J. Phys. Ther. Sci. 29: 1539–1542, 2017

The Journal of Physical Therapy Science

Original Article

Postactivation depression of soleus H-reflex increase with recovery of lower extremities motor functions in patients with subacute stroke

Yu Kawaishi, RPT, PhD[1)*], Naoki Matsumoto, RPT[1)], Toshiya Nishiwaki, RPT[1)], Tatsuro Hirano, RPT[1)]

[1)] *Department of Rehabilitation, Kobe Rehabilitation Hospital: 14-1 Nakaichiriyama, Shimotanigami-Aza, Ymada-cho, Kita-ku, Kobe-shi, Hyogo 651-1102, Japan*

Abstract. [Purpose] The soleus H-reflex is depressed at stimulation rates greater than 0.1 Hz. This reflex depression is referred to as postactivation depression. Postactivation depression reflects the reduced efficacy of the Ia-motoneurons synapses when they are evaluated after a previous activation. The aim of this study was to determine whether the recovery of motor functions in the lower extremities affects the PAD of the soleus H-reflex in patients with subacute stroke undergoing rehabilitation. [Subjects and Methods] Eight patients with subacute stroke patients were recruited. Postactivation depression, Fugl-Meyer score (lower-limb portion), walking velocity, the Modified Ashworth Scale, and center of pressure sway during standing were measured within three days of admission to rehabilitation and 50 days later. [Results] After rehabilitation, Fugl-Meyer scores, center of pressure path length, and walking velocity were significantly improved, and postactivation depression had significantly increased. There was a significant positive correlation between the rates of change of postactivation depression and center of pressure path length. [Conclusion] The results demonstrated that postactivation depression is partially normalized after rehabilitation in patients with subacute stroke, and suggested that the recovery in lower extremity function after stroke particularly standing stability is affected by spinal synaptic plasticity.

Key words: Stroke, Soleus H-reflex, Postactivation depression

(This article was submitted Apr. 12, 2017, and was accepted Jun. 5, 2017)

INTRODUCTION

The H-reflex is an electrical stimulation-induced analog of a monosynaptic reflex. The H-reflex test is extensively used to examine the influence of group Ia monosynaptic projection on spinal motoneuron activation[1)]. The H-reflex amplitude may vary depending on the excitability of the Ia afferent spinal loop. The H-reflex is depressed at stimulation rates greater than 0.1 Hz and is usually completely abolished at 10 Hz[2)]. This reflex depression is referred to as postactivation depression (PAD)[3)]. PAD is sustained by a mechanism of homosynaptic depression acting at the Ia-motoneuron synapse and results from a decrease in transmitter release due to repetitive activation of the synapse[2)]. In comparison to healthy controls, PAD has been found to be lower in patients with stroke[4, 5)]. Furthermore, a positive correlation has been reported between the diminished PAD and the severity of spasticity following stroke[6)].

However, the relationship between PAD and the recovery of motor ability in patients with stroke remains unclear. It has been reported that PAD increases after motor training in healthy subjects[7)]. Therefore, it can be hypothesized that PAD will change in relation to the recovery of motor ability due to rehabilitation after stroke.

The aim of this study was to determine whether the recovery of motor functions in the lower extremities affects the PAD

---

*Corresponding author. Yu Kawaishi (E-mail: yuyakedomo@yahoo.co.jp)

of the soleus H-reflex in patients with subacute stroke undergoing rehabilitation.

SUBJECTS AND METHODS

Eight patients with subacute post-stroke hemiplegia were recruited from the patients admitted to the hospital. The inclusion criteria were as follows: patients with hemiplegia diagnosed with stroke; onset of stroke three months or more prior to the study; the need of static standing and a cane walking independently; and those who understood the purpose of the study and the consented to participate. The experimental procedures were approved by the Kobe Rehabilitation Hospital ethics committee (F27-5). General characteristics of the subjects are presented in Table 1. All participants received conventional rehabilitation consisting of physical and occupational therapy for two hours per day during the investigation. Patients gave their informed consent prior to the experimental procedures, which were approved by the Kobe Rehabilitation Hospital ethics committee.

PAD, lower-extremity motor function, walking velocity, spasticity of the ankle extensor muscles, and quiet standing balance were measured over 3 days on admission to rehabilitation and 50 days after the first measurement. Lower-extremity motor function, walking velocity, and spasticity of the ankle extensor muscles were assessed using the lower limb portion of the Fugl-Meyer test, 10-meter walking test (10MWT), and the Modified Ashworth Scale (MAS) respectively. To measure quiet standing balance, center of pressure (COP) sway during static standing was assessed under both eyes open and closed conditions. During measurement, subjects were instructed to stand quietly for 30 seconds on a stable force plate with their arms at their sides and their feet 10 cm apart (ANIMA, GP-6000). Three trials were performed for each condition. The COP signals transmitted from the force plate were amplified and sampled at 100 samples/s. The COP path length over the time of a trial was calculated. The mean COP path length of the three trials was used as a measure of quiet standing balance.

