J. Phys. Ther. Sci.
27: 83–86, 2015

Original Article

The effects of vision on sit-to-stand movement

Akkradate Siriphorn[1)*], Dannaovarat Chamonchant[1)], Sujitra Boonyong[1)]

[1)] *Department of Physical Therapy, Faculty of Allied Health Sciences, Chulalongkorn University: 154 Rama I Road, Pathumwan, Bangkok 10330, Thailand*

Abstract. [Purpose] It is well known that vision is an important factor contributing to postural control. However, there has been little discussion about the effect of vision on sit-to-stand movement. The purpose of this study was to evaluate the effect of constrained vision on sit-to-stand movement. [Subjects and Methods] Twenty-three healthy subjects (11 males, 12 females) aged 18–23 years with normal body mass indices were recruited for this study. Each participant was asked to stand as quickly as possible from a height-adjustable chair 3 times under 2 conditions: with eyes closed (EC) and eyes open (EO). The weight transfer time, rising index, and center of gravity sway velocity were measured using a NeuroCom Balance Master. [Results] The results show there were significant differences between the EC and EO conditions in the weight transfer time and the centre of gravity sway velocity. No significant difference was found between the EC and EO conditions in the rising index. These findings suggest that visual perception may play a role in balance control while performing sit-to-stand movement.
Key words: Vision, Balance, Sit-to-stand

(This article was submitted May 20, 2014, and was accepted Jul. 18, 2014)

INTRODUCTION

Sit-to-stand (STS) movement is a basic ability that is necessary for functional movement and independent living[1, 2]. An observational study revealed that free-living adults perform the STS movement approximately 60 times per day[3]. As the ability to STS is a prerequisite for upright function and mobility, the inability to execute this basic movement leads to impairment of mobility-related functions and impaired quality of life[4–6].

STS movement is defined as a rapid transition from a large base of support (BOS) in a stable position, to a smaller BOS in a less stable position[3, 7, 8]. There are two biomechanical alterations that occur during STS: a reduction in BOS, and the movement of the center of mass (COM) in the forward and upward directions[6, 7, 9]. A movement of the COM that goes beyond the BOS may lead to imbalance and falling[10].

During STS, the postural balance control system must be continually updated to prevent falling. It is clear that three types of sensory receptor—visual, vestibular, and somatosensory (proprioceptors and mechanoceptors)—play an important role in sensorimotor integration during postural balance control[11–14]. The central nervous system integrates this sensory information to build an internal representation of the body in the brain, and issues a motor signal to control the COM in relation to the BOS[11]. Visual feedback is one of the major factors contributing to balance control. Chen et al. showed that low vision and blindness among the elderly increases postural sway more than is seen in the sighted elderly[15]. Comparing the three sensory systems (visual, vestibular, and somatosensory), Grace Gaerlan et al. demonstrated that the visual system is the main sensory system used to maintain a standing posture[12]. Therefore, we hypothesized that the visual information may also play a role in STS movement control. The objective of this study was to investigate whether visual information influences the STS performance of healthy young adults.

SUBJECTS AND METHODS

The subjects of this study were 23 healthy young adults (11 males and 12 females), aged between 18–23 years (21.1 ± 1.1 years) with body mass indices (BMIs) between 18.5–22.9 kg/m^2 (20.5 ± 1.0 kg/m^2) (Table 1). The inclusion criteria were 1) an aged between 18–25 years; 2) a body mass index (BMI) between 18.5–22.99 kg/m^2; 3) normal visual acuity and visual field; 4) normal hearing; 5) normal muscle strength in both lower limbs; and 6) the ability to stand on one leg ≥ 30 seconds without falling. Exclusion criteria were 1) a history of severe musculoskeletal problems; 2) a history of back or leg surgery; 3) a history of neurological diseases; or 4) a history of any arthropathy. All subjects were informed about the procedure and purpose of this study and gave their written informed consent prior to their participation. This study was approved by the Ethics Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University (Project # 102.1/54).

All the participants performed STS 3 times under 2 conditions: with the eyes closed (EC) and eyes open (EO). To

*Corresponding author. Akkradate Siriphorn (E-mail: akkradate@gmail.com)

Table 1. Characteristics of the participants

	Mean	SD	Range
Age (years)	21.1	1.1	(18–23)
Weight (kg)	55.9	5.2	(48.6–70.0)
Height (cm)	165.1	5.9	(156–176)
BMI (kg/m^2)	20.5	1.0	(18.5–22.9)
Gender (male:female)		11:12	

counterbalance order and fatigue effects, the participants were randomly divided into 2 groups: 1) the OC group performed the eyes-open test first, and 2) the CO group performed the eyes-closed test first.

