뇌졸중 후 편마비 환자의 체위변화에 따른 척수운동신경원 흥분성 변화

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Changes in the Spinal Motor Neuron Excitability Depending on Postural Changes in Post Stoke Hemiplegics

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Purpose: The purpose of this study was to measure changes in the H-reflex and V wave under loading conditions (e.g. prone and standing position) and to investigate whether postural change would affect the H-reflex and V wave in post stroke hemiplegic patients.

Methods: Thirty persons with hemiplegia resulting from stroke (20 males, 10 females) participated in this study. Electromyography (EMG) was used to electrically stimulate and record the soleus H-reflexes and V waves under various loading conditions. The normality of the distribution of each variable (H latency, H_{max}/M_{max} ratio, V_{max}/M_{max} ratio) was tested using the Kolmogorov-Smirnov test. The means of normally distributed continuous data were assessed by independent t-test (α=0.05).

Results: There were statistically significant differences in H_{max}/M_{max} ratio ($p<0.01$), V_{max}/M_{max} ratio ($p<0.01$), H latency ($p<0.01$) among the prone and standing position.

Conclusion: We found that the H-reflex and V wave in standing position was more active to weight bearing load than prone position.

Keywords: Loading, H-reflex, V wave, Stroke

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Ⅰ. Introduction

The H-reflex study is commonly used to investigate the excitability of the spinal motoneuron pool that may be affected by the inputs from various afferent and efferent pathways.[1] The H-reflex is a short latency electrical analogue of monosynaptic reflex. Assessment of soleus H-reflex (SOL H reflex)requires delivery of electrical stimulation to a posterior tibial nerve, and EMG recording from a muscle innervated by the nerve.[2] The H-reflex is used for a neurophysiological study to assess spasticity or/and hypertonus, for example in patients with spinal cord injury, post stroke,[3] cerebral palsy and traumatic brain injury. This SOL H reflex study has recently been used clinically in assessments of recovery of hemiplegic patients.[4]

The V wave may be a relatively simple method to analysisthe modulation adaptive neural alterations at spinal and supraspinal level during voluntary contractions, potentially involving changes in αα-motoneuron excitability and descending motor drive. If the maximum amplitude of H wave and M wave, the maximum ratio (H_{max}/M_{max} ratio) which can be quantified. Moreover, the concomitant study of activation level, reflex responses (Hmax, Hsup) and V wave may be an approach to studying nervous adaptations occurring after hypoactivity and/or hyperactivity.[5]

The soleus muscle is investigated because this muscle activationsan essential role in control of upright standing posture.[6] The SOL H-reflexis frequently used to examine the excitability of motoneurons in relation to movement patterns (e.g. muscle activation, posture, and locomotion) and clinical interventions (e.g. therapeutic effect). For example, The SOL H-reflex study has been used to assess the spinal motoneuronal excitability in stroke patients after a certain period of rehabilitation.[7]

The reliability of SOL H-reflex during rest has been extensively evaluated under a variety of experimental conditions. For examples, several studies have investigated the reliability of SOL H-reflex in lying, sitting, and standing positions.[8-10] Additional factors must be considered when measuring an H-reflex, including stimulus intensity, level of voluntary agonist or antagonist contraction, and postural state.[11]

The SOL H-reflex is usually tested clinically in patients lying prone, with the H-latency always the criterion of choice for detecting abnormality. The concept is that in the standing position, all forces of gravity and the body weight are functionally and provocatively acting on the involved neuromuscular structures. These results imply a significant interplay between peripheral and central mechanisms and their effects on the spinal motoneurons. This in turn suggests that testing of the H-reflex amplitude and latency under functional conditions, such as standing may be useful in detecting subtle changes in radiculopathy.[7,12]

Therefore, the purpose of this study was to measure changes in the H reflex and V wave under loading conditions (e.g. postural change) and to investigate whether postural change would affect the H reflex and V wave in hemiplegic persons with post stroke.

II. Methods

1. Subjects

Thirty hemiplegic persons resulting from stroke (20 males, 10 females, age: 53.42±9.54 years, height: 163.81±7.49 cm, weight: 60.73±7.02kg participated in this study)(Table 1). The inclusion criteria for the individuals with stroke were: (1) diagnostics of ischemic brain injury or intracerebral hemorrhage by magnetic resonance Imaging (MRI) or computed tomography (CT), (2) able to walk without using a cane or an ankle-foot orthosis, (3) no other neurologic or psychiatric problems, (4) able to follow commands. Persons with musculoskeletal or neurological disorders, sensory or visual deficit, and unilateral neglect in addition to their stroke were excluded.

