

Effects of Isometric Upper Limb Contraction on Trunk and Leg Muscles During Sit-to-stand Activity in Healthy Elderly Females

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| Abstract |

PURPOSE: The purpose of this study was to investigate the effects of isometric upper limb contraction on the trunk and lower extremity muscles during the sit-to-stand activity in elderly females.

METHODS: Eighteen healthy elderly females performed three directional isometric upper extremity contractions (flexion, extension, and horizontal abduction movements) using an elastic band during sit-to-stand activity. Electromyography signals were collected from the internal oblique, erector spinae, rectus femoris, and biceps femoris muscles.

RESULTS: Internal oblique activity was greater in bilateral shoulder flexion and bilateral shoulder horizontal abduction than in neutral position ($p < .05$). Erector spinae and rectus femoris muscle activities in bilateral shoulder flexion was greater than in neutral position and bilateral shoulder extension ($p < .05$). Biceps femoris activity was significantly greater in bilateral shoulder flexion than in bilateral shoulder extension and horizontal abduction, and in neutral position compared to bilateral shoulder extension ($p < .05$).

CONCLUSION: These results suggest that incorporating isometric upper limb contraction may be beneficial for enhancing the contribution of trunk and lower extremity muscle activities to trunk stabilization during sit-to-stand activity. Therefore, isometric upper limb contraction during sit-to-stand tasks, especially in flexion, may be used to elicit contraction of the lumbopelvic region muscles within a tolerable range, for developing endurance and strength in the elderly.

Key Words: Isometric contraction, Leg muscle, Sit-to-stand, Trunk muscle, Upper extremity

I. Introduction

The ability to rise from a seated position, otherwise known as sit-to-stand activity (STS), is essential for postural maintenance and controlled and coordinated movement (Park, 2002). Safe execution of STS is a prerequisite for activities such as walking and stair climbing (Papa and Cappozzo, 2000).

Age-related declines in lower limb strength and balance and sensory systems have independently been shown to impair safe and efficient execution of STS in older adults (Lord et al., 2002; Schenkman et al., 1996). In elderly women in particular, decreased muscle strength of the lower extremities occurs more quickly than in elderly men,

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reducing balance and gait ability (Park and Yoon, 2009). Standing up require greater muscle strength, range of motion and a peak joint moment than walking and stair climbing. It also requires the balance ability to translate the body mass forward and upward from a relatively stable sitting position to the feet. Because of these mechanical demands, elderly people may experience difficulty when standing from a chair (Carr and Shepherd, 2011; Yoshioka et al., 2009). It was found that older adults exhibited a longer execution time than younger adults for executing STS possibly due to the poorer leg muscle strength in elderly adults (Yamada and Demura, 2009).

Thus the balance training and muscle strengthening exercise may be required to successful STS performance in elderly people (Kim et al., 2010). Previous studies have been suggested that trunk and hip muscles may be affected by loading induced from upper- and lower-limb movement (Arokoski et al., 2001; Park and Yoon, 2009; Tarnanen et al., 2008). Arokoski et al. (2001) found that the activation patterns of the abdominal muscles were affected by the direction of restricted upper-limb movements. Other researchers have shown that the direction of resistance on the upper limb could affect the activation patterns of the abdominal muscles (Lee et al., 2012). However, these exercises were performed in a static posture only, such as a standing or sitting position. There are no studies on effects of the resistance direction of upper extremity on trunk and leg muscles during a dynamic movement such as STS. Therefore, the purpose of this study was to quantify and compare how isometric contractions of upper extremity affect trunk and lower extremity electromyography activity during STS in healthy old adults.

II. Methods

1. Subjects

We recruited 18 healthy elderly women volunteers from a community dwelling in Gimhae city. The mean age of

the subjects was 68 ± 1.97 years (mean \pm SD), mean height was 154.72 ± 4.21 cm, and mean body weigh was 54.61 ± 6.84 kg. The Inje University Faculty of Health Science Human Ethics Committee granted approval for this study, and all subjects provided written informed consent prior to participation.

2. Instrumentation

Surface EMG signals were recorded using four pre-amplified (gain: 1,000) active surface electrodes (Model DE-2.3, Delsys Inc., Wellesley, MA, USA) with surface electrodes fixed at an inter-electrode distance of 10 mm. The sampling rate was 1,000 Hz; the band-pass filter was 20–450 Hz. Raw data for the four muscles were processed into root-means square (RMS) data.

The electrodes were positioned on four sites on the right side of the subjects' bodies: internal oblique (IO), erector spinae (ES), rectus femoris (RF), and biceps femoris (BF) muscles. For normalization of the EMG signal, subjects were asked to perform a maximum voluntary isometric contraction (MVIC) maneuver for 5s. The EMG data expressed the entire STS task as a percentage of maximum voluntary isometric contraction (%MVIC). One infrared-retro reflective marker was placed on the superior aspects of the scapular acromion process to define the start and end positions of the STS (Vicon 512, Oxford Metrics Group, UK).

