J. Phys. Ther. Sci.
26: 1657–1659, 2014

Case Study

Neck Proprioceptive Training for Balance Function in Patients with Chronic Poststroke Hemiparesis: A Case Series

Gyoung-Mo Kim, PT, MSc[1)], Duck-Won Oh, PT, PhD[2)*]

[1)] *Department of Physical Therapy, Division of Health Science, Baekseok University, Republic of Korea*
[2)] *Department of Physical Therapy, College of Health Science, Cheongju University: 298 Daesung-ro, Sangdang-gu, Cheongju 360-764, Republic of Korea*

Abstract. [Purpose] This study investigated the effects of neck proprioceptive training on the balance of patients with chronic poststroke hemiparesis. [Subjects] Three patients with chronic stroke were recruited for this study. [Methods] The subjects underwent neck proprioceptive training using the red light of a laser pointer (30 min daily, five times per week for 4 weeks). Outcome measures included the stability and weight distribution indices measured with a Tetrax system and Timed Up and Go (TUG) and proprioception tests. [Results] For all subjects, the stability and weight distribution indices increased by 1.87–9.66% in the eyes-open and eyes-closed conditions, and the TUG and proprioception test scores improved by 2.49–15.27%. [Conclusion] Neck proprioceptive training may be a good option for improving the balance function of patients with chronic poststroke hemiparesis.
Key words: Neck proprioceptive training, Balance, Stroke

(This article was submitted Feb. 20, 2014, and was accepted Apr. 10, 2014)

INTRODUCTION

Stroke impairs an individual's motor, sensory, cognitive, and emotional control. An individual's capability to select sensory information for postural stability and process it suitably in spatial and temporal templates may be remarkably impaired by a stroke, leading to delayed balance reactions in various situations[1)]. These problems make postural control difficult and consequently contribute to disturbed performance of functional activities and walking[2)]. Furthermore, inappropriate somatosensory information arising from the affected side likely contributes to postural instability[3)].

Recent concepts require the understanding of trunk and neck controls that are required to maintain static and dynamic balance, although the proprioceptive feedback mechanism within the lower limbs has been traditionally considered an important component of optimal balance[4)]. In impaired proprioceptive processes of the lower limbs, compensation by the vestibulospinal reflexes and proprioceptive input from the cervical region may be inevitable for maintaining appropriate body balance[5)]. With the high density of proprioceptors such as muscle spindles and the Golgi tendon organ, the cervical region plays an essential role in an individual's ability to recognize their spatial orientation and body position and maintain equilibrium in changing environments during daily activities[6)]. That is, its contributions to maintenance of static and dynamic balance may be responsible for the regular connection between afferent inputs from joint and muscle proprioceptors and those from visual and vestibular systems.

Although some studies have investigated the effects of sensory feedback for improving balance and postural control, their findings have failed to provide sufficient evidence[7, 8)]. Therefore, in this field, studies should focus on exploring novel methods to reinforce the balance control mechanism in patients with chronic poststroke hemiparesis, which increases functional performance, rather than investigating the efficacy of current therapeutic strategies. To our knowledge, proprioceptive training using neck movements has received little attention in the management of patients with chronic poststroke hemiparesis, despite its easy application and comfort of use for clinicians. Hence, this study aimed to investigate a proprioceptive training procedure using cervical movement and report the results.

SUBJECTS AND METHODS

The subjects included three patients with chronic poststroke hemiparesis. The inclusion criteria were as follows: first onset of stroke and onset duration of >6 months, no cognitive impairment (>24 points on the mini-mental state examination-Korean version)[9)], ability to stand and walk 10 meters independently without supervision; and no orthopedic or other neurological disorders that impede balance

*Corresponding author. Duck-Won Oh (E-mail: odduck@cju.ac.kr)

function. Prior to initiation of the study, detailed information about the experimental procedure and safety were provided to the subjects, each of whom signed a written consent form. All subjects agreed to the publishing of their study data. General subject characteristics are summarized in Table 1.

Outcome measures included the stability and weight distribution indices under the eyes-open and eyes-closed conditions measured by a Tetrax system (Sunlight Medical Ltd., Ramat Gan, Israel) using four force plates to detect the ground reaction force for both feet during standing, Timed Up and Go (TUG), and proprioception tests.

