Abstract

Physical Therapy

SCHEDULE

Session 1: 11 : 00 ~ 12 : 00

Session chair: Prof. Morio Kawamura

Session chair: Associate Prof. Kazuto Ishida

1. Effects of selective attention task on postural adjustment during choince step reaction.
   Kazuki Uemura

2. Effects of motor skills training on motor function and neural plasticity following intra-cerebral hemorrhage in rats. Keigo Tamakoshi

3. Interaction between down-regulation of KCC2 expression in plasma membranes of spinal motoneuron and spasticity after stroke in mice. Takuya Toda

Session 2 : 13 : 30 ~ 14 : 30

Session chair: Prof. Sang Hyun Cho

4. A Comparison of Trapezius Muscle Activity While Performing a Dictation Task, Sitting in an Auditorium Chair and a Classroom. Tae Jim Kim

5. Muscle activation of the gluteus maximus and hamstrings during prone hip extension with knee flexion in three hip abduction positions. Sunyoung Kang

6. Janda's sensorimotor training in the upper crossed syndrome. Jae Jin Lee

—15 minutes rest –

Session 3 : 14 : 45 ~ 15 : 25

Session chair: Prof. Sumio Yamada

7. Feasibility of Emerging devise for Electrical Muscle Stimulation immediately after Cardiovascular Surgery. Kotaro Iwatsu

8. The effect of internet based cardiac rehabilitation with pulse monitoring device on improvement of exercise tolerance and coronary risk factor modification: a pilot study.
   Yuta Hagiwara

—15 minutes rest –

Session 4 : 15 : 40 ~ 16 : 20

Session chair: Prof. Sang Hyun Cho

9. Immediate Effects of Soft Tissue Massage on Acromiohumeral Distance, Anterior Translation of Humeral Head, and Glenohumeral Range of Motion in Subjects With Posterior Shoulder Muscle Tightness: A Preliminary Study. Sil-Ah Choi

10. Effects of Breathing Maneuver and Sitting Posture on Muscle Activity in Inspiratory Accessory Muscles in Patients with Chronic Obstructive Pulmonary Disease.
    Ki-song Kim

EFFECTS OF SELECTIVE ATTENTION TASK ON POSTURAL ADJUSTMENT DURING CHOICE STEP REACTION

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Introduction

A delayed choice step reaction has been shown to be a marker of increased risk of falling in older adults. Avoiding a fall depends not only on a person's sensorimotor function but also on cognitive processes that allow appropriate corrective responses to be selected. Anticipatory postural adjustment (APA) was originally defined as a change in postural control associated with voluntary movements, potential error in the direction of which (indicating a motor program error) account for slow choice step reaction [1].

Tests that have been previously used for assessing the physical performance, including walking speed and step reaction time, could not evaluate the multiple aspects of postural control deficits and the potential mechanism of movement prolongation. Given that an initial motor program error leads to incorrect and prolonged APA, processing and judgment may be vital and critical in determining the accuracy and speed of step execution. Selective attention task have been used to measure conflict resolution and visual interference effects [2]. Assessing stepping performance in response to the selective task may enable us to investigate the processing and judgment during movement initiation. The purposes of this study is to develop the assessment methods of postural control addressing cognitive process, such as judgment and attention, during movement.

Materials and Methods

The contents of this research were 1) to determine whether visual interference of slective attention task has any effect on the initial motor program and choice step execution, 2) to examine the effects of a speed or accuracy strategy on response interference control, 3) to examine the effects of aging on the reactive strategy and execution speed of choice stepping. These experimental procedures were approved by the local ethics committee (Graduate School of Medicine, Nagoya University, approval no. 11-514).

Study 1

*Subjects:*Twenty healthy young subjects participated in this study; these included 8 women and 12 men, with a mean ± SD age of 22.5 ± 0.9 years.

*Methods:*They were instructed to execute forward stepping as quickly and accurately as possible on the side indicated by the central arrow (←, left vs. →, right), moving their foot 30 cm on each step trial. In 1 block (neutral condition), only 1 arrow was shown in the same central location on the display. In the other block, flanker task was used as the selective attention task. In flanker condition, the visual display contained 5 arrows; the participants were asked to indicate the direction the central arrow was pointing while ignoring the 2 flanking arrows on each side. In half the trials, the flanking arrows pointed in the same direction as the central arrow cue (←←←←← or →→→→→; congruent condition), while in the other half, the flanking arrows pointed in the opposite direction (←←→←← or →→←→→; incongruent condition).

The vertical force data during the step execution were collected using 2 separate force platforms. Figure 1 shows data for the vertical force under both feet as a percentage of body weight, obtained during the 2 trials of step execution by the right foot. Figure 1A shows a trial in which the initial APA was in the correct direction (i.e., increased force under the swing foot to be lifted). Figure 1B shows a trial in which the initial APA was in the wrong direction (i.e., increased force under the initial stance leg), which delayed the step. Errors in the direction of the initial weight transfer (APA errors) were measured. Step execution time was calculated as the time from cue to foot contact. Individual phases of step execution were calculated according to the following definitions: (a) reaction phase, the time from cue to APA onset (even if it was an error); (2) APA phase, the time from APA onset to foot-off; (c) swing phase, the time from foot-off to foot contact.

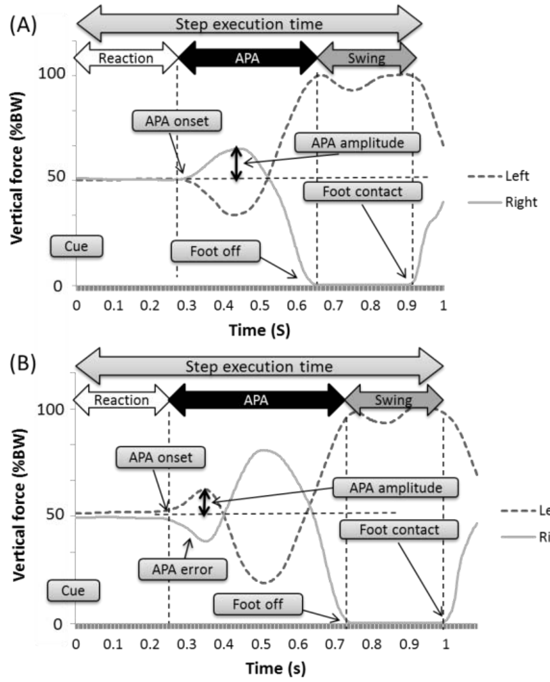

Figure 1. Two example data of the step execution trials.

First, 1-way repeated-measures analysis of variance [ANOVA; task condition] was used to analyze the individual response times and errors. To determine the effects of the conditions and the APA errors on step execution time, we used a linear mixed model with condition and APA error as the fixed factors and the participants as the random factor.

Study 2

*Subjects:*Eighteen healthy young subjects participated in this study, of whom 8 were women and 10 were men, with a mean age ± SD of 21.9 ± 1.5 years.

Methods: The emphasis placed in the instructions was changed in 3 ways. For the control instruction, participants were instructed to execute choice forward stepping as quickly and accurately as possible. For the accuracy instruction, participants were instructed to focus on making an accurate response without losing too much speed. For the speed instruction, participants were instructed to focus on speeding their responses and be less concerned about making errors, but not to the point of simply guessing a response [3]. Other experimental protocols and analysis were same with *study 1*.

Study 3

*Subjects:*Twenty-two healthy young subjects (gender, 9 female; age, 21.9 ± 1.4 years) and 21 healthy older adults (gender, 10 female, age, 72.6 ± 4.9 years) participated in this study. Older participants were included based on the following criteria: (1) free of neurological and orthopaedic disorders that might affect gait and/or cognitive function, (2) the ability to ambulate independently, (3) the Mini-Mental State Examination score greater than 24, (4) absence of serious visual impairment.

Methods: Experimental protocols and analysis were same with *study 1*. Two-way repeated-measures ANOVA (task condition× age group) was used in the statistical analysis of individual response times and errors. We used a linear mixed model approach to determine the effects of condition, and presence or absence of APA error on step characteristics in individual group.

Results

Study 1

APA errors rate, step execution time, reaction phase, and APA phase significantly increased in the incongruent condition compared to the neutral and congruent conditions. The linear mixed model revealed that the presence or absence of APA errors affects the individual timing of stepping in different ways. In trials with APA errors, step execution times and APA phases were significantly lengthened for all 3 conditions in a similar manner. On the other hand, the reaction phase was lengthened in trials with correct APAs.

Study 2

Interaction effects between instruction and condition showed that APA error was increased in response to the flanker task but step execution time was shortened with a speed strategy compared to an accuracy strategy. There was no statistical difference in step error rate between individual instructions in all conditions. The linear mixed model revealed that the presence of APA errors delays step execution time for all instruction methods. However, there is an interaction effect between conditions and APA errors only for the speed instruction, which suggests that the flanker interference task prolongs the step execution time of trials with APA errors more than simple choice reaction (i.e., neutral condition).

Study 3

Older group showed increased APA error rate compared to young group in the all task condition, and prolonged step execution time particularly in the incongruent condition. Linear mixed model found that interaction effect between APA error and condition was seen only in older group, which indicates that presence of APA error increases total step execution time prominently in incongruent condition (fig 2).

Discussion

Visual interference of selective attention task prolongs step execution, which mainly derived from initial motor program errors and its correction (i.e., prolonged APA), even though the reaction phase was prolonged in trials with correct APAs for cautious judgment. (Uemura K et al, Effects of visual interference on initial motor program errors and execution times in the choice step reaction. Gait & Posture. In Revision)

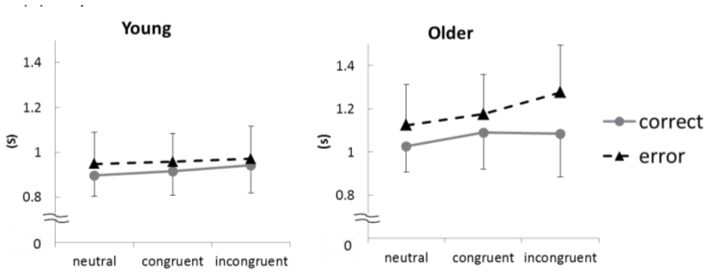

Figure 2. Effect of APA errors on the step execution time

Speed strategy, compared to an accuracy strategy, increased potential APA error in response to the selective attention task but step error rate remained unchanged, step execution time was shortened. However, in subjects who are more susceptible to APA errors during step initiation, an emphasis on speed might affect stepping performance adversely, because the flanker interference task prolongs the step execution time of trials with APA errors more than simple choice reaction only for the speed instruction. It is also important to keep the purpose and characteristics of the subjects in mind when manipulating task instructions.