Table1. General characteristics of the subjects

	Age (years)	Height (cm)	Weight (kg)
Mean±SD	53.42±9.54	163.81±7.49	60.73±7.02

2. Measurement

The H reflex and V wave were measured on paretic leg during prone and standing position. After the H reflex and V wave recordings, we were calculated to latency and amplitude of M wave and H wave, M-H interval, M_{max}/H_{max} ratio and M_{max}/V_{max} ratio.

The Cadwell II wedge electromyography (EMG) unit (Cadwell Laboratories Inc., USA) was used to electrically stimulate and record the soleus H-reflexes and V wave, reflecting adaptive neural alterations at both spinal and supraspinal levels.

(1) H-reflex recordings

To record the H reflex, the skin was cleaned with 70% alcoholic wipes, and conductive gel was rubbed into the skin to improve conduction. The active electrode for the PTNwas placed at 1/2 distance between the midline of the popliteal fossa and medial malleous of ankle. The reference electrode placed on the Achilles tendon. Ground electrode was placed lateral gastrocnemius muscles about 3 cm on the active electrode. Electrodes was used to self-adhesive ground electrode (1×1 cm, Neuro line disposable neurology electrodes 700 10-k, Medicotest A/S, Denmark). Stimulation intensity for the H reflex was maintained submaximal stimulation level using the bipolar probes at PTN. The duration of each contraction was at least 2s.

Each subject's H-reflex amplitudes were recorded during a fully relaxed prone position that pillowwas applied to the ankle after slight knee flexion. The ankle was positioned at a neutral position. Stimulation of the PTN was achieved by stimulator when M wave and H wave has been elicited at high level. Maximum SOLH reflex (H_{max}) and maximum soleus motor response (M_{max}) recruitment curves were then measured. The ratio of H-max to M_{max} was calculated at each condition.

During the standing position, subjects stood up with their knees fully extended (0°/neutral standing) and they were instructed to evenly distribute their body weight between the right and left lower extremities (body weight distribution was not monitored). As with prone position, Stimulation of the posterior tibial nerve was achieved by stimulator when M wave and H wave has been elicited high level. Maximum soleus H-reflex (H_{max}) and maximum soleus motor response (M_{max}) recruitment curves were then measured. The ratio of Hmax to Mmax was calculated at each condition.

(2) V-wave recordings

The skin was cleaned with 70% alcoholic wipes, and conductive gel was rubbed into the skin to improve conduction. After the H-reflex eliciting, stimulus intensity was increased until the H-reflex amplitude was minimize or vanished and M-wave amplitude was submaximal. And then the V-wave response was elicited when the PTNwas stimulated with supramaximal intensity during 30% maximum voluntary contraction (MVC) against resistance.

After the V-wave recording, V_{max} and M_{max} were elicited by modulating intensity. V_{max}/M_{max} was calculated by max amplitude ratio for action potential of V_{max} and M_{max}.

In standing position, participants were to maintain their weight equally on both legs and fully extend knee with hip during heel contact. When SOL H-reflex amplitude was minimize or vanished, and M-wave amplitude was submaximal, participants were performed plantar flexion of non paretic side during 30% MVC against resistance (e.g. heel off). Then, Instead of the H-reflex, new late response appeared that, this wave is V-wave.

3. Statistical analysis

Statistical analysis was performed using the SPSS 12.0 (SPSS Inc, Chicago, IL, USA). The normality of the distribution of each variable (H latency, H_{max}/M_{max} ratio, V_{max}/M_{max} ratio) was tested using the Kolmogorov-Smirnov test. The means of normally distributed continuous data were assessed by independent t-test (α=0.05).

III. Results

There was statistically significant difference in H_{max}/M_{max} ratio ($p<0.01$)(Figure 1), V_{max}/M_{max} ratio ($p<0.01$)(Figure 2), H latency ($p<0.01$)(Figure 3) among the prone and standing positions. The H reflex and V wave in standing position were more active to weight bearing load than prone position.

