J. Phys. Ther. Sci.
26: 543–547, 2014

Original Article

The Effects of Visual Field Conditions on Electromyography of the Lower Extremities during Reaching Tasks in Healthy Adults

Jun Hyuk Park, PT[1)], Kyeong Soon Lee, PT, PhD[2)], Tae Young Oh, PT, PhD[3)]*

[1)] *Department of Physical Therapy, Graduate School, Silla University, Republic of Korea*
[2)] *Department of Physical Therapy, Dongju University, Republic of Korea*
[3)] *Department of Physical Therapy, Silla University: 140 Baegyang-daero 700 beon-gil, Sassang-gu, Busan 670-713, Republic of Korea*

Abstract. [Purpose] The purpose of this study was to identify the effects of visual field condition on electromyography of the lower extremities during arm reaching in healthy adults, and to compare differences in electromyography of the lower extremities between young and old adults according to visual fields condition. [Subjects and Methods] Twenty-nine young persons in their 20s and 19 elderly persons in their 60s, a total of 48 persons, participated in this study. Prior to participation in the study, each subject signed an informed consent form to comply with ethics guidelines dictated by the ethics committee for research at Silla University, Korea. We collected the muscle activation data for both of tibialis anterior and gastrocnemius muscle during reaching by subjects using electromyography. Data analysis with SPSS for Window Version 20.0 was performed using repeated one-way analysis of variance according to visual fields and age. [Results] There were no significantly differences between subjects in their 20s and 60s to visual field conditions except for left tibialis anterior muscle activation during left-side reaching. Left tibialis anterior muscle activation in subjects in their 60s was higher than in subjects in their 20s during left-side reaching. [Conclusion] We determined that tibialis anterior muscle activation in subjects in their 60s was higher than in subjects in their 20s. We suggest that visual field conditions are the important factor for physical therapy interventions to improve balance and priority of intervention .

Key words: Visual field condition, Reaching task, Lower extremities muscle activity

(This article was submitted Sep. 3, 2013, and was accepted Nov. 4, 2013)

INTRODUCTION

Postural control is a system that uses visual, somatosensory, and vestibular input to understand the positions and motions of the body in space and integrate them at the level of the central nervous system[1)]. Visual sensation is a process in which the central nervous system integrates visual information from the retina and makes a decision to transform the basic data into cognitive concepts with the objective of reacting to the environment; it develops into oculomotor control, a visual field, visual concentration, and visual search and passes through shape recognition and visual memory to complete the upper level of visual cognition and induce mutual collaboration[2)]. In balance control, visual information provides information on distance and state according to changes in the surrounding environment, and the position and situation of the body are analyzed to control the extent of movement. In addition to vestibular and proprioceptive senses, it helps to control one's posture in a given situation[3)].

The dominant eye provides information on what objects are near. Regarding the relation between sight and the dominant eye, near sight is more correlated with preferential looking than long-range sight in the case of relaxed convergence, which is affected by a near point of convergence[4)]. Ibi[5)] found that the dominant eye looking at near and distant objects alternatively needed a shorter time for response and accommodation.

The nondominant eye affects postural control to maiintain balance, and the aged show a decreased ability to maintain their balance via postural control depending on whether they were looking with their dominant or nondominant eye[6, 7)].

Reaching is very important in performing motions for daily living, and normal people reaching use their trunk to stabilize their posture and to perform the motion of the upper limbs effectively when the target object is within reach[8)]. Reaching increases postural demand and requires the action of the muscles of the lower limbs and the trunk to prevent instability[9)]. Functional reach comprises forward movement of the trunk, slight extension of the ankles, and contraction of the tibialis anterior and gastrocnemius muscles[10)]. St-Onge and Feldman[11)] indicated that electri-

*Corresponding author. Tae Young Oh (E-mail: ohtaeyoung@silla.ac.kr)

cal activity of muscles correlates with their direction, size, and speed of movement. They suggested that in addition to examining balance, electromyography (EMG) could be used in patients suspected of having a balance disorder to measure muscular activation for measurement muscular strength and body movements to determining the degree of disorder and rehabilitation.

Studies on the effects of variations in visual range on balance control have been conducted in many ways. Most of the studies have looked at the differences between the dominant and nondominant eyes and on maintenance of balance, but no research has been conducted through dynamic tasks. While this study examines muscle activation in lower extremities through functional reaching as a dynamic task for controlling the body, no research has analyzed the effects of vision and age on variations in the muscles of the lower extremities. This study aims to examine the effects of reaching on muscle activation in the lower extremities according to variations in the visual range—both eyes, dominant eye, or nondominant eye—and determine the differences in muscle activation in the lower extremities by age using participants in their 20s and 60s.