Several age-related differences in choice stepping in response to the selective attention task were seen. Interaction effect between condition and group indicated that visual interference effect of flanker task affect reaction, APA phase and step execution in different manners. Visual interference, caused by incongruent condition, prolonged APA phase and step execution time particularly in older group in relative to young group. Usually, the step execution time in the trials with APA errors was longer than those without APA errors in young adults (*Study 1*), whereas older adults showed that step execution time in trials with APA errors increased prominently in the incongruent condition compared to neutral and congruent condition. Therefore older adults might be vulnerable to potential motor program error caused by interference effect.

Conclusions

We have developed the assessment methods of postural control, to analyze stepping performance in response to a selective attention task including potential motor program error. In the future, we should examine the effects of motor or cognitive deficits and risk of falling on the judgment process and step execution performance in response to a selective attention task.

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Effects of motor skills training on motor function and neural plasticity following intra-cerebral hemorrhage in rats

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Introduction

Intracerebral hemorrhage (ICH) is a cerebral vascular accident characterized by long-term impairments of motor function and activities of daily living (ADL). It is well known that rehabilitation is effective for functional recovery after intracerebral hemorrhage. A variety of rehabilitation strategies, such as environmental enrichment [1]), simple exercises(e.g., treadmill [2]), and forced-use therapies (e.g., “constraint-induced movement therapy” [3]) have been exermined in rodent ICH models. Learning new motor skills might brought in neuronal structural and functional plasticity,which has not been observed with simple movement repetition. It was reported that motor skills training promotes cerebral plasticity and motor functional recovery more than simple exercise in stroke rats [4]. Motor skill training after brain damage leads to adaptive neural plasticity which suggests that the mechanisms involved in learning a new task also play an important role in maintenance and reorganization of the injured cortex. However, it is not well-known about the effects of motor skills training following stroke, especially ICH. In this study, we investigated the effects of motor skills training on the motor functional recovery and synaptic plasticity following intra-striatal hemorrhage in rats.

Materials and Methods

Experimental animals: Adult male Wistar rats (250~270 g, 8-week-old) were used. Rats were housed at 23℃ during 12h light/dark cycle with food and water access ad libitum through the experiment. Animal care and surgical procedures were performed in accordance with the animal care guidelines of the Nagoya University. All efforts were made to minimize the suffering and the number of animals used. They were randomly assigned to sham or ICH. Each group was divided into two subgroups: acrobatic training and control (no exercise) group. Therefore, four groups were included in this study: SHAM, SHAM+AT, ICH, and ICH+AT.

Surgery: ICH was induced as described in previous studies[2,5]. Rats were anesthetized with sodium pentobarbital (45 mg/kg, i.p.) following injection of atropine sulfate and placed on a stereotaxic frame. Through a hole drilled in the skull, a needlewas implanted into the left striatum at the following coordinates: 3.0 mm lateral to the midline, 0.2 mm anterior to coronal suture, and depth 6.0 mm deep from the surface of the brain. 1.2 μl saline containing 0.24 U of bacterial collagenase (TypeⅣ; Sigma-Aldrich, St. Louis, MO, USA) was infused over 6 min. The needle remained in place for an additional 7 min after the infusion and was subsequently withdrawn slowly. Sham operated animals were injected with 1.2 μl of saline instead of collagenase.

Motor skills training: ICH-AT group rats were trained five kinds of acrobatic course, such as grid platform, rope ladder, parallel bars, rope, and barriers, as previously described that these courses requires rats to learn a variety of skilled forelimb, hindlimb, and coordinated whole-body movement. Each course was one meter length from starting to end point placed dark box, and required rats to spontaneously traverse for 25 days (4 trials a day) from 4 days after surgery. Almost rats were assisted occasionally by experimenters to avoid falling from each course from 4 to 6 days after surgery.

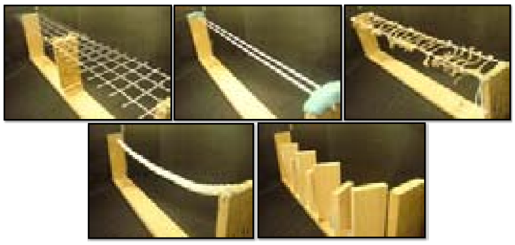


Figure 1 Acrobatic training

Behavioral testing: Motor Deficit Score (MDS) is composed of following four tests; (1) observation of spontaneously ipsilateral circling, graded from 0 (no circling) to 3 (continuous circling), (2) bilateral forepaw grasp, which measures the ability to hold onto a 2 mm diameter steel rod, graded 0 for a rat with normal forepaw grasping behavior to 3 for a rat unable to grasp with the forepaw, (3) contralateral hindlimb retraction, which measured the ability of the animal to replace the hindlimb after it was displaced laterally by 2-3 cm, graded from 0 (immediate replacement) to 3 (replacement after minutes or no replacement), and (4) beam walking ability, graded 0 for a rat that readily traverses a 2.4-cm-wide, 80-cm-long beam to 3 for a rat unable to stay on the beam for 10 s. MDS was calculated as the sum of the grades on the four tests, and evaluated at 1, 3, 7, 11, 14, 21 and 28 days after surgery. Beam walking test (a 2.4 cm and 1 cm wide, 80-cm-long beam) was performed at 1, 3, 7, 11, 14, 21 and 28 days after surgery, as described previously. Before surgery, all rats were trained two trials every other day until traverse a beam with no more than two foot slips. Performance was rated on the 7 point scale: (1) the rat is unable to place the affected hindpaw on the horizontal surface of the beam; (2) it places the beam and maintains balance but is unable to traverse the beam; (3) the rat traverses the beam dragging the affected hindpaw; (4) it traverses the beam and once places the affected hindpaw on the horizontal surface of the beam; (5) the rat crosses the beam and places the affected hindpaw on the horizontal surface of the beam to aid less than half its steps; (6) the rats uses the affected hindpaw to aid more than half its steps and, (7) the rat traverses the beam with no more than two foot slips.

Histology: At 29 days after surgery, rats were sacrificed under deep anaesthesia with sodium pentobarbital. They were transcardially perfused with 0.9 % saline followed by phosphate buffer (pH 7.5) containing 5% paraformaldehyde. The brains were removed and postfixed in the same fixative. Then, 50 μm thick coronal sections were taken every 450 μm from +1.8 to -1.7 using a cryostat after overnight cytoprotection in 30% sucrose solution. The volume of tissue lost and the cortical thickness were calculated by Image J version 1.42 (National institutes of Health, USA) using eight Hematoxillin-Eosin stained sections. And, the number of neurons were counted using Nissl stained sections. To investigate functional activation of remaining cortex, Neuronal activation was examined by immunohistochemistry of ΔFosB positive cells, which is cumulatively and persistently expressed in response to repeated neuronal activation. Immunocytochemistry for ΔFosB was used. Numbers of ΔFosB positive cells in the bilateral sensorimotor cortex at 14 and 29 days after surgery were counted. Cell counts were then normalized to 1mm^2.

Protein assay: Protein level of PSD-95 was analysed using western blotting. PSD-95, a synaptic scaffolding protein with multiple protein–protein interaction domains, is enriched in the postsynaptic density (PSD) and is an important regulator of synaptic strength and plasticity. At 14 and 29 days after surgery, animals placed under deep anesthesia with sodium pentobarbital (45 mg/kg, i.p.), transcardially perfused with phosphate buffered saline (PBS, pH7.4), and their brains removed.

.

Results

MDS of ICH-AT animals were significantly improved compared with ICH only animals at 11 and 14 days after ICH (Figure 2). A wide (Figure 3, left) and narrow (Figure3, right) beam walking ability of ICH-AT was significantly higher than ICH. The volume of tissue lost and cortical thickness were no significant differences between ICH and ICH-AT animals. The numbers of ΔFosB positive cells of ICH-AT were increased more than those of ICH at bilateral sensorimotor cortices at 14 days. PSD-95 protein levels of ICH-AT group were increased in bilateral sensorimotor cortices at 28 days and in bilateral striata at 14 days.

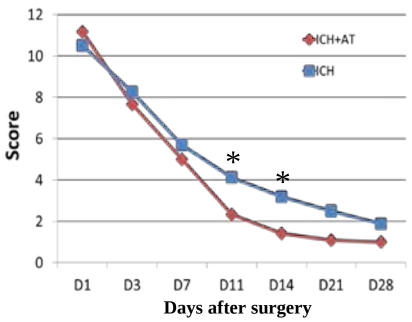
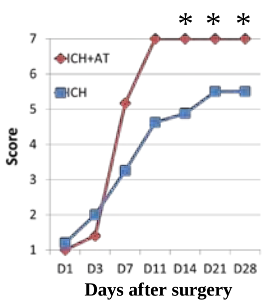


Figure 2 Motor Deficit Score



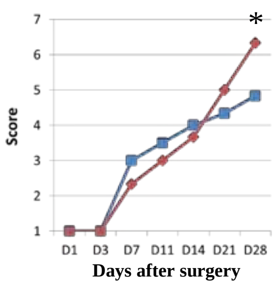


Figure 3 Beam Walking test

Discussion

These data suggest that motor skills training could enhance the neural activity and synaptic plasticity associated proteins at bilateral sensorimotor cortices and striata, and promote motor functional recovery after intracerebral hemorrhage in rats.

The volume of tissue lost and cortical thickness were unchanged by motor skills training following ICH. Previous research reported that reaching training didn't improve lesion volume following ICH. Motor skills training may have brought benefite recovery of motor function even though tissue loss was not prevented after ICH. Thus motor function may be improved by neural plasticity, not by tissue damage change.

ΔFosB positive neurons in bilateral sensorimotor cortex were increased by motor skills training at 14 days. ΔFosB protein was used as the maker of neural activity in this study. Motor skills training caused persistent neural activity until 14 days.

