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Original Article

Abdominal muscle activity according to knee joint angle during sit-to-stand

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Abstract. [Purpose] This study assessed the activity of the abdominal muscles according to the angle of the knee joints during sit-to-stand. [Subjects and Methods] Thirty healthy adult males participated in this study. Subjects initiated sit-to-stand at knee joint angles of 60°, 90°, or 120°. An electromyography system was used to measure the maximum voluntary isometric contraction of the rectus abdominis, external oblique, and internal oblique and transverse abdominis muscles. [Results] Percent contraction differed significantly among the three knee joint angles, most notably for the internal oblique and transverse abdominis muscles. [Conclusion] Wider knee joint angles more effectively activate the abdominal muscles, especially those in the deep abdomen, than do narrower angles.
Key words: Sit-to-stand, Knee joint, Abdominal

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INTRODUCTION

Sit-to-stand (STS) is an essential motion in daily life[1)], often performed when shifting body position, walking, or climbing stairs. STS requires a larger range of motion in the hip joints and knee joints than does walking or stair climbing[2, 3)]. Millington et al.[4)] and Schenkman et al.[5)] divided STS into four stages. In the first stage, which is the flexion moment phase, body weight shifts as the trunk bends while standing up. In the second stage, the buttocks detach from the chair, and the flexion of the ankle joint toward the top of the foot becomes maximal. In the third stage, unfolding occurs as the trunk, knee joints, and hip joints extend to achieve an upright standing position. The fourth stage is the stabilization phase. This classification has been widely used in motion analyses in kinematic and motor mechanic studies[1, 6)].

As determined via a literature review, biomechanical analyses of STS have focused mainly on the ankle joints and lower limb muscles. Previous studies examined the activity of the lower limb muscles during STS[7)], the activation of the vastus medialis oblique and vastus lateralis muscles in asymptomatic subjects during STS[8)], the effect of knee flexion angle on STS in individuals with hemiparesis[9)], the impact of foot location on STS in stroke patients[10)], and the coordinating relationship between the lower limb muscles in response to diverse external stimuli[11)]. However, STS requires not only use of the lower limbs but also of the trunk[12)]. Moreover, activation of the abdominal muscles in the trunk is essential for maintaining diverse body positions in daily life. Appropriate activation of the abdominal muscles is therefore very important for their endurance[13)]. Although a previous study showed that STS was closely related to both the activity of the abdominal muscles and body stability[14)], this finding has yet to be explored in detail. Hence, the present study examined the activity of the abdominal muscles during STS as a function of knee joint angle.

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SUBJECTS AND METHODS

Thirty healthy adult males in City B who did not have lower back pain in the six months preceding the study were selected as the study subjects. The average age of the study population was 28.23 ± 4.02 years, the average height was 174.5 ± 4.4 cm, and the average weight was 71.23 ± 10.04 kg. The research process was explained to the subjects, and a written consent to participate was obtained from them. The study was approved by the Bioethics Committee at Busan University (E-2015013).

To determine the effects of knee joint angle on the activity of the abdominal muscles during STS, the subjects began the STS motion from a sitting position in which the knee joint angle was 60°, 90°, or 120°, according to the tester's instructions. A surface electromyogram system (Telemyo 2400; Noraxon, Scottsdale, AZ, USA) was used to measure the activity of the abdominal muscles. To measure the activity of the rectus abdominis (RA) muscle, the electrode was attached 2 cm to the left of and 2 cm below the navel along the fibers of the RA. To measure the activity of external oblique (EO) muscle, the electrode was attached at the midpoint between the anterior superior iliac spine (ASIS) and the costal bone along the fibers of the OA. To measure the activity of the internal oblique (IO) and transverse abdominis (TrA) muscles (collectively referred to as "IO & TrA"), the electrode was attached 2 cm inside and 2 cm below the ASIS along the fibers of these muscles[15]. Muscle activity was measured in bandwidths of 20−450 Hz at a frequency of 1,000 Hz. The measured values were processed as the root mean square. To express the collected electromyogram signals as the maximum voluntary isometric contraction (MVIC), MVIC was performed for 10 seconds for each muscle; this time was determined in manual muscle tests[16]. The muscle signals measured in the first 4 seconds after removing the initial and the final 3 seconds were used in the data analysis. To minimize the muscle fatigue that can occur from consecutive measurements, the participants rested for 10 minutes after each exercise. The collected data were analyzed by using SPSS for Windows (ver. 20.0) and one-way analysis of variance. The Scheffe test was used for the ex-post analysis, and the significance level was set at 0.05.