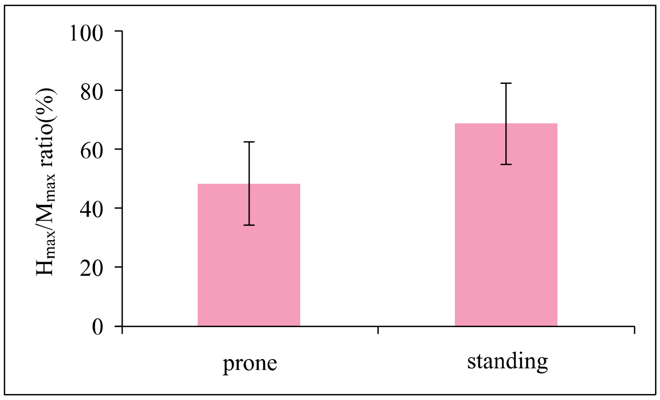

Figure 1. Comparison of the H_{max}/M_{max} ratio between the prone and standing position ($p<0.01$).

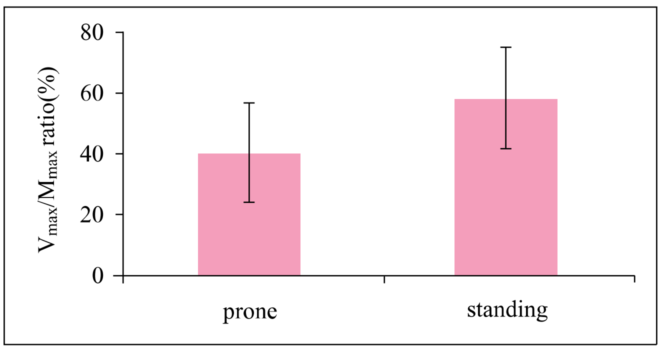

Figure 2. Comparison of the V_{max}/M_{max} ratio between the prone and standing position ($p<0.01$).

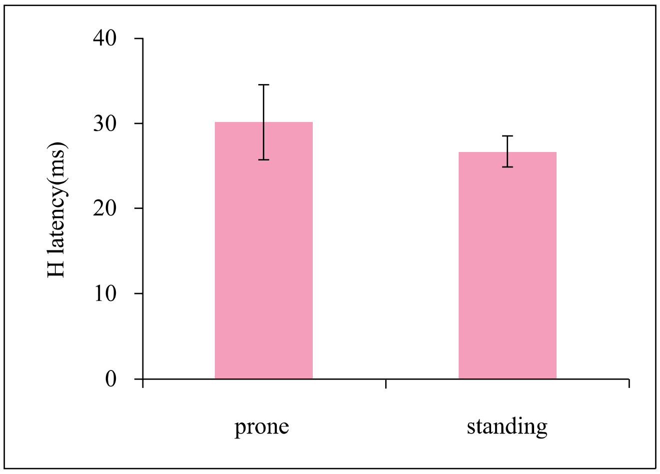

Figure 3. Comparison of the H latency between the prone and standing position ($p<0.01$).

IV. Discussion

The results of this researchappear to indicate that H reflex and V wave related parameters for assessment of soleus motoneuronal excitability are dependent on the loading conditions. Electrophysiological measurements such as stretch reflex, H-reflex and cutaneous reflexes are able toevaluate the integrity of spinal cord functions during gait and indirectly assess the integrity of the descending control system.[13] The M-response is a direct motor response and is not affected by physiological changes at the level of the spinal cord. It is typically measured in H-reflex studies to assess stability in the test conditions.[14] To quantify motoneuronal excitability, several H-related parameters have been proposed, including H_{max}/M_{max}, for maximal H-reflex and accompaniment M-response (H_{max}/MH), and for the slopes of the H-M development curves.[15,16] Standardizing the H_{max} amplitude to the M_{max} amplitude is another common method of H-reflex normalization. Because the Hmaxis an indirect estimate of the number of motor neurons (MNs) being recruited and the M_{max} represents the entire MN pool, the H_{max}/M_{max} ratio can be interpreted as the proportion of the entire MN pool capable of being recruited.[2] Previous studies showed that loading the participantwith weight resulted in a slight increase in the peak-to-peak amplitude of the H-reflex, probably due to increased excitability of the spinal motoneurons caused by increased muscle contraction forces of the leg muscles in order to support the body. In contrast, unloading the subject (by 25% of his or her body weight) caused no statistically significant changes in the amplitude of the H-reflex when compared to the standing condition. We believe that the recorded H-reflex suppression was probably due to relative mechanical compressive and loading forces on the lumbosacral spinal nerve roots.[17]

Other study reported that the SOL H-reflex is enhanced more with dynamic than with static inclinations of the body. In this character, in standing persons a considerable response has been represented when vestibular stimulation using by galvanic current was delivered during body movement compared to stationary body changes.[18] Also, the latter provides evidence that dynamic changes in body posture result in larger vestibular services to allow balance and movement to be synchronized, since vestibulospinal input depends on the amount of proprioceptive sensation from the lower limbs.[19]