The Tetrax system measures the pressure transferred to the force plates during standing and analyzes the data after amplification and filtering. Measurements were performed under eyes-open and eyes-closed conditions. The stability index represents the extent of postural sway and an individual's ability to compensate for it, and greater instability is indicated by greater values[10]. Further, the weight distribution index suggests the extent of weight distribution to both sides when standing on the force plates, and a higher score indicates a more severe pathological condition[10]. The test-retest reliability of measurements obtained with the Tetrax system is reportedly high ($r = 0.88$)[11]. The TUG is an assessment tool that is used to evaluate a subject's mobility and dynamic balance. In the TUG, subjects are instructed to rise from a chair, walk 3 m, turn around, return to the chair, and sit down[12]. The intra- and inter-test reliabilities were $r = 0.99$ and $r = 0.98$, respectively[13]. The proprioception test was performed using a method that blindly assesses the repositioning error of the cervicocephalic region[14]. For this test, subjects sat on a chair with a backrest facing a screen placed 1 m in front of them. A laser pointer was positioned at the middle top of the head to indicate the movement of the neck on the screen with a red dot. The first step was to identify the neutral head position by maintaining the red dot within a round 1-cm^2 area for 3 s, and then the subjects rotated their heads 30° to the right. The subjects were then asked to return to the neutral head position. The outcome was determined by measuring the error interval between the neutral position and the repositioning point. Data were averaged over three trials.

Subjects received a daily conventional therapy program, which comprised strengthening and stretching exercises for the upper and lower limbs and therapist-guided functional training, followed by proprioception training. Proprioception training included a self-detection effort to trace a neutral position from various directions of cervical movement[15]. The initial step, in which the subjects sat on a chair with a backrest, was the same as that for the proprioception test procedure. During the training, the trajectory of the red dot projected from the laser pointer offered real-time feedback about cervical movement. Prior to the training, a round area with a 30-cm diameter was marked on the screen at head height. All training procedures were performed with the eyes covered with an eye patch. To recognize the neutral position of the neck, the subjects maintained a neck position and then directed the red point to the round target on the screen for 3 s. After this procedure, the neck was positioned at the end range of flexion, extension, and rotation for 3 s each, the order of which was randomly generated using Microsoft Excel. The patients were then instructed to return to the neutral position. When they managed to successfully aim the laser pointer at the target area for 3 s, verbal feedback was provided. The training was performed for 30 min daily, 5 times a week for 4 weeks (for a total of 20 sessions).

This study was a case series with the aim of reporting the treatment findings of a very small population with chronic stroke. Thus, to illustrate the intervention effects directly, outcome data were provided as actual pre- and post-test scores without the use of statistical analysis.

Table 1. General characteristics of the subjects

	Subject 1	Subject 2	Subject 3
Gender	Female	Female	Male
Age (years)	62	64	66
Duration since stroke (months)	59	54	84
Hemiplegic side	Left	Left	Right
Stroke type	Hemorrhage	Hemorrhage	Hemorrhage
MMEST-K	28	29	28

MMSE-K: mini-mental state examination-Korean version

RESULTS

Table 2 represents the changes in the stability index, weight distribution index, TUG test score, and proprioception test score. The stability indices for subjects 1, 2, and 3 decreased by 4.17%, 3.96%, and 3.54% under the eyes-open conditions, respectively, and by 6.16%, 9.66%, and 1.87% under the eyes-closed conditions, respectively. The weight distribution index was reduced by 3.45%, 4.81%, and 1.39% under the eyes-open conditions, respectively, and by 7.63%, 11.41%, and 9.61% under the eyes-closed conditions, respectively. The TUG test scores of all subjects showed improvements of 3.32%, 3.62%, and 2.49% respectively, and the proprioception test scores increased by 15.57%, 3.24%, and 11.45%, respectively.

DISCUSSION

It is generally accepted that systematic processing and integration of visual, vestibular, and proprioceptive information from each part of the body has a great influence on maintaining optimal postural stability and movement control in space during daily activities. Hence, impaired sensory perceptions after stroke may be among the greatest challenges for maintaining postural control and stable balance patterns[2]. The pathological changes of the nervous system, the lack of movement and asymmetrical posture, contribute to decreased proprioceptive function after stroke.

Our results focused on the feasibility of neck proprioceptive training for improving the balance function of patients after stroke and demonstrated favorable effects on static and dynamic balance function. Asymmetrical posture in stroke may be closely associated with a biased weight distri-

Table 2. Comparison of pre- and post-training outcomes for all subjects

	Subject 1		Subject 2		Subject 3	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Stability index						
eyes-open	23.51	22.53	24.52	23.55	28.56	27.55
eyes-closed	48.67	45.67	48.98	44.25	51.23	50.27
Weight distribution index						
eyes-open	7.82	7.55	8.32	7.92	9.36	9.23
eyes-closed	10.48	9.68	11.57	10.25	12.69	11.47
TUG (sec)	15.05	14.55	17.12	16.50	15.69	15.30
Proprioception test (cm)	8.93	7.54	8.96	8.67	9.96	8.82

TUG: Timed Up and Go test

bution to the unaffected side, leading to postural instability with detrimental effects on balance during various activities. The neck is an essential component in the regulation of one's head and body orientation in space and is necessary for maintaining balance[16]. The abundance of peripheral proprioceptive organs in the cervical region, especially in the upper cervical muscles, is greatly advantageous in controlling and organizing somatosensory information related to balance and movement[7]. Proprioceptive information from these organs plays an important role in an individual's ability to adapt to a changing environment by controlling postural perturbations. This knowledge supports our hypothesis that neck proprioceptive training improves the balance function of patients after stroke.