STS performance was measured using a Balance Master (NeuroCom International, Inc., USA). The participants' start position was standardized. Prior to the STS testing, subjects' leg lengths were measured: lower leg—the distance from the lateral epicondyle of the femur to the floor with the participant barefoot in the standing position; and upper leg—the distance from the greater trochanter of the femur to the lateral knee joint line. The seat height was then adjusted to 100% of the lower leg length. A dark ink mark was made at 50% of the thigh length. Then the participant was asked to sit, and the mark was aligned with the anterior border of the seat[16]. Both heels were placed 10 centimeters behind line perpendicular from the center of the knee joint to the force plate[17]. A mark on the ground was used as a reference point for foot positioning. During STS, the subjects were instructed to keep both arms crossed on the thorax, sit steadily until hearing a buzzer sound or seeing a "GO" visual signal, then stand as quickly as possible and hold steady for five seconds. Prior to data collection, participants performed practice trials until familiar with the procedures. Each subject performed three trials under each experimental condition (EO and EC). Three parameters were measured[18]: 1) the weight transfer time, or the length of time between the initial prompt to move and the moment when the center of gravity (COG) shifted to over the feet; 2) the rising index, or the amount of force exerted by the legs to decelerate forward motion of the upper body during the rising phase; and 3) the COG sway velocity, or the mean velocity of COG sway during the rise to stand and the first five seconds during standing.

A counterbalanced repeated measures design was used in this study. The weight transfer time, rising index, and COG velocity were compared between the EO and EC conditions using the paired sample t-test. All data are presented as mean ± SD. Statistical significance accepted for values of $p < 0.05$. Graphpad Prism version 6 for Windows (Graphpad Software, Inc., CA, USA) was used for the statistical analysis.

RESULTS

The paired sample t-test demonstrated there was a significant difference in the mean weight transfer time (p = 0.0019) between the EO (mean ± SD = 0.53 ± 0.27 sec) and EC conditions (mean ± SD = 0.40 ± 0.20 sec). No significant difference was found in the mean rising index (p = 0.9437) between the EO (mean ± SD = 28.10 ± 7.33%body weight) and EC conditions (mean ± SD = 28.20 ± 7.47%body weight). A significant difference was found in the mean COG sway velocity (p = 0.0009) between the EO (mean ± SD = 2.81 ± 1.36 degree/sec) and EC conditions (mean ± SD = 3.59 ± 1.10 degree/sec). All results are presented in Table 2.

Table 2. Variability in center of gravity kinematics under the two experimental conditions: eyes open (EO) and eyes closed (EC)
Three parameters were measured: 1) the weight transfer time, or the length of time between the prompt to move and the moment when the center of gravity (COG) shifted to over the feet, expressed in seconds; 2) the rising index, or the amount of force exerted by the legs to decelerate forward motion of the upper body during the rising phase, expressed as a percent of body weight; and 3) COG sway velocity, or the mean velocity of COG sway during the rise to stand and the first five seconds during standing, expressed in degree per second

	EO	EC
Weight transfer time (sec)	0.53 ± 0.27	0.40 ± 0.20**
Rising Index (% body weight)	28.10 ± 7.33	28.20 ± 7.47
Sway velocity (degree/sec)	2.81 ± 1.36	3.59 ± 1.10**

** Significant difference from EO ($p < 0.001$).

DISCUSSION

This study investigated the effect of vision on STS performance. A within-subject repeated measures design was used to evaluate the differences between two experimental conditions, EO and EC. Three STS parameters were analyzed: the weight transfer time, rising index, and COG sway velocity.

The weight transfer time was defined as the length of time between the prompt to move and the moment when the COG shifted to over the feet. This parameter could be described as a simple reaction time (only one stimuli and one response). The weight transfer time from the seat to the feet during STS typically happens very rapidly. A slow weight transfer time diminishes a subject's ability to utilize momentum to move the body forward. In this study, the EC condition showed a statistically significant decrease in the weight transfer time compared to the EO condition. However, the results of this study are not supported by previous studies which have reported there are no significant difference in STS time between the EO and EC conditions[19, 20]. This result might be related to differences in neurobehavioral mechanisms between the EO and EC conditions. While wakeful, awareness shifts between the "exteroceptive state or focus on outside" when the eyes are open and the "interoceptive state or focus on inside" when the eyes are closed[21, 22]. Topological organization studies have revealed that the EO condition activates attentional and oculomotor systems, whereas the EC condition activates sensory cortexes (visual, auditory, and somatosensory cortexes)[21–23]. It has also been demonstrated that the synchronicity between the visual, somatosensory, auditory, and motor systems during EC is attenuated in EO[21]. In the EC condition of this study, participants may have focused on the interoceptive state and had quicker responses to the buzzer sound than those in the EO condition. Another possible explanation is that the simple reaction time responses to auditory signals are quicker than those to visual signals[24]. Thus, the result of this study may be due, in part, to the different types of prompt used for the two experimental conditions: an auditory signal for the EC condition versus a visual signal for the EO condition.