SUBJECTS AND METHODS

This study was conducted with 48 persons—29 in their 20s (14 males and 15 females) and 19 in their 60s (8 males and 11 females)—who agreed to participate in the study after receiving an explanation of the study. The right eye was dominant in 28 participants, and the left eye was dominant in 20; none of them: had received medication or treatment for any ophthalmologic disease within the previous 6 months, had congenital deformities or serious internal, surgical, or neurological diseases of the limbs, or had abnormal balance abilities. All participants signed consent forms after the study procedure was explained to them in detail. The study conformed to the declaration of Helsinki and was approved by the ethics committee for research at Silla University, Korea. The participants' general characteristics are shown in Table 1.

Table 1. General characteristics of subjects (n=48)

	20s Mean±SD	60s Mean±SD
Sex (male/female)	14/15	8/11
Age (year)	26.1±3.4	62.5±3.2
Weight (kg)	59.0±11.4	64.6±10.7
Height (cm)	169.0±6.9	163.4±7.7
Left dominant eye	16	12
Right dominant eye	13	7

To attach electrodes to the tibialis anterior and gastrocnemius muscles, hair was removed from the skin above them for measurement, which was then cleaned with sterilized cotton. An electrode was used to perforem surface EMG. The mean of 3 root mean squares (RMSs) in total was estimated for 3 seconds of resting time and 5 seconds of measuring time[12].

The participants were asked to stand comfortably with their legs shoulder-width apart and with their shoulder joints raised 90 degrees. A pole was placed at the point 5 cm from the third metacarpal finger joint at 45 degrees between the right and left arms[13, 14].

The experimental procedure was as follows.

First, measurement was performed by asking the participants to look at the pole to the left with both eyes open.

Second, measurement was performed by covering the participants' nondominant eye and asking them to look to the left with the dominant eye and stretch their left arm and to look to the right and stretch their right arm.

Third, measurement was performed by covering the participants' dominant eye and asking them to look to the left with the nondominant eye and stretch their left arm and to look to the right and stretch their right arm.

The ankle strategy was selected in pursuit of consistency, and rotational movement was restricted in pelvic and shoulder joints to prevent compensation.

A Keypoint® EMG system manufactured by Medtronic was used to collect surface electromyography data. The sampling rate of elctromyographic signals was set at 1000 Hz, the frequency bandwidth was set 20–450 Hz, and the notch filter was set at 50 Hz.

The most widely used kinesis test to determine the dominant eye is the hole-in-the-card method, called an ocular dominant eye or eye dominance test[15]. The dominant eye test for this study used a card with a hole 1.5 cm in diameter in the middle of an A4 sheet (210 mm in width and 299 mm in length). The subject was asked to hold the card at eye level with both hands and look at an object 5 m ahead through the hole. In this test, the tester covers each of the subject's eyes alternatively and considers the eye focused on the object to be the dominant eye.

Repeated measures ANOVA was performed to determine the relation between age and visual field conditions. In this study, the significance level was set to $\alpha=0.05$. The commercial statistical program SPSS version 20.0 for Windows was used for statistical treatment of data.

RESULTS

Correlation between visual field conditions and age in the left tibialis anterior muscle during reaching (Table 2)

During the task of reaching with the left arm, there was significant correlation between age and visual field conditions in the left tibialis anterior muscle ($p<0.05$). There was a significant difference in the visual fields of participants in their 20s ($p<0.05$), but there was no significant difference in the visual fields of participants in their 60s.

During the task of reaching with the right arm, there was no significant correlation between age and visual field conditions in the left tibialis anterior muscle. There was no significant difference in the visual fields of participants in their 20s, but there was a significant difference in the visual fields of participants in their 60s ($p<0.05$).