PSD95 was investigated to demonstrate an effect of motor skills training on synaptic plasticity in the sensorimotor cortex and striatum after ICH. PSD95 was increased in bilateral striatum at 14 days and sensorimotor at 28 days by motor skills training following ICH. Improved motor function may be an effect of synaptic plasticity in striatum at early phase and in sensorimotor at late phase.

Conclusion

We demonstrated that motor skills training after ICH in rats improved motor function, and enhanced neural activity and synaptic plasticity in the striatum and sensorimotor cortex.

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INTERACTION BETWEEN DOWN-REGULATION OF KCC2 EXPRESSION IN PLASMA MEMBRANES OF SPINAL MOTONEURON AND SPASTICITY AFTER STROKE IN MICE

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Introduction

Spasticity is one of the well known upper motor neuron syndromes resulting from the brain and spinal cord injuries. Many stroke patients suffer from spasticity and the prevalence of spasticity is reported 42.6% in stroke patients with limb paresis[1]. Furthermore, the spasticity adversely affects quality of life and can reduce a person's function to perform activities daily living. Although it has been clinically studied for many years until now, the exact mechanisms are still unclear. Recently, the study as the spasticity mechanism has been revealed that down-regulation of the K^+/Cl^- cotransporter 2 (KCC2) induced spasticity after spinal cord injury. The decrease of KCC2 induces that the action of γ-aminobutyric acide A ($GABA_A$) and glycine receptors change form inhibitory action to excitatory action, and so the motoneurons develop hyper-excitability[2]. This result led us to hypothesize that this disinhibition of motoneuron underlies spasticity after stroke. The aim of this study is that to investigate whether the expression of KCC2 was actually down-regulation in the affected motoneurons

Materials and Methods

Animals: Adult male C57BL/6J mice weighting 25-30 g (SLC, Shizuoka, Japan) were used. All procedures were approved by the Nagoya University Guidelines for the Care and Use of Laboratory Animals.

Photothrombotic Stroke model: Adult mice were anesthetized using somnopentyl (50 mg/kg body weight, Kyoritsu, Tokyo, Japan). We injected into the tail vein of mice with Rose Bengal (10 mg/ml, 0.03 mg/g body weight, Sigma, St. Louis, USA). The light beam exposed to the rostral and caudal forelimb areas on the skull for 15 min. We made a forelimb primary and non primary motor cortex lesion. Sham animals received the same injection of Rose Bengal but were not exposed a light.

Electrophysiological measurement: The Hoffman reflex (H-reflex) is characterized that the amplitude decreases depend on frequency of stimulation (rate-dependent depression: RDD). The RDD is gradually induced by repeated stimulations at high frequency than 0.1 Hz, and amplitude of H-reflex reduces to less than 80% at 5 Hz[3].We measured H-reflex until 21 days after stroke for spasticity assessment. Animals were anesthetized with ketamine (200 mg/kg additional dosage: 1/2 initial dose every 45 min, CS pharmaceutical Co., Nagoya, Japan), and we stimulated the ulnar nerve at 0.1 Hz with increasing current intensities for determining the minimum intensity to evoking H-reflex and this currents were used. After that we stimulated the ulnar nerve 23 times at 0.1, 0.5, 1, 2 and 5 Hz with 2 min intervals between each frequency. We recorded the H-reflex in the both abductor muscles of little finger of right and left forelimbs. We calculated the mean of the amplitude of H-reflex.

Immunohistochemical analysis: At 7 days after stroke we performed immunohistochemical staining for histological evaluation. We sampled a spinal cord at cervical level (C4-C7). The samples were cut coronally at 20 μm thickness using a cryostat and mounted onto slides. The coronal sections were incubated in 0.1% tripsin for 5 min at room temperature and blocking solution as 5% normal donkey serum diluted with Triton buffer (0.1% TritonX-100 in PBS) for ChAT antibody and 5% normal goat serum diluted in Triton buffer for KCC2 antibody, respectively. After that, the sections were incubated in goat anti-Choline Acetyltransferase (ChAT) antibody (1:100, AB144P, Millipore, Tokyo, Japan) and rabbit polyclonal anti-KCC2 antibody (1:500, 07-432, Millpore, Tokyo, Japan) at 4°C for overnight. The secondary antibodies were used Alexa Fluor 568 diluted donkey anti-goat immunoglobulin G (1:250; A11058, Invitrogen, Eugene, OR) and Alexa Fluor 488 diluted goat anti-rabbit immunoglobulin G (1:500, A11008, Invitrogen, NY, USA) diluted in blocking solution for 1 hour at room temperature, respectively.

Semi-quantification analysis for KCC2: We analysed 6 coronal sections per cervical segments (C4-7), 5 motoneurons per sections. We used a laser scanning confocal microscope (400 × magnification, A1Rsi-Nikon). All images were processed and measured the intensity of immunolabeling within the plasma membrane by using with imageJ. We calculated ratios of labeled pixel areas per somatic perimeters.

Measurement and statistics: All static test were performed at the level of significance of 0.05 by two-tailed test using one-way ANOVA, post hoc test Turkey-Kramer's and Mann-Whitney's U test.

Results

The rate-dependent depression of Hoffman reflex in affected muscle of stroke animals was significantly decreased after stroke: RDD of H-reflex is known to reduce at high frequency of stimulation in individual and animals with spasticity[3-4]. The mainly cause is considered the depression of synaptic efficiency due to a decrease of transmitter released from the synapses following activation of Ia afferents[4]. We recorded the evoked muscle potential at 7 days after stroke and sham surgery. The latency time of the recorded M-wave was 1-3 ms, and the recorded H-reflex was 5-7 ms. The amplitude of H-reflex reduced at 5 Hz compared with at 0.1 Hz in sham (Fig.1a-b), while in stroke, the amplitude of H-reflex remained high at 5 Hz (Fig.1c-d), that is, the RDD was reduced.

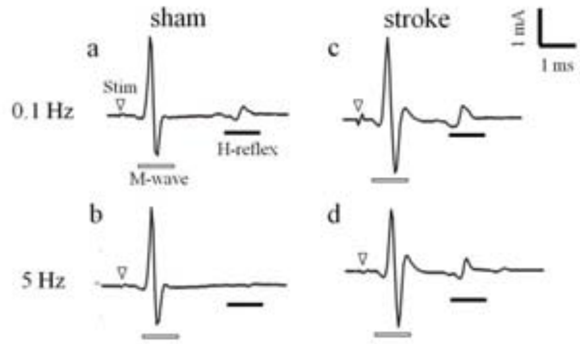

Figure 1: The evoked muscle potential recording 7 days after stroke.
We recorded the evoked muscle potential including an early M-wave (gray under bar) and a later H-reflex (black under bar) at low frequency (a-c) and high frequency stimulation (b-d) in 7days after sham surgery (a-b) and after stroke (c-d). Arrowheads indicate show time point of electric stimulation.

RDD reduced significantly at 5 Hz in stroke animal from 3 days until 21 days after stoke (Fig.2, $p < 0.01$)

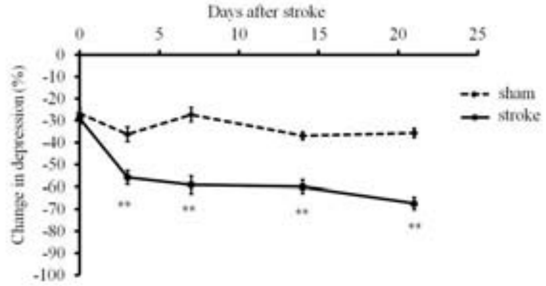

Figure 2: The time course of the change in RDD of H-reflex

The change in RDD of H-reflex at 5 Hz from 3 to 21 days after stroke. A dotted line shows sham group (n = 5), a solid line shows stroke group (n = 6). $^{**}p < 0.01$, ANOVA, post hoc test Turkey-Kramer test. Error bars represent s.e.m.

In affect side RDD of H-reflex was significantly decreased: We compared RDD of H-reflex in sham and affect and non affect sides in stroke before surgery, and so RDD of H-reflex was similarly observed in all groups (Fig.3a). In 7 days after stroke, RDD of H-reflex in affect side was significantly decreased at 2 and 5 Hz compared with sham group (Fig.3b, $p < 0.01$). Additionally RDD of H-reflex in affect side was significantly decreased at 5 Hz compared with non affect side in stroke group (Fig.3b, $p < 0.05$)

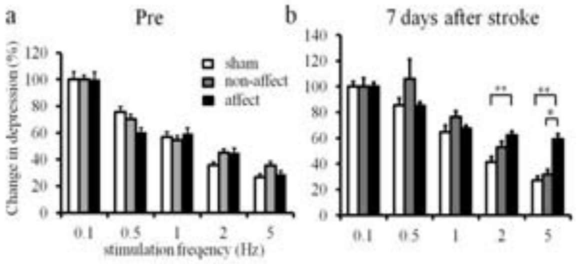

Figure 3: Change in mean relative amplitudes of H-reflex

Mean relative amplitudes of H-reflex at different stimulation frequencies in sham (n = 5) and affect and non affect sides in stroke (n = 6) before (a) and 7 days after surgery (b). RDD of H-reflex in affect side was significantly decreased at high frequency in 7 days after stroke. $^{**}p < 0.01$, $p < 0.05$, ANOVA, post hoc test Turkey-Kramer test. Error bars represent s.e.m.

KCC2-positive areas in plasma membrane were decreased after stroke: We analyzed the density pixel of KCC2 labeled in plasma membranes of motoneurons in 7 days after stroke, and so there was a significant decrease of KCC2-positive areas in plasma membranes of motoneurons in spinal ventral horn of all cervical levels compared with sham and non affect side in stroke (Fig.4, $p < 0.01$). These results suggested that down-regulation of KCC2 expression at plasma membranes of motoneurons in affect side spinal cord.

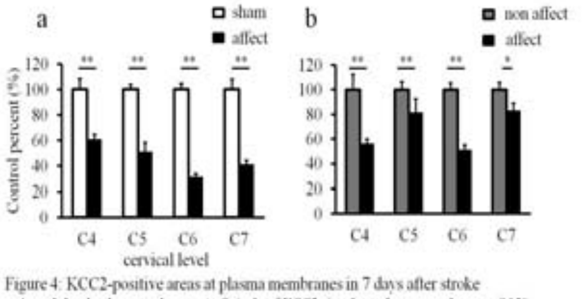

Figure 4: KCC2-positive areas at plasma membranes in 7 days after stroke

At each levels, the control percent of pixels of KCC2 signals at plasma membranes of 150 motoneurons from sham (n = 4) and 100 motoneurons from stroke (n = 3). There was significant decrease of KCC2-postive areas in affect side compared with sham (a) and non affect side (b). $^{**}p < 0.01$, $^{*}p < 0.05$, Mann-Whitney's U test. Error bars represent s.e.m.