3. Procedures

Subjects were instructed to sit with an upright trunk posture on a height-adjustable bed without back support and with feet flat on the floor. The hip, knee, and ankle joints were positioned at 90° flexion, and the feet were positioned shoulder-width apart with the toes pointing directly forward. The poles were placed directly in front of (extension condition) or behind (flexion condition) the trunk bilaterally at a distance of 1m, and the subject's shoulder height was measured to determine the fixed axis for the elastic band. A blue elastic therapeutic band

(TheraBand, Hygenic Corporation, USA) was used to regulate resistance in the upper limb. All subjects grasped the elastic band 50cm from the fixed axis with both arms so that same resistance was applied to the upper limb. A goniometer was used to determine the shoulder movement range (from neutral position to 40° flexion, neutral position to 40° extension, and from 90° flexion to 90° horizontal abduction), and then a target bar was placed in front (flexion condition) or behind (extension condition) of subjects to control shoulder movement (Lee et al., 2012).

Each subject was instructed to extend or flex both shoulders with full extension of the elbow joint during the entire STS motion and then to hold a standing position for 3s. Horizontal abduction started at 90° flexion of the shoulder. Subjects were asked to perform horizontal abduction with both arms with full extension of the elbow joint during the entire STS task and then to hold a standing position for 3s. EMG data for the four muscles were collected for each subject during the entire STS task.

Four types of STS experimental tasks were performed in random order: 1) Neutral STS (N), 2) STS with isometric upper limb extension (Ext), 3) STS with isometric upper limb horizontal abduction (H-Abd), and 4) STS with isometric upper limb flexion (Flex). To ensure sufficient practice and adherence to correct patterns, these strategies

were practiced repeatedly until the physician qualified the subject before entering the test. STS was performed at a self-paced comfortable speed.

4. Statistical analysis

Significant differences among the four conditions (neutral, extension, horizontal abduction, and flexion) were examined using a repeated-measures analysis of variance (ANOVA). If a significant difference was found, post hoc Fisher's Least Significant Difference (LSD) correction was performed to determine differences in pair-wise comparison. Data were analyzed using the SPSS software (ver. 18.0, Chicago, IL, USA), and the significance level was set at $p < .05$.

III . Results

The mean and standard deviations of %MVIC for each condition are presented in Table 1. EMG activity of IO was significantly greater for the Flex condition and the H-Abd condition compared to the N condition, and for Flex condition compared to the Ext condition ($p < .05$, respectively). EMG activity of ES was significantly greater for the Flex condition compared to N, Ext, H-Abd conditions ($p < .05$), and N condition compared to Ext condition ($p < .05$).

Table 1. The differences of muscle activities (%MVIC) during STS with isometric upper limb contraction (N=18)

Muscles	Condition				p-values
	N	Ext	H-Abd	Flex	
IO	35.76±13.47 ^a	38.03±14.34	41.76±14.01 [†]	43.15±15.13 [†]	.002*
ES	50.64±15.54	44.28±14.93	47.50±13.86	56.99±14.64 ^{†,‡}	.000*
RF	36.93±15.27	38.39±15.09	38.47±15.55	42.67±14.64 ^{†,‡}	.037*
BF	36.86±18.52	31.62±17.93 [†]	33.14±18.93	38.99±20.23 ^{†,‡‡}	.002*

Abbreviations: MVIC, maximum voluntary isometric contraction; N, neutral; Ext, extension; H-Abd, horizontal abduction; Flex, flexion; IO, internal oblique; ES, erector spinae; RF, rectus femoris; BF, biceps femoris.

^a Mean±SD.

* $p < .05$.

† Significantly different compared to the N

‡ Significantly different compared to the Ext

‡‡ Significantly different compared to the H-Abd

EMG activity of RF was significantly greater for the Flex condition compared to N and Ext conditions ($p < .05$), and EMG activity of BF was significantly greater for the Flex condition compared to Ext and H-Abd condition, and for N condition compared to Ext condition ($p < .05$, respectively).

IV. Discussion

The goal of this study was to investigate electromyography activities of trunk and lower limb muscles during STS with isometric upper limb contraction. Overall, the result of this study was increased muscle activities of the IO, ES, RF, and BF in Flex condition compared to N, Ext, and H-Abd conditions. Our study was the first to examine trunk and lower extremity muscle activation on isometric upper limb contractions during an STS activity.

Large movements are usually produced in both the hip joint and the knee joint during STS, and thus any problems with muscle weakness or postural instability will lead to the use of alternative strategies (Corcos et al., 1996; Inkster and Eng, 2004). Using momentum in any transfer technique is a valuable option to any person who exhibits muscle weakness or other problems in standing up (Nuzik et al., 1986). This is important, as these interventions are targeted toward older adults and those with pathologies.