After the COG has shifted to be over the feet, the upper part of the body must decelerate to discontinue the forward motion. Then, the leg should exert a pushing-down force against the floor and lift the body to the standing position. This force is measured and shown as the rising index. In this study, there was no significant difference in the mean rising index between the EO and EC conditions. This result is aligned with Giagazoglou et al. who reported no differences in most isometric and concentric lower limb muscles' strengths between blind and sighted participants[25]. These findings suggest that vision is not the major influence factor on muscles' ability to exert force.

Theoretically, the COG sway velocity throughout STS should be minimized. In this study, the mean COG velocity was greater in the EC condition than in the EO condition. This result is consistent those of several previous studies. In order to maintain balance, the central nervous system integrates information about variations in static and dynamic postures through several sensory inputs including those of the visual, vestibular, and somatosensory senses[11]. Perturbation of visual, vestibular, and proprioceptive information induces inter-modality re-weighting[13, 26]. Among these three sensory modalities, the visual system is predominantly used to maintain a standing posture since constraining vision induces higher postural sway during quiet standing[12]. It has been reported that visual constraint increased the postural sway of healthy subjects by 32%[27] and that balance control significantly increased with visual feedback training[28, 29], suggesting that it is beneficial to use visual input to maintain balance standing. Similarly, Giagazoglou et al. showed that the COG sway in both the anteroposterior and mediaolateral directions was greater in the EC condition in sighted participants during normal quiet stance, tandem stance, and one-leg stance. The same authors also found that COG sway was greater in blind participants than in sighted participants[25]. An increase in postural sway may increase the risk of falling[30].

In conclusion, this study has shown that constraint of vision increases postural sway and decreases weight transfer time during the performance of STS by young adults. A couple of limitations need to be noted. First, only young adults were investigated. Thus, it will be necessary to evaluate the effects of vision on the STS in other populations, including the elderly and people with neurological disorders (e.g., stroke, cerebellar ataxia). This study only investigated the COG movement parameter. Therefore, further study of the segmental joint motions and muscle activities should be considered.

ACKNOWLEDGEMENT

We would like to thank Ms. Nattawipa Wiboonsrisatja, Ms. Chanoknath Kongthon, and Ms. Kwansuda Samrejchockdee for their assistance with the data collection.