Discussion

We confirmed the decrease of KCC2 expressions in the motoneuron of stroke mice with spasticity by semi-quantification immunohistochemical analysis. KCC2-positive areas was significantly decreased in plasma membranes of motoneurons in affect side at 7 days after stroke. This result presents a possibility that down-regulation contributes to spasticity after stroke.

KCC2, which is only channel of Cl^{-} extrusion in neuron, works in order to maintain low intracellular chloride concentration. Therefore down-regulation of KCC2 underlie a shift of GABA-mediated action from inhibition to excitation[5]. KCC2 expression is known to decrease following neuronal stress[6-7]. In this study, KCC2-postive area in plasma membranes of motoneurons reduced to a less than 60% compared with sham surgery. Previous study reports that KCC2 expression in postnatal 5-8 days rats, in which the shift from depolarizing to hyperpolarizing inhibitory postsynaptic potentials had already occurred, is a less than 70% compare with adult rats[8]. Another study reports that KCC2 expression in hippocampal neurons decrease a less than 50% after oxidative stress and a less than 70% 6 hour after seizure activity and hyper excitability, and so GABA-mediated action change to excitability from inhibitory[6]. For these reasons, decrease of KCC2 in this study is enough amount to change in inhibitory receptor to excitability.

Conclusions

This study presented a possibility that down-regulation of KCC2 contributes to spasticity after stroke. In future, we will investigate to reveal the exact mechanisms of spasticity after stroke.

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A Comparison of Trapezius Muscle Activity While Performing a Dictation Task, Sitting in an Auditorium Chair and a Classroom Chair

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Introduction

Auditorium chairs on a University campus are less compatible to Korean Industrial Standard (KS) than classroom chairs on the same campus. Due to variations in body size of students, gaze levels from student's eyes to the blackboard are different. During class hours, students move their eyes and neck repeatedly for writing. Auditorium chairs, which are designed for students who sit on the back line in order to increase concentration by securing one's attention, were not made with consideration for students' movement character. Prolonged sitting position affects muscle activity of the neck and shoulders and induces various secondly musculoskeletal problems, such as muscle myalgia, muscle strain, and so on (cotton et al., 2002; Jensen et al., 1993; Mandal, 1981; Waris, 1980). The purpose of this study was to investigate the effect of the two different types of chairs on trapezius muscle activation during performance of dictation tasks.

Methods

Seventeen university students, each of whom was within ±1 standard deviation of the mean Korean standard body size, voluntarily participated in this study. The subjects sat on two different types of chairs randomly and performed dictation tasks for 10 minutes. The dictation tasks included three different gaze levels (≅15° upward, ≅15° downward, and horizontal direction at eye level).

Surface EMG collection and signal processing

Surface electromyography was used for collection of electrical signals from both the upper and lower trapezius muscles. The Noraxon Telemyo 2400T system (Noraxon, USA Inc., USA) was used to capture the EMG signals with sampling rates of 1500Hz. All EMG data were processed in a hardware filter (10Hz high-pass filter and 1500Hz low-pass filter) and software filter (Butterworth 10Hz high-pass and 400Hz low-pass filter). Root mean square (RMS) values were calculated from raw EMG data over a consecutive time window (.125 s) and these RMS EMG data were normalized with reference voluntary contraction (%RVC). Normalization of EMG data could make it possibly to compare both between and within subjects repeated measure EMG signals.

APDF analysis

Amplitude Probability Distribution Function (APDF) was performed for analysis of muscle activity. The APDF method introduced by Jonsson (1988) is the traditional solution for such a data reduction. It is calculated based on a recording over time. This function is integrated in order to yield a cumulative probability function. The amplitude can be normalized according to any of the approaches (%RVC or %MVC) and it can represent relative muscle contraction level. Figure 1 shows the APDF plot of the upper trapezius muscle of subject 1 during performance of a dictation task of downward gaze on an auditorium chair. X-axis is %RVC domain and Y-axis is Amplitude probability (.0~1.0) of each %RVC. The indexes of APDF are 10th, 50th, 90th, and 99th percentile, and the MATLAB (MathWorks Inc., Natick, Massachusetts, U.S.A.) program was used for these four indexes.

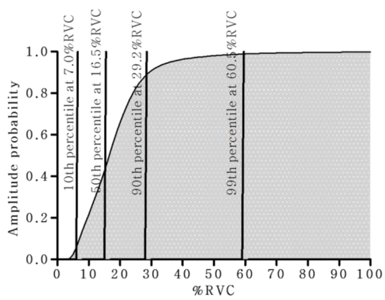

Figure 1. APDF plot of the upper trapezius muscle of subject 1

percentile of APDF, 3-way ANOVA (2 muscle sides x 2 chair types x 3 gaze levels) with repeated measure was performed. And post-hoc analysis followed by Bonferroni adjustment. PASW statistics ver. 18 was used in performance of these statistical analyses.

Results

The findings of this study were 1) The backrest-point height of the auditorium chair and the height, length and width of the connected desk were shorter than what was suggested by the KS. Another difference was that the auditorium chair had a larger angle of the backrest, compared to the classroom chair. 2) Regarding within-subject effect, the sole statistically significant difference was found between activation of the upper trapezius muscle. The upper trapezius muscle's %RVC in the APDF 10th-50th-90th percentile was statistically higher for participants sitting in the auditorium chair than for participants sitting in the classroom chair ($p<.05$). 3) An interaction effect was observed between the “two chair-types” and the “two muscle-sides” in the APDF 10th-50th percentile ($p<.05$). 4) An interaction effect was observed between the “two chair-types” and the “three gaze-levels" in the APDF 90th percentile ($p<.05$).

Discussion

If one sustains posture for a few minute, muscles repeat contraction, and micro-resting were performed in order to avoid fatigue. If this micro-resting is decreased, APDF 10th percentile will increase. Also, if the muscle activity is increased, the 50th, 90th, and 99th percentiles of APDF will also increase. According to Jonsson(1998), when the 10^{th} percentile of APDF was high, muscle fatigue will be easily induced by an increase in muscle activity. And recent research has demonstrated the relationship of several indexes like 50th, 90th and 99th percentiles, as well as the 10^{th} percentile of APDF between muscle activity and muscle pain (Blangsted et al., 2003; Østensvik, 2009; Szeto et al., 2005; Westgaard et al., 2001). According to our results, the upper trapezius muscle's %RVC in the APDF 10th-50th-90th percentile was statistically higher for participants sitting in the auditorium chair than for participants sitting in the classroom chair. This means that micro-resting of the upper trapezius muscle’s on the auditorium chair is less than that of the classroom chair.

Conclusion

The findings of this study indicated that maintaining a writing posture for a prolonged period of time in an auditorium chair resulted in significantly increased activation of the left upper trapezius muscle, compared to a classroom chair.

Key words: Amplitude Probability Distribution Function; Chair; Surface electromyography; Trapezius muscle.

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MUSCLE ACTIVATION OF THE GLUTEUS MAXIMUS AND HAMSTRINGS DURING PRONE HIP EXTENSION WITH KNEE FLEXION IN THREE HIP ABDUCTION POSITIONS

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Introduction

The direction of fiber alignment within a muscle is known to influence the effectiveness of muscle contraction [1]. When the line of action of the muscle matches the line of fiber of the muscle, the effect of muscle contraction is augmented [2]; however, most of the commonly used clinical gluteus maximus (GM) exercises do not consider the downward and outward fiber alignment within the muscle and no study has considered the effect of hip abduction position in relation to muscle fiber arrangement during GM exercises. Therefore, the purpose of this study was to investigate the EMG amplitude and relative onset difference of the GM and HAM during prone hip extension with knee flexion (PHEKF) exercise in three hip abduction positions (0°, 15°, and 30° hip abduction). We hypothesized that the EMG amplitude of the GM would increase and the EMG onset of the GM would be earlier than that of the HAM in the 30° hip abduction position.

Materials and Methods

Subjects: Thirty healthy subjects (18 men, 12 women) were recruited at Yonsei University in Korea (age: 22.8 ± 2.9 yrs, body mass: 66.9 ± 10.8 ㎏, height: 170.3 ± 4.1 ㎝). The exclusion criteria included (1) a history of lumbar, sacroiliac or lower limb injury within the past year, (2) past or present neurological, musculoskeletal, and cardiopulmonary diseases, and (3) lumbar or hip pain when performing PHEKF. Four musculoskeletal examinations of the lower extremities were performed to avoid compensations related to muscle shortness around hip joint; thomas test, ober's test, adduction contracture test, and active straight-leg raises [3]. Prior to participation in the experimental data collection, the principal investigator explained the entire procedure to the subjects. This study was approved by the Yonsei University Wonju Campus Human Studies Committee and all participants gave written informed consent.

Experimental Apparatus: EMG data from the GM and HAM of the dominant leg were collected using a Noraxon Telemyo 2400T system (Noraxon, Inc., Scottsdale, AZ, USA). The EMG electrodes were placed in parallel to the muscle fibers according to the methods described by Cram [4]. The reference electrode was attached to right anterior superior iliac spine (ASIS). For normalization, the mean RMS of three trials of 5-second maximal voluntary isometric contraction (MVIC) was calculated for each muscle. MVIC data were obtained in the manual muscle testing positions recommended by Kendall [5]. The data for each trial were expressed as a percentage of the calculated mean RMS of the %MVIC, and the mean %MVIC of three trials was used for statistical analysis.

The baseline EMG was calculated by averaging the EMG activity for 5-seconds in a resting position. The onset of EMG activity of each muscle was determined when the EMG amplitude exceeded two standard deviations of the baseline level for a minimum of 50 ms. The relative onset difference between the GM and HAM was calculated by the following equation:

relative onset difference = GM onset - HAM onset (in ms)

A positive value indicates that the HAM fired before the GM. When the GM fires earlier than the HAM, the relative onset difference becomes a negative value [6].