Table 2. Correlation between visual field condition and age in the left tibialis anterior muscle when performing the task of reaching (unit: $\%MVC_{RMS}$)

Muscle	Reaching	Visual field	20s Mean±SD	60s Mean±SD	Between group
Left Tibialis anterior	Left reaching	Both eyes	6.3±3.6	11.471±7.1	
		Dominant eye	7.3±3.8	13.972±8.7	*
		Nondominant eye	8.2±3.8*	16.172±9.9	
	Right reaching	Both eyes	5.5±3.4	8.00±4.8*	
		Dominant eye	6.0±4.0	7.86±4.6	
		Nondominant eye	6.1±3.7	7.99±4.4	

Table 3. Correlation between visual field condition and age in the right tibialis anterior muscle when performing the task of reaching (unit: $\%MVC_{RMS}$)

Muscle	Reaching	Visual field	20s Mean±SD	60s Mean±SD	Between group
Right Tibialis anterior	Left reaching	Both eyes	4.8±2.3	9.3±7.2	
		Dominant eye	5.1±2.3	9.9±8.0	
		Nondominant eye	5.2±2.4	9.7±8.6	
	Right reaching	Both eyes	5.6±3.0	10.3±5.2	
		Dominant eye	6.9±4.3	12.7±6.8	
		Nondominant eye	8.4±4.9*	15.3±8.1	

Correlation between visual field condition and age in the right tibialis anterior muscle during reaching (Table 3)

During the task of reaching with the left arm, there was no significant correlation between age and visual field condition in the right tibialis anterior muscle. There was no significant difference in visual field condition in participants in their 20s and their 60s.

During the task of reaching with the right arm, there was no significant correlation between age and visual field condition in the right tibialis anterior muscle. There was a significant difference in visual field condition in participants in their 20s ($p<0.05$), but there was no significant difference in visual field condition in participants in their 60s.

Correlation between visual field condition and age in the left gastrocnemius muscle during reaching (Table 4)

During the task of reaching with the left arm, there was no significant correlation between age and visual field condition in the left gastrocnemius muscle. There was no significant difference in visual field condition in participants in their 20s and 60s.

During the task of reaching with the right arm, there was no significant correlation between age and visual field condition in the left gastrocnemius muscle. There was no significant difference in visual field condition in participants in their 20s and 60s.

Correlation between visual field condition and age in the right gastrocnemius muscle during reaching (Table 5)

During the task of reaching with the left arm, there was no significant correlation between age and visual field condition in the right gastrocnemius muscle. There was no significant difference in visual field condition in participants in their 20s and 60s.

During the task of reaching with the right arm, there was no significant correlation between age and visual field condition in the right gastrocnemius muscle. There was a significant difference in visual field condition in participants in their 20s ($p<0.05$), but there was no significant difference in visual field condition in participants in their 60s.

DISCUSSION

Visual sensation and proprioceptive senses are very closely correlated with maintaining posture and balance[16]. Yelnik et al.[17] showed that space perception ability could affect postural balance control. Without visual information, maintaining initial posture is improved by co-contraction of the tibialis anterior and gastrocnemius muscles; therefore, variation in the range of vision dramatically changes the strategy to maintain postural stability[18]. This result suggests that otolith or somatosensory information should cause a muscular response, and electrical activation of muscles including the tibialis anterior and gastrocnemius muscles is correlated with the slow shift in the center of gravity and the head[19]. Dominance of the hands and feet as a kinetic function of the cerebrum is functionally overlapped on both sides or fails to be expressed dually. However, dominance of the eyes is dually expressed as a sensory function expressed in the both occipital lobe cortex of the cerebrum. One can consciously use one hand; in contrast, one unconsciously uses both eyes[20].

This study examined variations in activation of the tibialis anterior and gastrocnemius muscles when performing the task of reaching by age according to variations in the

Table 4. Correlation between visual field condition and age in the left gastrocnemius muscle when performing the task of reaching (unit: $\%MVC_{RMS}$)

Muscle	Reaching	Visual field	20s Mean±SD	60s Mean±SD	Between group
Left Gastrocnemius	Left reaching	Both eyes	43.8±21.0	35.4±16.2	
		Dominant eye	59.2±29.8	46.7±15.8	
		Nondominant eye	73.6±29.9**	58.2±17.0**	
	Right reaching	Both eyes	34.0±21.1	20.7±13.2	
		Dominant eye	35.7±23.1	21.3±15.3	
		Nondominant eye	37.4±22.9	21.3±14.9	

Table 5. Correlation between visual field condition and age in the right gastrocnemius muscle when performing the task of reaching (unit: $\%MVC_{RMS}$)

