting compared to CB ($p<0.001$).

## DISCUSSION

The purposes of this study were to investigate the influences of position on %MVIC of spinal stability muscles and to find the most effective breathing pattern for the activation of spinal stability muscles. The results of this study show that the positions and breathing patterns had important influences on spinal stability muscle activities and their influence was different depending on the muscles.

The deep muscles and EO showed greater activation in standing than in sitting, while the superficial muscles showed greater activation in sitting than in standing. This might be due to the unique functions of each muscle group. It is well-known that the deep muscle group provide segmental stability while the superficial muscle group provide torque production and general trunk stability[17]. To maintain a standing posture, increased segmental stability might be needed rather than increased torque, which is provided by the superficial muscle group. The results of many studies support this assumption. Some studies have reported that activation of the deep muscle group is more effective at increasing spinal stability than activation of the superficial muscle group[17, 18]. In other studies, subjects demonstrated optimal lower back stabilization during exercises with appropriate deep muscle activation[19, 20]. In addition, sitting posture showed increased trunk sway with decreased compensatory postural control[21]; therefore, more torque might be needed to minimize trunk sway in sitting, possibly explaining the increase in superficial muscles' activities in sitting compared to standing. We suggest that the reason for this is that the lower extremities are unavailable to compensate for respiratory perturbation in sitting.

In this study, the spinal stability muscles, except MF, were activated the most by RMET, DB, CB, PLB and QB in declining order, whereas MF was activated the most by RMET, in the order of CB, DB, PLB and QB. Among the different breathing patterns, RMET induced significantly greater activation of the spinal stability muscles than the other breathing patterns. No significant differences in muscle activities were observed between PLB and QB. For IO/TrA, %MVIC in DB increased as much as in RMET, and %MVIC in DB was significantly higher than that in PLB or QB. For MF, %MVIC in CB was not significantly different from that in RMET, even though %MVIC in CB was significantly higher than that in PLB or QB. RMET was the breathing pattern that induced the greatest activation of the spinal stability muscles. However, for subjects who have difficulty performing RMET, DB or CB could be used as an alternative method for activation and strengthening of the spinal stability muscles.

Although, position and breathing patterns showed meaningful impacts on spinal stability muscle activation, interaction effects between position and breathing patterns were found for a few muscles in a few breathing patterns. In general, %MVIC changes in the spinal stability muscles induced by FRM were independent of position with a few exceptions: IO/TrA in PLB and RMET showed increased activation that was greater than the possible position effect compared to the change in QB, while MF in QB was activated more than the possible position effect compared to the change in CB. However, absolute %MVIC of both of these muscles with RMET was the highest.

In conclusion, increased respiratory demands of FRM induced greater activation than QB, and RMET was found to be the most effective breathing pattern for increasing the activities of the spinal stability muscles regardless of position. In RMET, the increases in muscle activities induced by increase in respiratory demand was not different between sitting and standing. Therefore, it can be expected that RMET in a sitting position activates the spinal stability muscles in a manner comparable to that of standing. Subjects with difficulty in maintaining a standing posture could start a spinal stability muscle strengthening program using RMET in a sitting position and progress to RMET in a standing position as spinal stability improves. A previous study showed lumbar stability improved with increased TrA contractility after 4 weeks of deep breathing exercises[22]. However, further research will be required in order to determine whether spinal stability muscles are strengthened by RMET in sitting, and whether a spinal stability strengthening program with RMET can improve spinal stability.

## ACKNOWLEDGEMENT

This work was supported by research grants from the Catholic University of Daegu in 2012.