Experimental Procedure: Each participant was positioned prone on a therapeutic table with their feet shoulder-width apart and arms at their sides. 0°, 15°, and 30° hip abduction angles were guided by a board beneath the lower extremity. The hip abduction angle was considered the line between the ASIS and mid-point of the patella based on the starting position. For the PHEKF exercise, at the starting position, the subject was asked to bend his or her knee to 90° and relax by resting their leg on a vertically positioned wooden device [7]. Two vertical wooden guides were aligned with the lower extremity to limit substitutions by knee flexion or hip rotation of the examined leg. Then the participant was given a verbal cue to lift their dominant leg toward the ceiling until the patella was lifted 5 ㎝ off of the supporting surface, and then asked to maintain the extended hip for 5 seconds. The subjects performed the PHEKF exercise three times for each hip abduction position with a 30 s inter-trial period and a 2-minute rest period was given between the positions.

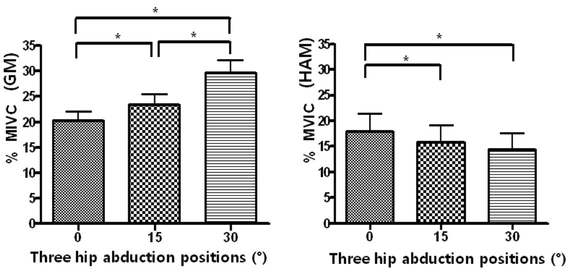
Data analysis: All dependent variables were presented as the mean ± standard deviation (SD). Repeated measures analysis of variance (ANOVA) with the Bonferroni correction was used to compare the EMG amplitude and relative onset differences among the three hip abduction positions. The level of statistical significance was set at 0.05. The Statistical Package for the Social Sciences for Windows version 18.0 (SPSS, Inc., Chicago, IL, USA) was used for all statistical analyses.

Results

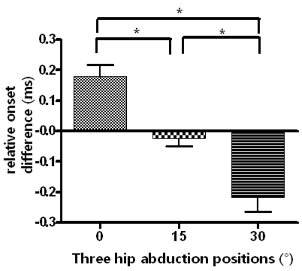
EMG Amplitude: The GM and HAM amplitudes during PHEKF exercise were significantly different among the three hip abduction positions (p < 0.001). Our post hoc comparison revealed that GM amplitude was greatest in the 30° hip abduction position, followed by 15° and then 0° hip abduction during PHEKF exercise (p_{adj} < 0.001). On the other hand, the HAM amplitude at 0° hip abduction was significantly greater than at 15° and 30° hip abduction (p_{adj} = 0.008). There was no significant difference in the EMG amplitudes in the HAM between the 15° and 30° hip abduction positions during PHEKF (p_{adj} = 0.049) (Fiqure 1).

EMG Onset : the relative onset differences were a significant different acrosee the three hip abduction positions (p < 0.001).

Post hoc comparisons revealed significant differences between each of the hip abduction positions. The relative onset difference was greatest in the 0° hip abduction position, followed by 15° and then 30° hip abduction during PHEKF exercise (Fiqure 2).



Fiqure 1. EMG amplitude of the GM and HAM in three hip abduction positions. The means and SDs are show as bars and hatches. $^{*}p_{adj} < 0.05/3$.



Fiqure 2. The relative onset difference between the gluteus maximus and hamstrings in three hip abduction positions. Relative onset difference = GM onset - HAM onset. Means and SDs are shown as bars and hatches. $^{*}p_{adj} < 0.05/3$.

Discussion

In this study, the subjects performed PHEKF exercise in three different hip abduction positions (0°, 15°, and 30°). The results of this study showed when the angle of hip abduction is greater, the GM amplitude increases and the HAM amplitude decreases.

In general, the location of muscle attachment and joint position are critical in effective motion production since they are the determining factors in the generation of torque or a turning moment at the joint [1]. The GM muscle is considered a fusiform muscle that are composed of fibers that run parallel to the longitudinal axis of the muscle. In order to optimize muscle activation, the muscle fibers should lie in the same direction as the line of pull of the muscle [2,8]. The GM arises from the posterior gluteal line of the ilium and the posterior surface of the sacrum and coccyx, and is directed downward and outward into the iliotibial tract and the gluteal tuberosity of the femur [9]. By performing hip abduction during PHEKF exercise, the direction of muscle pull runs parallel to the fiber of the muscle, leading to increased EMG amplitude.

Synergistic muscles such as the HAM and GM in hip extension produce movement around a joint, work together and influence each other through movement patterns [6]. Under the assumption that the movement occurs in the same range of motion, increased EMG amplitude of one muscle can create efficiencies in the movement, thereby decreasing the workload of another muscle [10]. In this study, we can speculate that the decreased activity of the HAM in abducted position may associated with the increased activity of the GM during PHEKF exercise as a synergistic muscle. These results suggest that performing hip abduction during hip extension could be a good strategy to selectively increase GM activation.

Another finding of this study was that the relative onset difference between GM and HAM at the 15 and 30° hip abduction positions was negative, meaning that the GM was firing in advance of the HAM. This change in relative EMG onset could be explained by the function of the GM muscle as abductor of the hip [9]. In this experiment, subjects started to perform PHEKF exercise in abducted hip position and maintained hip abduction while performing the exercise. This led to activation of the GM as a hip abductor, and increased its responsiveness to the load applied to maintain the position during the exercise. When compared of relative onset differences between 15° and 30° hip abduction, GM firing in 30° hip abduction occurred earlier than in 15° hip abduction. This result implies that performing PHEKF in 30° hip abduction position may be an effective method to reduce delyaed GM onset and may be beneficial for preventing motor control dysfunction of the hip extensors.

Conclusions

These findings indicate that performing PHEKF exercise in the 30° hip abduction position may be recommended as an effective way to selectively activate the GM and to reduce the delay in GM firing in asymptomatic individuals. This finding provides preliminary evidence that GM amplitude and onset time can be modified by the extent of hip abduction. However, this suggestion needs to be confirmed that this change could be maintained and transferred to functional movements in future research.

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JANDA'S SENSORIMOTOR TRAINING IN THE UPPER CROSSED SYNDROME

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Introduction

Cervical crossed syndrome (CCS) is a common musculoskeletal impairment, resulting from the neuromuscular imbalance between the tonic-flexor (i.e., overactive and tight sternocleidomastoid, SCM; upper trapezius, UT; pectoralis major, PM) and phasic-extensor (underactive longus colli, LC; lower trapezius, LT) systems within the sensorimotor system [1]. This muscle imbalance impairment is often associated with a prolonged habitual forward head posture (FHP) in response to a functional task demand (i.e., a desk computer work), subsequently leads to adaptive neuromechanical changes in postural and movement patterns [1, 2]. The neuromuscular imbalance (i.e., recruitment patterns, length and tension) between the flexor and extensor systems alters arthrokinematic movement, thereby leading to joint decentration and associated deterioration or cervical spine pathology [1].

Conventionally, the resistive, isometric neck flexion exercise (RIE) has been used to improve deep neck flexor stability and to correct this impairment [3], but its therapeutic efficacy and underlying mechanisms remains unclear. It is unknown whether or not LC is selectively activated while the antagonistic UT and SCM are reciprocally deactivated. It is belived that the isometric contraction of neck flexor along with concurrent activation of the shoulder and elbow flexors as in RIE may further strengthen the neck flexor system which is prone to be overactive. Janda developed the sensorimotor training (SMT) to restore neuromuscular imbalance [1], which involves isometric exercise to activate LC while inhibiting SCM and UT using elastic band (theraband). Nevertheless, underlying mechanism of this approach was rarely studied. Hence, our specific aim is to determine the intervention-related changes in the muscle activation patterns (muscle imbalance ratio, MIR) and muscle thickness data between two interventions. Our basic premise was that Janda's SMT would increase greater activation in underactive LC while inhibiting overactive UT and SCM when compared RIE.

Methods

1. Subjects: Eighteen subjects (7 female) volunteered for this study. The mean age was 24±4 years (range 20-35 years). Inclusion criteria entailed those individuals with FHP (anterior deviation of the lobe of the ear more than 1cm to the plumb line [5]), but were free from any neuromotor or musculoskeletal impairments. Informed consents were obtained prior to the study.

2. Measurements

2.1. Ultrasonography(US): SonoAce (X8, Medison Co., Ltd, Korea) with a 10MHz transducer was used to measure SCM and LC thickness unilaterally (right side) during rest and both exercises. The subjects were seated with both arms rested on the laps and neutral head and neck position. The LC was identified by palpating the thyroid cartilage marked 2 cm below this level in a relaxed position. The transducer was then placed perpendicular to the vertical axis of cervical spine and the US image was obtained 3 times [4].

2.2. Electromyography (EMG): The EMG device (WEMG-8 System, LXM 5308; Laxtha, Daejeon, Korea) was used to collect muscle activation data. EMG data were collected simultaneously from the SCM, UT, LT and PM. The sampling rate was 1024 Hz, and the EMG signal was amplified with an overall gain of 1785 and digitized by using Telescan 3.03 software (Laxtha). Band-pass (20–450 Hz) and notch filters (60 Hz) were used. EMG data was expressed as a percentage of root mean square (RMS) of maximum voluntary isometric contraction (%MVIC). Onset time for each muscle was set to three standardized deviation of the mean resting amplitude.

2.3. *Handheld dynamometer(HHD):* The handheld dynamometer (Commander muscle tester, JTECH MEDICAL, USA) was used to determine and monitor submaximal isometric resistance (20% of maximum isometric contraction) applied throughout the entire experimental tests and intervention so as to ensure consistent measurement and feedback.

3. Procedure: All subjects performed SMT and RIE with maximum effort and the effort was measured by HHD placed on the hand which detects the pressure caused by exercises. Then subjects performed 3times each exercise for data collection with 20% of maximum effort. During the exercises US imaging and EMG data were collected.

3.1. SMT: The subjects placed both hands on forehead to hold an elastic band which encircles head and gently extended their arms against an elastic band. Simultaneously, they were instructed to perform cervical retraction.

3.2. RIE: The subjects placed both hand on against the forehead and gently pressed the forehead. The HHD was placed between hands and forehead to detect the intensity of the exercise.

4. Statistical analysis: Paired *t*-test was used to compare muscle thickness change for SCM and LC, to compare muscle activity patterns for SCM, PM, UT and LT between SMT and RIE. The level of statistical significance was set at $p<0.05$.