Muscle	Reaching	Visual field	20s Mean±SD	60s Mean±SD	Between group
Right Gastrocnemius	Left reaching	Both eyes	31.3±20.9	23.0±13.1	
		Dominant eye	36.9±26.0	24.9±13.4	
		Nondominant eye	37.4±27.5	23.9±15.1	
	Right reaching	Both eyes	43.9±23.4	40.9±18.2	
		Dominant eye	57.8±26.6	53.1±18.7	
		Nondominant eye	71.2±26.7**	66.0±19.4**	

range of vision in both eyes, the dominant eye, and the nondominant eye. The results showed significant correlation between age and variation in the range of vision for the left tibialis anterior muscle when performing the task of reaching with the left arm and that participants either in their 20s or 60s had variations in the range of vision that affect the left gastrocnemius muscle when performing the task of reaching with the left arm and the right gastrocnemius muscle when performing the task of reaching with the right arm. Park et al.[21] assessed the effects of the dominant and nondominant eyes on postural control in a standing still position among general people aged 20–29 and 60–80 and measured them by using a dynamic posture tester. The tester graded the subjects balance based on the degree of backward and forward movement: the higher the grad, the better the subject's balance. The results showed that there was no significant difference among participants in their 20s and that the dominant eye received higher balance grades than the nondominant eye among participants in their 60s or older. The older subjects showed serious disorder of postural control with the nondominant eye. This study confirmed the findings of a prior study showing that the older the person, the worse the postural control with the nondominant eye. Park et al.[21] found that participants aged 60 or older showed higher activation of the gastrocnemius muscle with a longer section than the tibialis anterior muscle in performing the task of reaching and that the longer section for reaching caused greater bodily unrest, as the tibialis anterior and gastrocnemius muscles contribute to postural control. While Park et al.[21] examined static postural control, the present study investigated the ability to perform the task of reaching. It was thus confirmed that there were significant differences in activation of the gastrocnemius muscle with the nondominant eye in performing the task of reaching among participants either in their 20s or 60s.

As for variation by age between participants in their 20s and 60s, those in their 60s showed significantly higher activation for the right and left tibialis anterior muscles when performing the task of reaching with the left arm and for the right tibialis anterior muscle when performing the task of reaching with the right arm with both eyes, the dominant eye, and the nondominant eye. Faraldo-Garcia et al.[6] divided subjects into seven groups according to age and used a static posture analyzer and a SwayStar unit(Balance International Innovations, Iseltwald, Switzerland) to determine how balance was affected by age and gender according to eye opening and closing. The results showed that vestibular contribution began to increase at the age of 20, reached the maximum in the 30s, and decreased gradually until the 60s, after which it began to increase again. The SwayStar unit revealed that the importance of visual sensation decreased in people in their 40s and increased again in the aged group. In contrast, it was reported that the relative importance of vestibular information increased steadily, reaching the maximum by 40 to 49 years of age and beginning to decrease in the aged group. Swan et al.[22] divided the subjects into a young group aged 19 to 25 and an old group aged 60 to 74 and found that the latter could improve their balance with lower scores for posture unrest by applying a visual-perceptual task for spatial memory. Prior research found that the role of visual information began to increase due to the decline of the vestibular organs due to aging at the age of 60 or older, and the present study confirmed that higher muscle activation in the lower extremities of participants in their sixties was due to lower dependence on the vestibular organs and the greater importance of visual information with aging.

The present study found that participants in their 20s showed significantly higher activation of the right gastrocnemius muscle with both eyes, the dominant eye, and the nondominant eye open when performing the task of reaching with the left arm and significantly higher activation of the left gastrocnemius muscle with both eyes and the nondominant eye open when performing the task of reaching with the right arm.

The present study has limitations in that it is difficult to make inferences from the results of the test implemented among normal persons and that only the task of reaching was performed in those situations that could occur in daily life. In consideration of these limitations, further research needs to be conducted to complement the present study through more diverse clinical applications and employment of diverse methods of performing a task.

In this study, we found that there is no correlation between variation in the range of vision and age, the tibialis anterior and gastrocnemius muscles are used to maintain balance according to variations in the range of vision, and the gastrocnemius muscle usually shows higher electrical activation than the tibialis anterior muscle in performing the task of reaching. Muscles for maintaining balance show greater activation in task performance with the nondominant eye, and older people have increased activation of the tibialis anterior muscle for postural control. Further research should examine muscle activation according to variations in the range of vision when performing more diverse tasks and apply them to hemiplegia with neglect syndrome to decide on the dominant eye, which will be useful in rehabilitation.