REFERENCES

1) de Bruin ED, Najafi B, Murer K, et al.: Quantification of everyday motor function in a geriatric population. J Rehabil Res Dev, 2007, 44: 417–428. [Medline] [CrossRef]
2) Mazzà C, Benvenuti F, Bimbi C, et al.: Association between subject functional status, seat height, and movement strategy in sit-to-stand performance. J Am Geriatr Soc, 2004, 52: 1750–1754. [Medline] [CrossRef]
3) Dall PM, Kerr A: Frequency of the sit to stand task: an observational study of free-living adults. Appl Ergon, 2010, 41: 58–61. [Medline] [CrossRef]
4) Buatois S, Perret-Guillaume C, Gueguen R, et al.: A simple clinical scale to stratify risk of recurrent falls in community-dwelling adults aged 65 years and older. Phys Ther, 2010, 90: 550–560. [Medline] [CrossRef]
5) Brunt D, Greenberg B, Wankadia S, et al.: The effect of foot placement on sit to stand in healthy young subjects and patients with hemiplegia. Arch Phys Med Rehabil, 2002, 83: 924–929. [Medline] [CrossRef]
6) Yamada T, Demura S: Relationships between ground reaction force parameters during a sit-to-stand movement and physical activity and falling risk of the elderly and a comparison of the movement characteristics between the young and the elderly. Arch Gerontol Geriatr, 2009, 48: 73–77. [Medline] [CrossRef]
7) Janssen WG, Bussmann HB, Stam HJ: Determinants of the sit-to-stand movement: a review. Phys Ther, 2002, 82: 866–879. [Medline]
8) Mourey F, Grishin A, d'Athis P, et al.: Standing up from a chair as a dynamic equilibrium task: a comparison between young and elderly subjects. J Gerontol A Biol Sci Med Sci, 2000, 55: B425–B431. [Medline] [CrossRef]
9) Miyoshi K, Kimura T, Yokokawa Y, et al.: Effect of aging on quadriceps muscle strength and on the forward shift of center of pressure during sit-to-stand movement from a chair. J Phys Ther Sci, 2005, 17: 23–28. [CrossRef]
10) Mak MK, Hui-Chan CW: Switching of movement direction is central to parkinsonian bradykinesia in sit-to-stand. Mov Disord, 2002, 17: 1188–1195. [Medline] [CrossRef]
11) Sousa AS, Silva A, Tavares JM: Biomechanical and neurophysiological mechanisms related to postural control and efficiency of movement: a review. Somatosens Mot Res, 2012, 29: 131–143. [Medline] [CrossRef]
12) Grace Gaerlan M, Alpert PT, Cross C, et al.: Postural balance in young adults: the role of visual, vestibular and somatosensory systems. J Am Acad Nurse Pract, 2012, 24: 375–381. [Medline] [CrossRef]
13) Polastri PF, Barela JA, Kiemel T, et al.: Dynamics of inter-modality re-weighting during human postural control. Exp Brain Res, 2012, 223: 99–108. [Medline] [CrossRef]
14) Wu G, Haugh L, Sarnow M, et al.: A neural network approach to motor-sensory relations during postural disturbance. Brain Res Bull, 2006, 69: 365–374. [Medline] [CrossRef]
15) Chen EW, Fu AS, Chan KM, et al.: Balance control in very old adults with and without visual impairment. Eur J Appl Physiol, 2012, 112: 1631–1636. [Medline] [CrossRef]
16) Lecours J, Nadeau S, Gravel D, et al.: Interactions between foot placement, trunk frontal position, weight-bearing and knee moment asymmetry at seat-off during rising from a chair in healthy controls and persons with hemiparesis. J Rehabil Med, 2008, 40: 200–207. [Medline] [CrossRef]
17) Khemlani MM, Carr JH, Crosbie WJ: Muscle synergies and joint linkages in sit-to-stand under two initial foot positions. Clin Biomech (Bristol, Avon), 1999, 14: 236–246. [Medline] [CrossRef]
18) Feland JB, Hager R, Merrill RM: Sit to stand transfer: performance in rising power, transfer time and sway by age and sex in senior athletes. Br J Sports Med, 2005, 39: e39. [Medline] [CrossRef]
19) Assaiante C, Chabeauti PY, Sveistrup H, et al.: Updating process of internal model of action as assessed from motor and postural strategies in young adults. Hum Mov Sci, 2011, 30: 227–237. [Medline] [CrossRef]
20) Kuramatsu Y, Muraki T, Oouchida Y, et al.: Influence of constrained visual and somatic senses on controlling centre of mass during sit-to-stand. Gait Posture, 2012, 36: 90–94. [Medline] [CrossRef]
21) Xu P, Huang R, Wang J, et al.: Different topological organization of human brain functional networks with eyes open versus eyes closed. Neuroimage, 2014, 90: 246–255. [Medline] [CrossRef]
22) Marx E, Deutschländer A, Stephan T, et al.: Eyes open and eyes closed as

rest conditions: impact on brain activation patterns. Neuroimage, 2004, 21: 1818–1824. [Medline] [CrossRef]
23) Hüfner K, Stephan T, Flanagin VL, et al.: Differential effects of eyes open or closed in darkness on brain activation patterns in blind subjects. Neurosci Lett, 2009, 466: 30–34. [Medline] [CrossRef]
24) Pascual-Leone A, Brasil-Neto JP, Valls-Solé J, et al.: Simple reaction time to focal transcranial magnetic stimulation. Comparison with reaction time to acoustic, visual and somatosensory stimuli. Brain, 1992, 115: 109–122. [Medline] [CrossRef]
25) Giagazoglou P, Amiridis IG, Zafeiridis A, et al.: Static balance control and lower limb strength in blind and sighted women. Eur J Appl Physiol, 2009, 107: 571–579. [Medline] [CrossRef]
26) Hwang S, Agada P, Kiemel T, et al.: Dynamic reweighting of three modalities for sensor fusion. PLoS ONE, 2014, 9: e88132. [Medline] [CrossRef]
27) Palm HG, Strobel J, Achatz G, et al.: The role and interaction of visual and auditory afferents in postural stability. Gait Posture, 2009, 30: 328–333. [Medline] [CrossRef]
28) Kang KY: Effects of visual biofeedback training for fall prevention in the elderly. J Phys Ther Sci, 2013, 25: 1393–1395. [Medline] [CrossRef]
29) Jung J, Goo B, Lee D: Effects of 3D visual feedback exercise on the balance and walking abilities of hemiplegic patients. J Phys Ther Sci, 2011, 23: 859–862. [CrossRef]
30) Hughes MA, Duncan PW, Rose DK, et al.: The relationship of postural sway to sensorimotor function, functional performance, and disability in the elderly. Arch Phys Med Rehabil, 1996, 77: 567–572. [Medline] [CrossRef]