Results

1. Muscle thickness: There was significant difference of SCM thickness change between two exercises. SCM thickness was decreased during SMT wherease it was increased during RIE ($p=0.00$). Otherwise significant increae of lateral demension(LD) thickness of LC was observed during SMT compared to RIE ($p=0.02$). During SMT, anterior posterior(AP) thickness of LC was also increased more than RIE but it was not statistically significant ($p=0.29$) (Table 1).

2. Muscle activity: Muscle activity of LT was increased significanlty during SMT compared to RIE ($p=0.00$). During RIE, SCM ($p=0.01$) and PM ($p=0.04$) activity was significantly increased compared to SMT (Table 2).

During SMT, muscle onset order was LT(0.09±0.19), PM(0.11±0.21), SCM(0.25±0.16), UT(0.32±0.12) while onset order duing RIE was LT(0.14±0.14), SCM(0.21±0.10), PM(0.23±0.10), UT(0.25±0.06) (Fig. 1).

Table 1 Comparison of muscle thickness increase between SMT and RIE

Increase of muscle thickness	SMT	RIE	*t*	*p*
SCM thickness(mm)	-0.03±0.11	0.27±0.14	7.95	0.00*
LC LD(mm)	0.21±0.08	0.06±0.16	-3.73	0.02*
LC AP(mm)	0.11±0.22	0.05±0.07	-1.08	0.29

SCM thickness: SCM thickness during SMT or RIE - SCM thickness during rest
LC AP: LC anterior posterior thickness during SMT or RIE - LC anterior posterior thickness during rest
LC LD: LC lateral dimension thickness during SMT or RIE - LC lateral dimension thickness during rest

Table 2 Comparison of muscle imbalance ratio (agonist/antagonist) between SMT and RIE

Muscle imbalance ratio	SMT	RIE	*t*	*p*
SCM/UT	0.41±0.19	0.56±0.12	3.25	0.01*
PM/(UT+LT)	0.52±0.10	0.62±0.27	2.25	0.04*
LT/UT	0.72±0.30	0.55±0.27	-3.90	0.00*

SCM/UT: %MVIC of SCM/%MVIC of UT
PM/(UT+LT): %MVIC of PM/%MVIC of UT+LT
LT/UT: %MVIC of LT/%MVIC of UT
*: $p<0.05$

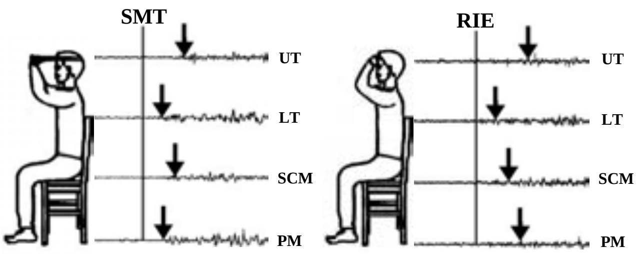

Fig. 1 Comparison of muscle onset time between SMT and RIE

Discussion

The present study highlighted the efficacy and neuromotor control mechanism of Janda's SMT when compared to RIE. As we anticipated, our findings demonstrated that Janda's SMT is effective therapeutic exercise for FHP compared to RIE.

US imaging data showed that SMT significantly increased LC muscle thickness and decreased SCM when compared with RIE, suggesting a superior effect on muscle activation of the deep neck stabilizer. A correlational study showed that muscle thickness in US represents muscle activation [7, 8]. Similarly, our EMG analysis of muscle imbalance ratio revealed that muscles (SCM, PM, UT) that are prone to overactivation were decreased while the muscle (LT) that is prone to inhibition was increased in EMG amplitude measurements in the SMT. This finding corroborates Janda's notion that SMT is more benefical for restoring muscle imbalance between the tonic-flexor and phasic-extensor systems, in a such way that it reciprocally deactivate the overactive antagonist (i.e., UT) and facilitate the underactive agonist (i.e., LT). Consequently, this restored muscle imbalance can correct altered cervical spine alignment, length-tension relationship, creating a optimal joint centration during neck movement in individuals with cervical pathology associated muscle imbalance in FHP. UT and SCM overactivation with LC underactivation are important biomakers for CCS associated with FHP, rounded shoulder, shoulder impingement and headache [1, 6]

Taken together, our novel findings suggest that Janda's SMT approach is useful to improve muscle imbalance syndrome. Hence, our results provide clinical insight for effective therapeutic exercise in individuals with neuromuscular imbalance and associated CCS.

Conclusions

Our present study first demonstrated that SMT was more beneficial for LC and LT activation than the RIE. This finding suggests that SMT could be appropriated therapeutic exercise for the patient with CCS.

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Feasibility of Emerging devise for Electrical Muscle Stimulation immediately after Cardiovascular Surgery

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Introduction

After surgical trauma, muscle protein is wasted because of accelerated protein catabolism[1-3]. Since loss of muscle protein is accompanied by a loss of muscle strength which induces functional decline of patients after cardiovascular surgery, preservation of skeletal muscle protein is of major clinical issue in postsurgical rehabilitation.

Electrical muscle stimulation (EMS) has been focused with substantial clinical interest that could induce sufficient muscle activities without patients' cooperation even immediately after surgery [4-7]. However, EMS devices used in clinical practice were limited to induce sufficient muscle torque response because of pain.

We, therefore, aimed to examine feasibility of our new EMS experimental system which allowed us to prescribe EMS based on maximal voluntary contraction (MVC) with less pain in patients immediately after cardiovascular surgery.

Materials and Methods

Patient population

Patients were consecutively included if they at least 20 years of age and were intended for elective major cardiovascular surgery (coronary artery bypass surgery, valvular surgery, aortic surgery, or combined surgery). Exclusion criteria were: age under 20 years, chronic renal failure (estimated glomerular filtration rate: eGFR<30 ml/min./1.73m^2), peripheral arterial disease (Fontein classification ≧ Ⅲ, psychiatric disease, neuromuscular disease, and dementia (Mini-Mental State Examination <18 points). Patients with technical obstacles that did not allow the implementation of EMS such as intra-aortic balloon pumping were also excluded, but patients with pacemaker were included. Informed consent was obtained from each patient as approved by the Ethics Review Committee of Nagoya University Graduate School of Medicine (1272).

Study Protocol

In all cases, measurement of MVC and determination of the intensity of EMS were performed on the day before the operation. After surgery, EMS was implemented on the bilateral quadriceps and triceps surae muscles daily from second to sixth day after surgery (5 sessions). The duration of the session was 60minutes. Blood pressure, heart rate, electrocardiogram and muscle soreness during EMS were monitored by physiotherapist in each session. Blood pressure, heart rate and rhythm were measured by Patient Monitor system (IntelliVue MP70, PHILIPS). Muscle soreness was assessed by the Faces pain scale (16).

EMS

In this study, stimulus pattern of EMS was the variable frequency train which was developed in our laboratory to theoretically optimize muscle contraction as voluntary contraction and to induce 20% MVC without pain. The variable-frequency train included initial two high-frequency (200Hz) bursts at the onset of low-frequency (20Hz) stimulation. The waveform of EMS was a symmetric biphasic square wave. The stimulator was configured to deliver a direct electrical current for 10 seconds followed by 30 seconds of rest. The intensities of the stimulation were set at 10% or 20% of MVC and the repetitions of 10%-10%-20%MVC were prescribed throughout the session.

Feasibility Assessment

Feasibility criteria was established as follows: 1) more than 80% of participants who could complete more than 4 of 5 sessions, 2) change in systoic blood pressure during EMS <20mmHg, 3) change in heart rate during EMS <20bpm, 4) incidence of new onset post-operative atrial fibrillation (POAF) during study period < 30% in CABG, <40% in valvular surgery, and <50% in combined and aortic surgery. In this study, we defined successful EMS session as the session in which patient could receive EMS for 30minutes and over.

Statistics

Data for descriptive statistics are expressed as percentages, or mean±SD. Data are analyzed for all days that EMS had been applied during the enrollment period

Results

Patient population

From November 2011 to August 2012, a total of 95 patients intended for elective cardiovascular surgery were included in this study and 40 patients fulfilled exclusion criteria or refused to participate. The study population consisted of 55 patients. Patient demographics are listed in Table1

Table1. Patients Demographics

Demographics	n=46
Age, yrs	65.7 ± 11.6
Male, %	76.1%
Body mass index, kg/m^2	23.6 ± 3.3
Operative procedure	
CABG, no (%)	19 (41.3%)
Valvelar, no (%)	17 (37.0%)
Aortic, no (%)	6 (13.0%)
Combined, no (%)	4 (8.7%)
Time from surgery to initial EMS session, days	1.3±0.5
Intravenous drugs at 1st EMS session	
Norepinephrine, no (%)	9 (19.6%)
Dobutamine, no (%)	15 (32.6%)
Dopamine, no (%)	9 (19.6%)
Milrinone, no (%)	4 (8.7%)
Furosemide, no (%)	4 (8.7%)
Carperitide , no (%)	2 (4.3%)
Nicardipine, no (%)	7 (15.2%)
Nicorandil, no (%)	18 (39.1%)
landiolol, no (%)	3 (6.5%)

Feasibility of EMS

Thirty-seven out of Forty-five (82.2%) patients had successively completed 4-5 sessions. None of patients did not experience the change in systolic blood pressure>20 mmHg and/or heart rate>20bpm during EMS. Response to EMS in systolic blood pressure and heart rate at first EMS session was shown in Table 2.

Table 2. Cardiovascular response at 1st EMS session

	Rest	CV at rest	⊿10min	⊿20min	⊿30min	⊿40min	⊿50min	⊿60min	CV at EMS
sysBp	106.7 (97.3-112.7)	3.5 (2.1-5.5)	3.3 (-1.7-7.3)	3.3 (-3.7-6.0)	1.3 (-11.6-14.3)	2.7 (-0.9-5.8)	0.3 (-5.3-4.7)	1.3 (-5.3-4.7)	3.7 (2.7-4.3)
HR	84.7 (74.7-92.0)	1.3 (0.7-2.6)	0.0 (-1.3-1.7)	0.7 (-0.3-3.0)	0.0 (-1.3-2.3)	1.0 (-1.0-3.3)	0.7 (-1.0-3.3)	1.3 (-1.3-3.7)	2.2 (0.9-4.1)

sysBp, systolic blood pressure; HR, heart rate; CV, coefficient of variance. Data are presented as median (interquartile range)

There was not clinically significant change in systolic blood pressure and heart rate. Incidence of POAF was 20.0% (3/15) in CABG, 18.2% (2/11) in valvular surgery, and 16.6% (1/6) in combined and aortic surgery (Table 3). The two patients who received CABG manifested paroxysmal AF during ES. Five out of 45 patients (11.1%) dropped out due to muscle soreness or fatigue at first ES session after the operation.