PAD was quantified as the ratio between H-reflex amplitude at 1 Hz and at 0.1 Hz, consistent with previously reported methods[8)]. During testing, subjects were instructed to lie on a bed relaxed in a prone position. Surface electromyograms (EMG) were recorded from the soleus muscle using Ag/AgCl surface electrodes with a 20 mm inter-electrode distance. Recorded EMG signals were amplified (10 Hz–1 kHz), stored, and analyzed by an evoked-potential-measuring system (Nihon Kohden MEB-9104). For electrical stimulation of the soleus H-reflex, a bar-type paired electrode was placed on the tibial nerve, longitudinally, at the midline of the popliteal fossa. Rectangular wave pulses (1 ms in duration) were applied with an evoked-potential-measuring system (Nihon Kohden, MEB-9104).

At the beginning, to record the H-reflex and M-wave recruitment curve, the stimulus intensity was increased gradually by 0.5 mA from the threshold of the H-reflex to the supramaximal value of the M-wave. The inter-stimulus interval was at least 10 s to avoid the possible influences of PAD[9)]. The Hmax/Mmax (maximum H-reflex to maximum M-wave) ratio was then calculated. After Hmax/Mmax ratio calculation, 20 soleus H-reflexes were evoked at 0.1 Hz frequency. The stimulus intensity was set to produce H-reflexes with an amplitude ranging from 30% to 50% of H-max and were preceded by a small M-wave. Afterwards, 20 soleus H-reflexes were elicited at 1 Hz frequency at the same intensity. PAD was defined as the ratio of the mean amplitude of the H-reflexes obtained at 1 Hz to the mean amplitude of the H-reflexes obtained at 0.1 Hz. The greater the 1 Hz/0.1 Hz ratio represents smaller the PAD.

The Wilcoxon signed-rank test was used to compare each parameter between baseline and the day 50 measurement. The rate of change of each parameter was calculated as the value of the first measurement minus the value of the day 50 measurement divided by the value of first measurement. To examine the relationship between the improvement of each clinical measure and change in PAD, Spearman's rank correlation coefficient was used, and the correlation between the rate of change of PAD and the rate of change of the other clinical parameters was caluculated. All hypotheses tests were evaluated at $p<0.05$. All data were analyzed using Dr. SPSS 2 (SPSS Inc.).

RESULTS

The results of all clinical measures and PAD are shown in Table 2. After 50 days of rehabilitation, COP path length during quiet standing under both eyes open and closed conditions, Fugl-Meyer score, and walking velocity were improved significantly and PAD increased significantly. However, the MAS score did not change significantly.

The results of Spearman's rank correlation coefficient between the rate of change of PAD and the rate of change of the other clinical measures are shown in Table 3. There was a significant positive correlation between the rate of change of PAD and the rate of change of the COP path length during quiet standing under the eyes closed conditions. However, the other clinical measures did not reveal a significant correlation with the rate of change of PAD.

DISCUSSION

The results showed that PAD increased after 50 days of rehabilitation and was accompanied by an increase in motor ability. This indicates that motor training for rehabilitation can induce changes in synaptic efficacy between the Ia fibers and motoneurons in patients post stroke. In previous studies, they were shown that motor training, including treadmill walking and robotic gait training, induced PAD to normalize partially in patients with spinal cord injury[10)] and stroke[8)]. The suggested

Table 1. General characteristics of the subjects

Gender (Male/Female)	7/1
Age (years)	61.1 ± 12.3
Height (cm)	165.5 ± 2.6
Weight (kg)	60.6 ± 7.2
Type of stroke (Infarction/Hemorrhage)	6/2
Duration (days)	113.4 ± 49.7

Mean ± SD

Table 2. The results of all clinical measures and PAD

	First measurement	After 50 days
PAD	0.92 ± 0.11	0.80 ± 0.19*
Lower limb portion of the Fugl-Meyer test	18.0 ± 6.5	21.3 ± 7.9*
10-meter walking test(s)	39.3 ± 34.5	26.0 ± 24.3*
Modified Ashworth Scale	1.5 ± 0.9	1.6 ± 1.1
COP path length during quiet standing		
Eyes open condition (cm)	68.6 ± 27.1	53.9 ± 15.9*
Eyes closed condition (cm)	111.1 ± 51.1	83.5 ± 32.7*

Mean ± SD. *p<0.05

Table 3. The correlation between the rate of change of PAD and the rate of change of each clinical measure

	Correlation coefficient
Lower limb portion of the Fugl-Meyer test	−0.49
10-meter walking test	0.07
Modified Ashworth Scale	0.09
COP path length during quiet standing	
Eyes open condition	0.21
Eyes closed condition	0.71*

Mean ± SD. *p<0.05

mechanism for this finding is that repetitive sensory inputs from soleus muscle spindles induced by gait training may have led to the reorganization of spinal neural circuits8). In the present study, participants has been received physical therapy between the first and second measurements, and physical therapy consisted of multiple motor exercises including gait training, balance training, ballistic strength training, and lower limb stretching, among other activities. Therefore, participants also received repetitive sensory input from the soleus muscle spindles during the investigation, which could have induced an increase in PAD.