## REFERENCES


1) Hodges PW, Heijnen I, Gandevia SC: Postural activity of the diaphragm is reduced in humans when respiratory demand increases. J Physiol, 2001, 537: 999–1008. [Medline] [CrossRef]
2) Hodges PW, Gandevia SC: Changes in intra-abdominal pressure during postural and respiratory activation of the human diaphragm. J Appl Physiol 1985, 2000, 89: 967–976. [Medline]
3) Hodges PW, Gandevia SC: Activation of the human diaphragm during a repetitive postural task. J Physiol, 2000, 522: 165–175. [Medline] [CrossRef]
4) Hodges PW: Changes in motor planning of feedforward postural responses of the trunk muscles in low back pain. Exp Brain Res, 2001, 141: 261–266. [Medline] [CrossRef]
5) V Akuthota AF, Moore T, Fredericson M: Core Stability Exercise Principles.pdf. Curr Sports Med, 2008, 7: 39–44.
6) Hodges PW, Sapsford R, Pengel LH: Postural and respiratory functions of the pelvic floor muscles. Neurourol Urodyn, 2007, 26: 362–371. [Medline] [CrossRef]
7) Gandevia SC, Butler JE, Hodges PW, et al.: Balancing acts: respiratory sensations, motor control and human posture. Clin Exp Pharmacol Physiol, 2002, 29: 118–121. [Medline] [CrossRef]
8) Stevens VK, Bouche KG, Mahieu NN, et al.: Trunk muscle activity in healthy subjects during bridging stabilization exercises. BMC Musculoskelet Disord, 2006, 7: 75. [Medline] [CrossRef]
9) Stevens VK, Coorevits PL, Bouche KG, et al.: The influence of specific training on trunk muscle recruitment patterns in healthy subjects during stabilization exercises. Man Ther, 2007, 12: 271–279. [Medline] [CrossRef]
10) Kong YS, Cho YH, Park JW: Changes in the activities of the trunk muscles in different kinds of bridging exercises. J Phys Ther Sci, 2013, 25: 1609–1612. [Medline] [CrossRef]
11) Silfies SP, Squillante D, Maurer P, et al.: Trunk muscle recruitment patterns in specific chronic low back pain populations. Clin Biomech (Bristol, Avon), 2005, 20: 465–473. [Medline] [CrossRef]
12) van Dieën JH, Cholewicki J, Radebold A: Trunk muscle recruitment patterns in patients with low back pain enhance the stability of the lumbar spine. Spine, 2003, 28: 834–841. [Medline] [CrossRef]
13) Kweon M, Hong S, Jang GU, et al.: The neural control of spinal stability muscles during different respiratory patterns. J Phys Ther Sci, 2013, 25: 1421–1424. [Medline] [CrossRef]
14) Johanson E, Brumagne S, Janssens L, et al.: The effect of acute back muscle fatigue on postural control strategy in people with and without recurrent low back pain. Eur Spine J, 2011, 20: 2152–2159. [Medline] [CrossRef]
15) Hanada EY, Hubley-Kozey CL, McKeon MD, et al.: The feasibility of measuring the activation of the trunk muscles in healthy older adults during trunk stability exercises. BMC Geriatr, 2008, 8: 33. [Medline] [CrossRef]
16) Marshall PW, Murphy BA: Core stability exercises on and off a Swiss ball. Arch Phys Med Rehabil, 2005, 86: 242–249. [Medline] [CrossRef]
17) Panjabi M, Abumi K, Duranceau J, et al.: Spinal stability and intersegmental muscle forces. A biomechanical model. Spine, 1989, 14: 194–200. [Medline] [CrossRef]
18) Bergmark A: Stability of the lumbar spine. A study in mechanical engineering. Acta Orthop Scand Suppl, 1989, 230: 1–54. [Medline] [CrossRef]
19) Hodges PW: Is there a role for transversus abdominis in lumbo-pelvic stability? Man Ther, 1999, 4: 74–86. [Medline] [CrossRef]
20) O'Sullivan PB: Lumbar segmental 'instability': clinical presentation and specific stabilizing exercise management. Man Ther, 2000, 5: 2–12. [Medline] [CrossRef]
21) Bouisset S, Duchêne JL: Is body balance more perturbed by respiration in seating than in standing posture? Neuroreport, 1994, 5: 957–960. [Medline] [CrossRef]
22) Kim E, Lee H: The effects of deep abdominal muscle strengthening exercises on respiratory function and lumbar stability. J Phys Ther Sci, 2013, 25: 663–665. [Medline] [CrossRef]