Table3. Criteria for Success of Feasibility and Associated Outcomes

Variable	Criteria for Success of Feasibility	Study outcome
Compliance	>80% of participants can complete ≧4 of 5 sessions	41 of 46 (89.1%)
Cardiovascular response to EMS		
Systolic blood pressure	In all of participants, changes in systolic blood pressure from rest to EMS do not excess 20mmHg	100%
Heart rate	In all of participants, changes in heart rate from rest to EMS do not excess 20bpm	100%
Incidence of POAF	< 30% in CABG	5 of 19 (26.3%)
	< 40% in valvular surgery	3 of 17 (18.8%)
	< 50% in aortic or combined surgery	3 of 10 (30.0%)

Discussion

Clinically insignificant responses of systolic blood pressure and heart rate, incidence of POAF, and good complement rate indicated that emerging new EMS which can induce strong muscle contraction can be safely implemented even immediately after cardiovascular surgery. In our knowledge, this is first study that reports the feasibility and safety of such an aggressive EMS intervention.

The intensities of EMS in previous studies were limited at intensities able to cause visible contractions (<5% of MVC) [4-7]. In contrast, our study demonstrates that EMS inducing stronger muscle contraction at 10% and 20% of MVC is feasible in patients immediately after cardiovascular surgery. Since there is the dose-response relationship between muscle protein synthetic response and intensity of muscle contraction [8], EMS which induces higher intensity muscle contractions might be more effective for preventing loss of muscle protein. Thus, our study suggests that more effective EMS intervention for preventing muscle protein degradation after cardiovascular surgery is feasible and safe in terms of cardiovascular response to EMS.

Conclusions

New EMS which can induce stronger muscle contraction is both feasible and safe even immediately after cardiovascular surgery. This preliminary report provides a basis of carrying out our future research to examine the effects of our new EMS on prevention of muscle loss after cardiovascular surgery.

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The effect of internet based cardiac rehabilitation with pulse monitoring device on improvement of exercise tolerance and coronary risk factor modification: a pilot study.

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Introduction

Cardiac rehabilitation (CR) has been proved beneficial in increasing exercise capacity and reducing coronary risk factors. Despite the documented benefits of CR, attendance at the CR program is remained much poor. The previous study reported that the overall rate of participation of acute myocardial infarction (AMI) patients in CR in Japan was estimated at 4.8-11.7% [1]. The barriers of time and distance were reported the reason for this low participation rate [2]. These problems could be overcome by home based CR, which patients could perform CR whenever and wherever they want. Telehealth intervention (phone, e-mail and internet) was considered as one of the strategies supported for home based CR [3, 4]. However, previous studies did not use sensor device for monitoring exercise. Thus we developed a new system for internet based CR with using pulse monitoring device (PMD). By using PMD, we could perform exercise prescription by means of objective data and patient could manage the exercise intensity at CR. This study aimed to investigate the effect of internet based CR with PMD in increasing exercise tolerance and reducing risk factors.

Materials and Methods

Subjects: We recruited the patients with AMI who underwent percutaneous coronary intervention at Nagoya Daini Red Cross Hospital. Inclusion criteria were patients with AMI who met the criteria for risk classification for exercise training: Class B from the statement of American Heart Association. We excluded the patients with inaccessible to computers, hemodialysis, chronic atrial fibrillation, orthopedic or neurogenic disorders and cognitive impairment.

Procedures: This study was constructed as a case series design to investigate the effects of internet based CR with PMD. The CR program started one month after discharge and performed 8 weeks. For primary outcomes, we assessed exercise tolerance and coronary risk factors before and after CR program. And we also measured physical activity for secondary outcomes. The study protocol was approved by the Ethics Review Board of Nagoya University School of Medicine, and written informed consent was obtained from all of the patients.

Exercise tolerance: Each patient underwent cardiopulmonary exercise testing (CPX) at a progressively increasing work rate to maximum tolerance on a cycle ergometer. The test protocol was in accordance with the recommendations of the American College of Sports Medicine [5]. We assessed oxygen uptake at anaerobic metabolic threshold ($ATVO_2$) and peak point ($PeakVO_2$) as exercise capacity by using the analysis equipment for respiratory gas exchange.

Coronary risk factors: We assessed body mass index (BMI), home blood pressure (Home BP), lipid profiles, glycated hemoglobin and smoking habits as coronary risk factors. Home BP was defined as the average of consecutive 7 days. We evaluated serum high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein cholesterol (LDL-C) and hemoglobin A1c (HbA1c) by using standard methods from fasting samples. Smoking habits was determined by self-report questionnaire.

Physical activity: The mean daily step count and the duration of low-, moderate- and high-intensity physical activity were used (total count over 7 days/7) for 1 week as an index of the physical activity of the patient. Low-, moderate- and high-intensity activity correspond to less than 3.0 METs, 3.0～6.0 METs and more than 6.0 METs, respectively. To estimate the daily physical activity, an electrical accelerometer (Kenz Lifecorder, Suzuken, Nagoya, Japan) was selected. All patients were instructed on how to put on the accelerometer themselves and use the accelerometer 24 h/day for 1 week, except while bathing and sleeping.

Intervention: We gave patients to PMD (figure1), the laptop pre-installed with the application software and education materials about lifestyle modification for secondary prevention. The patients entered their records of home BP, weight, and implementation status of exercise. These data could be sent to Nagoya University through the internet and we could confirm patients' status at university. The patients were received exercise prescription which was determined based on their CPX data and their self-monitored pulse rate by using the PMD. As PMD was connected to the laptop, the exercise records were automatically sent to Nagoya University. We performed some advice about exercise and feedback based on PMD data once a week for the first 4weeks, once two weeks for the next 4weeks.

Data analysis: A paired-t test was used to compare the differences in exercise tolerance and coronary risk factors between pre and post-intervention. All analyses were performed with the SPSS 16.0 software package (SPSS Inc., Tokyo, Japan). A p-value of less than 0.05 was considered statistically significant.

Figure 1 Pulse monitoring device (PMD)
The patients could monitor their pulse rate during home exercise.

Results

11 AMI patients who could not attend outpatient CR program participated in this study between December 2010 and December 2011. Results were expressed as mean ± standard deviation (Table1). $ATVO_2$, $PeakVO_2$ and HDL-C were significantly increased, and LDL-C was significantly decreased during the intervention period. Similarly, there were significant increase in daily step counts and duration of physical activity in moderate to high intensity. On the other hand there were no significant changes in BMI, Home SBP, Home DBP, and HbA1c.

Table 1 Changes in exercise tolerance and coronary risk factors at baseline and after 8-week CR program

	Baseline	8-week CR program	*P*
AT VO_2 (ml/min/kg)	12.0 ± 2.1	13.5 ± 2.5	0.014*
Peak VO_2 (ml/min/kg)	21.6 ± 5.0	24.0 ± 4.6	0.004*
BMI (kg/m^2)	23.6 ± 3.6	23.4 ± 3.4	0.296
Home SBP (mmHg)	120.4 ± 19.8	115.5 ± 19.4	0.361
Home DBP (mmHg)	77.4 ± 12.4	79.3 ± 10.9	0.680
HDL-C (mg/dL)	39.7 ± 7.0	50.0 ± 15.8	0.007*
LDL-C (mg/dL)	118.0 ± 38.9	84.5 ± 27.6	0.011*
HbA1c (%)	6.1 ± 1.3	5.7 ± 0.6	0.120

*P<0.05 compared to baseline (paired t-test)
AT VO_2: oxygen uptake at anaerobic metabolic threshold
Peak VO_2: oxygen uptake at peak point
BMI: Body mass index
SBP: Systolic blood pressure
DBP: Diastolic blood pressure
HDL-C: High-density lipoprotein cholesterol
LDL-C: Low-density lipoprotein cholesterol

Discussion

The results of our study demonstrated that internet based CR with PMD has favorable effects on ATVO2, PeakVO2 and lipid profile in AMI patients. To our knowledge, this is the first study to demonstrate the effect of internet based CR program on exercise tolerance and coronary risk factors.

Exercise capacity significantly increased after 8-week CR program. The rate of improvement of AT VO_2 and $PeakVO_2$ were 12.5% and 11.1%, respectively. In the previous study which compared active outpatient CR participants with non-active participants [6], the active CR participants showed a significantly greater improvement in exercise capacity than non-active participants (15.6% vs 8.6%). Thus, it seemed that internet based CR could act as an alternative to conventional outpatients CR. By using PMD, patients could manage their exercise duration and intensity. As a result, daily step counts and duration of physical activity over moderate intensity were significantly increased after internet based CR. The increase of physical activity might contribute to increasing exercise capacity.

There were significantly increased in HDL-C and decreased LDL-C. The magnitudes of the HDL-C and LDL-C chnage were 25.9% and 28.4%, respectively. Previous studies have reported that the mean change of HDL-C by exercise was 9.0% [7], and by medications was 5.9% [8]. Therefore, the results of the present study might have combined effects of exercise and medications. On the other hand, there is no consensus the effects of exercise on reducing LDL-C. Thus, it was difficult to determine the effects of internet based CR on reducing LDL-C on the basis of this study.

The small sample size and the only intervention group might affect the results or our findings. Therefore, this study could function as a preliminary study to demonstrate the effect of internet based CR. However, our results were obtained in a selected AMI patients considered a representative sample of the most AMI patients who supposed to apply for internet based CR. Further research was required to compare the efficacy of conventional and internet based CR.

Conclusions

The results of our study suggest that internet based CR with PMD may have a favorable effect on increasing exercise capacity and reducing coronary risk factors. Further research is needed to establish the usefulness of internet based CR.