Another result of this study is that the rate of change of PAD was correlated to the rate of change of the COP path length during quiet standing under the eyes closed conditions. This indicates that the recovery of balance ability is accompanied by the normalization of synaptic efficacy between the Ia fibers and motoneurons in patients with subacute stroke.

In previous studies, it has been reported that balance training induces downward modulation of the H-reflex11, 12). Moreover, it was founded that ballet dancers, who require a high level of balance ability as athletes, demonstrated greater depression of H-reflexes than other athletes trained for gross physiological power (e.g., runners, swimmers, and cyclists)13). These findings reveal that there is a relationship between balance ability and spinal reflex modulation, and support the present results.

Furthermore, PAD was significantly correlated to COP path length in only the eyes closed condition in static standing and not in the eyes open condition. With regard to this finding, static standing in the eyes closed condition requires subjects to control their posture without relying on visual information, and therefore seems to be based predominantly on somatosensory feedback. The extent of PAD reflects the effect of somatosensory inputs from the lower extremity muscles on the spinal reflex. Therefore, it is likely that the extent of improvement in standing balance ability in the eyes closed condition was more substantially affected by a change in PAD.

On the other hand, the rate of change of PAD did not show significant correlation with the rate of change of the MAS. Nevertheless previous studies have revealed a relationship between diminished PAD and the severity of spasticity in patients with hemiplegia6). With regard to this finding, only one of eight subjects in the present study demonstrated a change in the MAS during the investigation. Therefore, the relationship between the normalization of PAD and the rate of change of spasticity in patients with subacute stroke who are recovering their motor ability may not to have been examined correctly in the present study. Further research including more subjects with stroke is needed to verify this.

In conclusion, the present results demonstrate that PAD is partially normalized after a course of motor rehabilitation in patients with subacute stroke and the rate of change of PAD is related to the extent of improvement in static standing sway. This suggests that the recovery of lower extremity function after stroke particularly balance ability is affected by spinal plasticity of synaptic transmission.

REFERENCES

1) Magladery JW, Porter WE, Park AM, et al.: Electrophysiological studies of nerve and reflex activity in normal man. IV. The two-neurone reflex and identification of certain action potentials from spinal roots and cord. Bull Johns Hopkins Hosp, 1951, 88: 499–519. [Medline]
2) Hultborn H, Illert M, Nielsen J, et al.: On the mechanism of the post-activation depression of the H-reflex in human subjects. Exp Brain Res, 1996, 108: 450–462. [Medline] [CrossRef]
3) Crone C, Nielsen J: Methodological implications of the post activation depression of the soleus H-reflex in man. Exp Brain Res, 1989, 78: 28–32. [Medline] [CrossRef]
4) Grey MJ, Klinge K, Crone C, et al.: Post-activation depression of soleus stretch reflexes in healthy and spastic humans. Exp Brain Res, 2008, 185: 189–197. [Medline] [CrossRef]
5) Aymard C, Katz R, Lafitte C, et al.: Presynaptic inhibition and homosynaptic depression: a comparison between lower and upper limbs in normal human subjects and patients with hemiplegia. Brain, 2000, 123: 1688–1702. [Medline] [CrossRef]
6) Lamy JC, Wargon I, Mazevet D, et al.: Impaired efficacy of spinal presynaptic mechanisms in spastic stroke patients. Brain, 2009, 132: 734–748. [Medline] [CrossRef]
7) Meunier S, Kwon J, Russmann H, et al.: Spinal use-dependent plasticity of synaptic transmission in humans after a single cycling session. J Physiol, 2007, 579: 375–388. [Medline] [CrossRef]
8) Trompetto C, Marinelli L, Mori L, et al.: Postactivation depression changes after robotic-assisted gait training in hemiplegic stroke patients. Gait Posture, 2013, 38: 729–733. [Medline] [CrossRef]
9) Palmieri RM, Ingersoll CD, Hoffman MA: The hoffmann reflex: methodologic considerations and applications for use in sports medicine and athletic training research. J Athl Train, 2004, 39: 268–277. [Medline]
10) Trimble MH, Kukulka CG, Behrman AL: The effect of treadmill gait training on low-frequency depression of the soleus H-reflex: comparison of a spinal cord injured man to normal subjects. Neurosci Lett, 1998, 246: 186–188. [Medline] [CrossRef]
11) Trimble MH, Koceja DM: Modulation of the triceps surae H-reflex with training. Int J Neurosci, 1994, 76: 293–303. [Medline] [CrossRef]
12) Trimble MH, Koceja DM: Effect of a reduced base of support in standing and balance training on the soleus H-reflex. Int J Neurosci, 2001, 106: 1–20. [Medline] [CrossRef]
13) Nielsen J, Crone C, Hultborn H: H-reflexes are smaller in dancers from The Royal Danish Ballet than in well-trained athletes. Eur J Appl Physiol Occup Physiol, 1993, 66: 116–121. [Medline] [CrossRef]