As described here, the stability and weight distribution indices showed greater improvements under the eyes-closed conditions than under the eyes-open conditions. Vision provides strong sensory feedback to support an individual's physical control and performance and is frequently used to compensate for impaired proprioceptive function during movement[17]. However, under conditions of visual deprivation, proprioceptive input from the cervical region may be a major factor in the recognition of spatial orientation, position, and equilibrium[7]. In such aspects, the favorable outcome of the proprioceptive test observed here may be strongly related to the improved static and dynamic balance scores. The improved TUG test scores observed here imply that neck proprioceptive training can be adapted for improving mobility and walking after stroke.

Although the implication is that the use of neck proprioceptive training may be clinically feasible for increasing balance function, there are several limitations to generalizing our results. First, because this study included only three patients after stroke and there was no control group, it may be difficult to interpret our findings beyond this group. Second, our purpose was to assess the balance function of these patients after training; therefore, the results cannot be understood as physical performance findings. Finally, the findings did not demonstrate our subjects' abilities in a changing outdoor environment. Therefore, further studies are needed to validate our results.

REFERENCES

1) Bonan IV, Colle FM, Guichard JP, et al.: Reliance on visual information after stroke. Part I: Balance on dynamic posturography. Arch Phys Med Rehabil, 2004, 85: 268–273. [Medline] [CrossRef]
2) Bohannon RW, Leary KM: Standing balance and function over the course of acute rehabilitation. Arch Phys Med Rehabil, 1995, 76: 994–996. [Medline] [CrossRef]
3) Allum JH, Honegger F: Interactions between vestibular and proprioceptive inputs triggering and modulating human balance-correcting responses differ across muscles. Exp Brain Res, 1998, 121: 478–494. [Medline] [CrossRef]
4) Horak FB, Shupert CL, Dietz V, et al.: Vestibular and somatosensory contributions to responses to head and body displacements in stance. Exp Brain Res, 1994, 100: 93–106. [Medline] [CrossRef]
5) Bloem BR, Allum JH, Carpenter MG, et al.: Triggering of balance corrections and compensatory strategies in a patient with total leg proprioceptive loss. Exp Brain Res, 2002, 142: 91–107. [Medline] [CrossRef]
6) Boyd-Clark LC, Briggs CA, Galea MP: Muscle spindle distribution, morphology, and density in longus colli and multifidus muscles of the cervical spine. Spine, 2002, 27: 694–701. [Medline] [CrossRef]
7) Barclay-Goddard R, Stevenson T, Poluha W, et al.: Force platform feedback for standing balance training after stroke. Cochrane Database Syst Rev, 2004, 4: CD004129. [Medline]
8) Geurts AC, de Haart M, van Nes IJ, et al.: A review of standing balance recovery from stroke. Gait Posture, 2005, 22: 267–281. [Medline] [CrossRef]
9) Folstein MF, Folstein SE, McHugh PR: "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res, 1975, 12: 189–198. [Medline] [CrossRef]
10) Kohen-Raz R, Kohen-Raz A, Erel J, et al.: Postural control in pilots and candidates for flight training. Aviat Space Environ Med, 1994, 65: 323–326. [Medline]
11) Schwartz S, Segal O, Barkana Y, et al.: The effect of cataract surgery on postural control. Invest Ophthalmol Vis Sci, 2005, 46: 920–924. [Medline] [CrossRef]
12) Shumway-Cook A, Brauer S, Woollacott M: Predicting the probability for falls in community-dwelling older adults using the Timed Up & Go Test. Phys Ther, 2000, 80: 896–903. [Medline]
13) Podsiadlo D, Richardson S: The timed "Up & Go": a test of basic functional mobility for frail elderly persons. J Am Geriatr Soc, 1991, 39: 142–148. [Medline]
14) Loudon JK, Ruhl M, Field E: Ability to reproduce head position after whiplash injury. Spine, 1997, 22: 865–868. [Medline] [CrossRef]
15) Revel M, Andre-Deshays C, Minguet M: Cervicocephalic kinesthetic sensibility in patients with cervical pain. Arch Phys Med Rehabil, 1991, 72: 288–291. [Medline]
16) Bove M, Courtine G, Schieppati M: Neck muscle vibration and spatial orientation during stepping in place in humans. J Neurophysiol, 2002, 88: 2232–2241. [Medline] [CrossRef]
17) Piontek T, Ciemniewska-Gorzela K, Szulc A, et al.: Strategy of visual proprioceptive control in patients with injury to the anterior cruciate ligament of the knee and healthy individuals (soccer players). Biol Sport, 2012, 29: 57–62. [CrossRef]