According to previous findings (Arokoski et al., 2001; Park and Yoon, 2009; Tarnanen et al., 2008) that suggested that trunk and hip muscles may be affected by loading induced from upper and lower limb movement, we used the extra loading provided by applying isometric upper limb contractions such as arm extension, horizontal abduction, and flexion resistance during STS movement. In this study, IO and RF muscles were activated more during the STS with isometric upper limb contraction than during STS alone. These results support that loading resistance induced from limb movement requires an

additional stabilization effort to keep trunk and hip stability at an optimal level (Park and Yoon, 2009).

In this study, we also investigated the effects of resistance direction using an elastic band on trunk and hip muscle activities during STS with isometric upper limb contraction. The results indicate that the direction of resistance on the upper limb appeared to affect the activation patterns of the IO, ES, RF, and BF muscles. When a limb is moved, the body reacts with forces that are equal in magnitude, but in the opposite direction to the limb movement. Tarnanen et al. (2008) reported that bilateral shoulder extension produced the greatest activity in the abdominal muscles. During bilateral shoulder extension, a long lever arm and the upper-body muscles are able to produce sufficient torque to load the trunk muscles. Arokoski et al. (2001) found that simultaneous resisted upper extremity extension while standing caused high abdominal muscle activity, whereas resisted upper extremity flexion while standing caused high back muscle activity. As in previous studies, the current study revealed that EMG activities of back extensor muscle such as ES and BF muscle were significantly higher in Flex than in Ext and H-Abd during the STS movement. However, STS with the Flex condition led to increased activation of IO and RF muscle as well as ES and BF muscles to control against the force of gravity and provide more momentum for balance and stability than the Ext condition.

These results could be affected by the experimental posture. The previous studies were performed in a static position, such as standing or sitting, whereas in this study the STS movement required forward and upward movement of the body mass from a base of support provided by the chair and the feet to the feet only, while maintaining balance (Shepherd and Gentile, 1994). A therapeutic band used in this experiment was able to resist a counter force in the opposite direction. During STS with Ext and H-Abd conditions, the therapeutic band was fixed to the front side of the body, and therefore the band tension was exerted

in the same direction toward the body mass transfer that might act to support the STS activity. However, during STS with the Flex condition, the fixed band was at the back of the body to provide resistance against moving the body mass forward and to possibly induce co-activation of the IO, RF, ES, and BF muscles. It has been suggested that co-contraction could be a control mechanism to maintain postural stability, or to recover from perturbations or the decrease in force and torque production capability that result from aging (Benjuya et al., 2004; Cenciari et al., 2010). Previous researchers suggested that the elderly tend to increase stability by stiffening the trunk or legs to compensate for impaired neuromotor functions and decreased muscle strength. In the elderly, this phenomenon elevates antagonist muscle activity, which in turn increases muscle coactivity (Izquierdo et al., 1999). Elevated muscle co-activation increases joint stiffness; hence, joint stability is also increased in the lower extremities (Baratta et al., 1988). During the STS with isometric arm Flex condition, most subjects appeared to respond with strong co-contractions of trunk and lower extremity muscles.

Our results therefore suggest that including isometric upper limb contraction may be beneficial for enhancing the contribution of trunk and hip muscle activity to trunk stabilization during STS movements. Our findings also support previous studies that have indicated that isometric upper limb contraction are beneficial for reinforcing the activity of the trunk and hip muscles (Saliba et al., 2010). Therefore, it can be supposed that isometric upper limb contraction during STS activity, especially the Flex condition, may be used to elicit a contraction of the lumbopelvic region muscles within a tolerable range for developing endurance and strength in the elderly for successful STS activity. However, it should be taken into account that muscle activation may be influenced by the resistance intensity as well as the resistance direction and posture.

This study was limited in several respects. First, the present study did not measure arm muscles that act directly

on the movement. Second, we did not control of resistance amount by applying in the individually. Further studies are needed to measure the strength of the arm muscles by an objective method and to investigate whether these results have implications for patient rehabilitation.

V. Conclusion

This study investigated the effect of the resistance direction of upper limb on trunk and lower extremity muscle activity during STS. With isometric upper limb Flex condition, most subjects appeared to respond during STS with strong co-contractions of trunk and lower extremity muscles. The STS activity with isometric upper limb Flex condition may have better prepared the subjects for higher skilled muscular responses to destabilizing forces when performed independently from STS activity. These results will be helpful in developing strategies for successful STS task performance in training programs for older women with muscle weakness. Further studies are needed to measure the control of resistance amount by applying in the individually. Measuring strength of the upper and lower limb muscles by an objective method and investigating whether these results have implications for the rehabilitation of patients is also a topic for further research.

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