RESULTS

The abdominal muscle activity at knee joint angles of 60°, 90°, and 120° is presented in Table 1. There was a significant difference in percent MVIC among the three angles. The ex-post analysis also showed a significant difference in percent MVIC for the IO & TrA muscles.

DISCUSSION

Moving from a relatively stable position (sitting down) to a relatively unstable position (standing while maintaining balance), as done during STS, shifts the body's center of gravity[17]. To accurately shift the center of gravity during STS, the placement of the feet in relationship to the base of the body, as well as the surrounding tissues, is important. Harmonious contraction of the trunk muscles, in addition to those in the lower limbs, is also required[18]. To stabilize the trunk and to control posture, the abdominal muscles should simultaneously contract[12, 19, 20]. Hence, this study determined the relationship between the activity of the abdominal muscles during STS and the angle of the knee joints.

Our results indicate that the abdominal muscles, especially those in the deep abdomen, become more active when the knee joint angle is increased during STS. According to Hodge and Richardson[21], the TrA is the first muscle in the hip joint to contract regardless of the direction of the force, and as reported by Cresswell[22], it is the first muscle activated in response to physical disturbance, such as trembling of the body. Park and Lee[23] determined the activity of the trunk muscles in subjects leaning against a wall in an abdominal hollowing exercise, which is similar to the STS movement. The activities of the EO and TrA were found to be 2.35 and 2.7 times higher, respectively, than the activity of the RA on average, indicating that the deep abdominal muscles were the most active. In the present study, the activities of the EO and TrA were 1.16 and 2.13 times higher, respectively, than the activity of the RA on average. These findings suggest that the deeper the abdominal muscle is, the stronger its activity will be during STS, and are consistent with previous results.

Previous studies showed that increasing the knee joint angle while in the sitting position increased the backward incline

Table 1. Activity of the abdominal muscles according to the knee joint angle

% MVIC	RA	EO	IO & TrA
60°*	3.83 ± 0.50^a	4.37 ± 0.48^a	8.87 ± 0.70^b
90°*	4.61 ± 0.54^a	5.48 ± 0.60^a	10.05 ± 0.79^b
120°*	6.59 ± 0.75^a	7.71 ± 0.82^a	12.76 ± 1.06^b

Units are expressed as percentages.
*Statistically significant (p<0.05)
The different superscripts indicate significant differences.
MVIC: maximum voluntary isometric contraction, RA: rectus abdominis, EO: external oblique, IO: interior oblique, TrA: transverse abdominis

of the pelvis[24] and that the muscles that control the trunk became more active when the pelvis was inclined backward during STS[25]. In other words, increases in the knee joint angle increase the activity of the abdominal muscles that control the trunk. This is consistent with the results of this study, which showed that abdominal muscle activity differed according to the knee joint angle during STS. A particularly strong activation was observed in the deep abdominal muscles. Hence, performance of the STS movement can effectively train the deep abdominal muscles in a clinical setting.

A limitation of this study is that the research subjects were healthy people. Moreover, this study analyzed the functioning of only contracted abdominal muscles. Future studies will investigate the effects of knee joint angle on muscle activity in patients with limited movement owing to neurologic or musculoskeletal defects. In addition to quantitative analysis of the contraction of the abdominal muscles, it will be necessary to conduct a dynamic analysis of factors other than knee joint angle, such as muscle contraction speed and recruitment features, to account for body structure.