REFFERENCES

1) Lopez RL, Fernandez NP: Pruebas vestibulares y posturografia. Rev Med Univ Navarra, 2003, 47: 21–28.
2) Warren M: Evaluation and treatment of visual deficit. In: Pedretti LW, Occupational therapy practice skill for physical dysfunction. St Louis: Mosby, 2001, pp 386–421.
3) Umphred DA: Neurological rehabilitation, 5th ed. St Louis: Mosby, 2007, pp 616–660.
4) Porac C, Whitford FW, Coren S: The relationship between eye dominance and monocular acuity: an additional consideration. Am J Optom Physiol Opt, 1976, 53: 803–806. [Medline] [CrossRef]
5) Ibi K: Characteristics of dynamic accommodation responses: comparison between the dominant and non-dominant eyes. Ophthalmic Physiol Opt, 1997, 17: 44–54. [Medline] [CrossRef]
6) Faraldo-García A, Santos-Pérez S, Crujeiras-Casais R, et al.: Influence of age and gender in the sensory analysis of balance control. Eur Arch Otorhinolaryngol, 2012, 269: 673–677. [Medline] [CrossRef]
7) Park RY, Kee HS, Kang JH, et al.: Effect of dominant versus non-dominant vision in postural control. Ann Rehabil Med, 2011, 35: 427–431. [Medline] [CrossRef]
8) Kim KS, Yoo HS, Jung DH, et al.: Analysis of movement time and trunk motions according to target distances and use of sound and affected side during upper limb reaching task in patient with hemiplegia. KAUPTP, 2010, 17: 36–42.
9) Shumway-Cook A, Woollacott MH: Motor Control: Translating Research into Clinical Practice Translating Research into Clinical Practice. 2006, pp 533–561.
10) Jonsson E, Henriksson M, Hirschfeld H: Does the functional reach test reflect stability limits in elderly people? J Rehabil Med, 2003, 35: 26–30. [Medline] [CrossRef]
11) St-Onge N, Feldman AG: Referent configuration of the body: a global factor in the control of multiple skeletal muscles. Exp Brain Res, 2004, 155: 291–300. [Medline] [CrossRef]
12) Fransson PA, Gomez S, Patel M, et al.: Changes in multi-segmented body movements and EMG activity while standing on firm and foam support surfaces. Eur J Appl Physiol, 2007, 101: 81–89. [Medline] [CrossRef]
13) Park JS, Kwon OY, Choi HS, et al.: Effects of the movement strategies on functional forward reach in standing. KAUPTP, 2000, 7: 46–54.
14) Ko BW, Song WK, Kim K, et al.: The effect of direction of targets on muscle activity healthy and stroke during task. HCE, 2012, 7: 506–510.
15) Heinrich SP, Kromeier M, Bach M, et al.: Vernier acuity for stereodisparate objects and ocular prevalence. Vision Res, 2005, 45: 1321–1328. [Medline] [CrossRef]
16) Patel M, Gomez S, Lush D, et al.: Adaptation and vision change the relationship between muscle activity of the lower limbs and body movement during human balance perturbations. Clin Neurophysiol, 2009, 120: 601–609. [Medline] [CrossRef]
17) Yelnik AP, Kassouha A, Bonan IV, et al.: Postural visual dependence after recent stroke: assessment by optokinetic stimulation. Gait Posture, 2006, 24: 262–269. [Medline] [CrossRef]
18) De Nunzio AM, Nardone A, Schieppati M: Head stabilization on a continuously oscillating platform: the effect of a proprioceptive disturbance on the balancing strategy. Exp Brain Res, 2005, 165: 261–272. [Medline] [CrossRef]
19) Buchanan JJ, Horak FB: Emergence of postural patterns as a function of vision and translation frequency. J Neurophysiol, 1999, 81: 2325–2339. [Medline]
20) Lee DY, Song CH: The effects of visuo-prceptual task exercise on postural balance and independent pattern in hemiplegic chronic stroke patients. J Spec Educ Rehabil Sci, 2009, 48: 65–84.
21) Park JS, Nam YK, Kim MJ, et al.: Analysis of muscular activity of tibialis anterior and gastrocnemius muscle in functional reach test of elderly according to different surfaces. J Korean Acad Clin Electrophysiol, 2011, 9: 25–30. [CrossRef]
22) Swan L, Otani H, Loubert PV, et al.: Improving balance by performing a secondary cognitive task. Br J Psychol, 2004, 95: 31–40. [Medline] [CrossRef]