Imposed static and dynamic low-frequency changes in body orientation in healthy participants induced a significant facilitation of the SOL H reflex that occurred independently of the movement direction of the body axis. We believe that the reflex facilitation was largely driven from supraspinal influences and in particular from the vestibular system, mediated by otolith and semi-circular afferents, impinging onto soleus alpha MNs.[20]

On the order hand, the SOL H-reflex amplitude was inhibited during neutral standing and standing with kneeflexion in comparison to lying, whereas vastus medialis H-reflex amplitudes showed no measurable changes during neutral standing but showed facilitation during standing with knee flexion. The differences in the SOL and vastus medialis H-reflex behavior during standing and knee flexion may be explained by the role each muscle might have to assume in supporting the body during the stance phase of gait. The suppression of the soleus H-reflex amplitude during standing across all degree of knee flexion might bedue to increased presynaptic inhibition. The source of this increased presynaptic inhibition might be the somatosensory afferents of the foot sole.[21]

Hwang et al[7] have demonstrated that H reflex amplitudes were not affected by different loading (10%, 50%, and 90% of body weight) conditions in standing for both healthy subjects and patients who had a previous stroke. There were two major findings in this research: (1) posture-dependent depression of TS (triceps surae) H-reflex from sitting with the test knee straight to standing was present in the healthy subjects, but not in the patients with hemiplegia, and (2) weight load had no significant effects on alpha motoneuronal excitability of the TS for both the healthy and stroke groups.

Another studies reported that non-injured persons and persons with i-SCI respond similarly to bilateral limb unloading (40% BWS) during standing with no significant change in H-reflex amplitude. It appears that although soleus H-reflex amplitude is significantly greater after SCI and is exhibited even during quiet standing, load does not alter SOL H-reflex excitability.[22]

Butler et al[23] found that both the H-reflex and V-wave amplitudes were linearly related to plantar flexor contraction levels ranging from 0 to 50% of the maximal voluntary contraction. In contrast, Fumoto et al[24] demonstrated that the H-reflex waspoorly related to the exerted force level.

Generally, reflexes are measured at rest. Measurements at rest did not accurately represent the H-reflex during motor tasks. Additional factors must be considered when measuring an H-reflex, including stimulus intensity, level of voluntary agonist or antagonist contraction, and postural state. Because the H-reflex is often tested clinically, reflex function in healthy, neurologically normal individuals must be understood to recognize when something is wrong.[10]

Marigold et al[25] reported that changes in weight-bearing load do not change postural reflex muscle onset latencies in stroke. Because deficits in the latency of paretic lower limb muscles can be attributed to the loss of supraspinal control, inappropriate modulation of these reflexes from various descending inputs, and/or alterations in muscle properties resulting from the stroke. Lee et al[26] reported that load stimulus in the stroke patients were effective in improving static balance ability. But hemiplegic persons with post stroke were limited in postural control due to excitability level of spasticity. Thus, delayed paretic limb muscle onset latencies in conjunction with impaired modulation of dorsiflexor muscle postural reflex magnitude may contribute to the instability and frequent falls observed among individuals with stroke.[25]

V. Conclusion

This study was purposed to measure changes in the H reflex and V wave under loading conditions and to investigate whether postural change would affect the H reflex and V wave in hemiplegic persons with post stroke. The results of the study showed that the relatively large H reflex and V wave recorded in standing position compared to prone position indicates that the spasticity may influence the muscle mechanics in standing position by contributing to the motor output and enhancing muscle stiffness. In other words, excitability of the spinal motoneurons in hemiplegic persons with post stroke take effected on spasticity more than muscle contraction supporting body weight. In conclusion, Functional movement of hemiplegic persons with post stroke would be restricted by hyper excitability of spinal motoneuron due to spasticity and muscle contraction supporting body weight. Therefore spasticity is to be controlled in low weight load. But this study was evaluated only the EMG test, therefore many other studies to support this research will be needed.

Author Contributions

Research design: Park YH, Kim TY
Acquisition of data: Park YH, Kim SH, Oh S
Analysis and interpretation of data: Park YH, Oh S
Drafting of the manuscript: Park YH, Kim TY, Kim YN
Administrative, technical, and material support: Oh S, Kim SH, Choi JH
Research supervision: Kim TY

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