REFERENCES

1) Riley PO, Schenkman ML, Mann RW, et al.: Mechanics of a constrained chair-rise. J Biomech, 1991, 24: 77–85. [Medline] [CrossRef]
2) Andriacchi TP, Andersson GB, Fermier RW, et al.: A study of lower-limb mechanics during stair-climbing. J Bone Joint Surg Am, 1980, 62: 749–757. [Medline]
3) Berger R, Riley P, Mann R, et al.: Total body dynamics in ascending stairs and rising from a chair following total knee arthroplasty. Proceedings of Trans 34th A Mtg Orthop Res Soc, 1988, 542.
4) Millington PJ, Myklebust BM, Shambes GM: Biomechanical analysis of the sit-to-stand motion in elderly persons. Arch Phys Med Rehabil, 1992, 73: 609–617. [Medline]
5) Schenkman M, Berger RA, Riley PO, et al.: Whole-body movements during rising to standing from sitting. Phys Ther, 1990, 70: 638–648, discussion 648–651. [Medline]
6) Hughes MA, Weiner DK, Schenkman ML, et al.: Chair rise strategies in the elderly. Clin Biomech (Bristol, Avon), 1994, 9: 187–192. [Medline] [CrossRef]
7) Bohannon RW: Sit-to-stand test for measuring performance of lower extremity muscles. Percept Mot Skills, 1995, 80: 163–166. [Medline] [CrossRef]
8) Choi B: Activation of the vastus medialis oblique and vastus lateralis muscles in asymptomatic subjects during the sit-to-stand procedure. J Phys Ther Sci, 2015, 27: 893–895. [Medline] [CrossRef]
9) Lee MY, Lee HY: Analysis for sit-to-stand performance according to the angle of knee flexion in individuals with hemiparesis. J Phys Ther Sci, 2013, 25: 1583–1585. [Medline] [CrossRef]
10) Camargos AC, Rodrigues-de-Paula-Goulart F, Teixeira-Salmela LF: The effects of foot position on the performance of the sit-to-stand movement with chronic stroke subjects. Arch Phys Med Rehabil, 2009, 90: 314–319. [Medline] [CrossRef]
11) Zajac FE, Neptune RR, Kautz SA: Biomechanics and muscle coordination of human walking. Part I: introduction to concepts, power transfer, dynamics and simulations. Gait Posture, 2002, 16: 215–232. [Medline] [CrossRef]
12) Kim SG, Yong MS, Na SS: The effect of trunk stabilization exercises with a swiss ball on core muscle activation in the elderly. J Phys Ther Sci, 2014, 26: 1473–1474. [Medline] [CrossRef]
13) Handa N, Yamamoto H, Tani T, et al.: The effect of trunk muscle exercises in patients over 40 years of age with chronic low back pain. J Orthop Sci, 2000, 5: 210–216. [Medline] [CrossRef]
14) Hodges PW, Richardson CA: Inefficient muscular stabilization of the lumbar spine associated with low back pain. A motor control evaluation of transversus abdominis. Spine, 1996, 21: 2640–2650. [Medline] [CrossRef]
15) Criswell E: Cram's introduction to surface electromyography. Jones & Bartlett Publishers, 2010.
16) Hislop H, Avers D, Brown M: Daniels and Worthingham's muscle testing: Techniques of manual examination and performance testing. Elsevier Health Sciences, 2013.
17) Roebroeck ME, Doorenbosch CA, Harlaar J, et al.: Biomechanics and muscular activity during sit-to-stand transfer. Clin Biomech (Bristol, Avon), 1994, 9: 235–244. [Medline] [CrossRef]
18) Lee TH, Choi JD, Lee NG: Activation timing patterns of the abdominal and leg muscles during the sit-to-stand movement in individuals with chronic hemiparetic stroke. J Phys Ther Sci, 2015, 27: 3593–3595. [Medline] [CrossRef]
19) Hodges PW, Gurfinkel VS, Brumagne S, et al.: Coexistence of stability and mobility in postural control: evidence from postural compensation for respiration. Exp Brain Res, 2002, 144: 293–302. [Medline] [CrossRef]
20) Mok NW, Brauer SG, Hodges PW: Hip strategy for balance control in quiet standing is reduced in people with low back pain. Spine, 2004, 29: E107–E112. [Medline] [CrossRef]
21) Hodges PW, Richardson CA: Contraction of the abdominal muscles associated with movement of the lower limb. Phys Ther, 1997, 77: 132–142, discussion 142–144. [Medline]
22) Cresswell AG, Oddsson L, Thorstensson A: The influence of sudden perturbations on trunk muscle activity and intra-abdominal pressure while standing. Exp Brain Res, 1994, 98: 336–341. [Medline] [CrossRef]
23) Park DJ, Lee HO: Activation of abdominal muscles during abdominal hollowing in four different positions. J Phys Ther Sci, 2010, 22: 203–207. [CrossRef]
24) Kuo YL, Tully EA, Galea MP: Video analysis of sagittal spinal posture in healthy young and older adults. J Manipulative Physiol Ther, 2009, 32: 210–215. [Medline] [CrossRef]
25) Choi JD, Kwon OY, Yi CH, et al.: Kinematic and EMG analysis of Sit-to-Stand with changes of pelvis tilting. Korean Research Society of Physical Therapy, 2003, 10.