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Immediate Effects of Soft Tissue Massage on Acromiohumeral Distance, Anterior Translation of Humeral Head, and Glenohumeral Range of Motion in Subjects With Posterior Shoulder Muscle Tightness: A Preliminary Study

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Introduction

Shoulder impingement syndrome is one of the most common musculoskeletal problems and is related to narrowing of the acromiohumeral distance (AHD). AHD was defined as the shortest distance between the inferior surface of the acromion and superior aspect of the humeral head (Kalra et al, 2010). Reduced AHD may be associated with limited glenohumeral (GH) horizontal adduction and internal rotation, while increased AHD may relieve the symptoms of compression of the subacromial space structures (Kalra et al, 2010; McClure et al, 2007).

Especially, posterior shoulder muscle tightness such as posterior deltoid and teres minor is frequently observed in subjects with shoulder impingement syndrome because the posterior portion of the shoulder muscle tightness causes anterior and superior translation of the humeral head in relation to the glenoid fossa (McClure et al, 2007; Tyler et al, 2000).

Ultrasonography (US) as an imaging modality is less costly and more practical than magnetic resonance imaging (MRI) or computed tomography (CT), and has established concurrent validity with radiographic AHD measures (r = 0.77-0.85). However, the effects of soft tissue massage on AHD and anterior translation of the humeral head have not been investigated in subjects with posterior shoulder muscle tightness using US.

Thus, the purpose of this study was to determine the immediate effect of soft tissue massage on AHD, anterior translation of the humeral head, and GH range of motion (ROM) in subjects with posterior shoulder muscle tightness.

Materials and Methods

Subjects: We recruited 27 subjects (14 male, 13 female) with a 10° or greater difference in the range of GH horizontal adduction between right and left sides (Park et al, 2010). The age of subjects was 21.37±1.75 years, height was 169.07±8.41 cm, and weight was 61.51±11.55 kg. Prior to collecting data, the examiner informed subjects of all procedures. Subjects read and signed written consent forms. The study protocol was approved by Yonsei University Wonju Campus Human Studies Committee.

Instrumentation: US was utilized with 7.5 MHz linear transducer (SonoAce X8, Medison Co., Ltd, Seoul, Korea) to measure AHD and anterior translation of humeral head. An industrial digital inclinometer (GemRed DBB, Gain Express Holdings, Ltd., Hong Kong, China) was used for measuring the range of GH horizontal adduction and internal rotation in this study.

Inclinometer measurement of the ROM of GH horizontal adduction: The subject was positioned supine on the therapeutic table and the test shoulder with the elbow in 90° of flexion and the shoulder abducted 90°. The examiner stabilized the lateral border of the scapula by providing a posteriorly directed force. The examiner grasped the subject's forearm, and then moved the humerus into horizontal adduction passively until the end-feel. The assistant examiner placed a digital inclinometer aligned with the midline of the humerus. The angle between the humerus and a vertical line to therapeutic table was measured (Intraclass correlation coefficient; ICC = 0.93) (Moore et al, 2011; Park et al, 2010).

Inclinometer measurement of the ROM of GH internal rotation: The subject was positioned supine with the shoulder abducted 90° and the elbow flexed 90°. A folded towel was placed under the distal humerus so that the humerus was aligned in the scapular plane. The pressure biofeedback unit was placed between the therapeutic table and the subject's scapula for stabilizing the scapula. The elastic bag of the pressure biofeedback unit was inflated up to 40mmHg, and the humerus was passively rotated internally. When the pressure changes ±2mmHg from 40mmHg during passive GH internal rotation, an examiner stopped passive internal rotation and determined this ROM as GH internal rotation without compensation. In this position, the assistance examiner placed a digital inclinometer on the dorsal surface of the forearm aligned with the long axis of the ulna. The angle between the forearm and a vertical line to therapeutic table was measured (ICC = 0.93) (Lunden et al, 2010; Kim et al, 2010; Moore et al, 2011).

US measurement of AHD: AHD was measured between the inferior surface of the acromion and the superior aspect of humerus. Placement of the US transducer was standardized, with its location on the posterior to middle portion of the acromion in the coronal plane, and then the transducer was placed parallel to the superior aspect of the acromion so that both the acromion and humerus were visualized (ICC= 0.92) (Kalra et al, 2010; Nové-Josserand et al, 1996).

US measurement of anterior translation of humeral head: We modified an US method that was first described by Court-Payen et al (1995). The transducer was placed on the anterior aspect of the shoulder. Two well-defined bony structures could be identified anteriorly: the greater tuberosity of the humerus and the coracoid process of the scapula. We defined the amount of anterior translation of humeral head as the difference between the coracoid process and the greater tuberosity of the humerus head (ICC=0.86).

Soft tissue massage on posterior deltoid and teres minor: We applied deep gliding massage which is one of the soft tissue massage therapy techniques for myofascial release (Sherman et al, 2006). The subject was in the side-lying position on the side not being massaged and the subject's shoulder and elbow being massaged were placed in 90° of flexion with humerus in neutral rotation. The scapula of subject's shoulder being massaged was stabilized in a full retraction by examiner's hand. For the soft tissue massage, the examiner palpated posterior deltoid and teres minor. Posterior deltoid is located in two finger breadths caudal to the posterior margin of the acromion, and teres minor is located in one-third of the way between the acromion and the inferior angle of the scapula along the lateral border (Yang et al, 2012). The examiner's thumb was placed on the target muscles, and then the examiner applied pressure firmly into target muscles while asking the subject to slowly turn the trunk backward. This intervention was performed in 5 repetitions with each repetitions lasting for 20 second and resting period of 10 seconds between repetitions (Park et al, 2010). The intensity of massage was modulated individually by the subject's reaction to pain or discomfort. If the subject complained of discomfort or pain, the intensity of soft tissue massage was reduced.

Data Analysis

Descriptive statistics were calculated for all variables. Kolmogorov-Smirnov Z-tests were performed to assess normality of distribution. Paired t-test was used to compare AHD, anterior translation of the humeral head, and the range of GH horizontal adduction and internal rotation before and after soft tissue massage. The statistical significance level was set at 0.05. All statistical analyses were performed using PASW statistics version 18.0 (SPSS, Inc., Chicago, IL).

Results

All dependent variables were found to approximate a normal distribution (Kolmogorov-Smirnov Z-test, $p>0.05$). AHD increased significantly from 1.13±0.13 to 1.22±0.17 after the soft tissue massage ($p<0.05$). The difference between the coracoid process and the greater tuberosity of the humerus head increased slightly from 0.32±0.31 to 0.34±0.34 after the soft tissue massage. This increment indicates the humeral head was moved posteriorly in the glenoid fossa and that is to say that anterior translation of the humeral head was reduced after soft tissue massage. However, this increment was not significant ($p=.40$). Also the range of horizontal adduction and internal rotation in GH joint increased significantly from 22.45±5.12 to 31.08±5.30 and from 61.63±9.48 to 68.11±9.06, respectively ($p<0.05$).

Discussion

In this study, we investigated the effects of soft tissue massage on AHD, anterior translation of humeral head and the ROM of GH joint in subjects with posterior shoulder muscle tightness. To the best of our knowledge, this study is the first trial to measure AHD and anterior translation of humeral head to determine the effect of soft tissue massage to posterior shoulder muscle tightness by using US.

After soft tissue massage, AHD increased significantly by 8% and the amount of anterior translation of the humeral head decreased by 6%, however, this reduction was not significant. Additionally, we assessed the range of horizontal adduction and internal rotation of GH joint before and after soft tissue massage. There were significant increment of the range of horizontal adduction and internal rotation by 38% and 10% respectively. These ROM findings are in agreement with the results from previous studies that soft tissue massage increased the angle of horizontal adduction and internal rotation significantly.

Our study has several limitations. First, our findings could not be generalized to patient population because healthy young subject with a 10° or greater difference in the range of GH horizontal adduction between right and left sides participated in this study. Second, this study was a cross sectional study to see the immediate effect of soft tissue massage. Therefore longitudinal study should be undertaken recruiting old subjects with shoulder impingement syndrome or anterior translation syndrome to confirm the effects of soft tissue massage on posterior shoulder muscle tightness. Third, though we tried to provide a consistent pressure and maintain exact position of the US transducer during data collection, measurement error was likely to occur. So a hands-free method of attaching the transducer to subjects, like a transducer holder, may be considered in the future studies. Fourth, since our study is a preliminary study with one group pretest and posttest design, randomized controlled trial is warranted to validate the results of our study.

Conclusions

Our findings indicate that soft tissue massage on posterior deltoid and teres minor result in significantly greater increase in AHD, slight decrease in anterior translation of humeral head, significantly increased the range of GH horizontal adduction and internal rotation in subjects with posterior shoulder muscle tightness. Therefore, soft tissue massage can be recommended as an effective method to increase AHD and the range of GH horizontal adduction and internal rotation.

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Effects of Breathing Maneuver and Sitting Posture on Muscle Activity in Inspiratory Accessory Muscles in Patients with Chronic Obstructive Pulmonary Disease

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Introduction

Breathing training [1] and a sitting posture with a forward-leaning trunk [2] have been advocated as therapeutic interventions in patients with chronic obstructive pulmonary disease (COPD) to relieve dyspnea and improve pulmonary function. However, the effects of a forward-leaning position on inspiratory muscle activity remain unclear. Thus, this study was performed to compare the tidal volume (TV), respiratory rate (RR), and activity of respiratory accessory muscles during quiet natural breathing (QB) and pursed lips breathing (PLB) in three different sitting positions: a neutral position (NP), with arm support (WAS) in a forward-leaning position, and with arm and head support (WAHS) in a forward-leaning position in patients with COPD.

Materials and Methods

Subjects: Twelve male subjects (age = 68.2 ± 8.2 years; weight = 60.4 ± 6.9 kg; height = 1.7 ± 0.4 m; body mass index = 21.3 ± 2.0 kg/m^2) diagnosed with COPD were recruited from the Division of Pulmonary Medicine, Department of Internal Medicine, Gangnam Severance Hospital, Yonsei University College of Medicine, Yonsei University Health System, Seoul, Korea. All subjects were classified as stage 2 or 3 COPD (forced expiratory volume in 1 s percent predicted (FEV_1 %pred) (50.75 ± 9.27)) by the GOLD criteria [3].

Measurement tools: Inductive respiratory plethysmography and surface electromyography were performed using an Embla N7000 (Embla Systems, Broomfield, CO) to enable the simultaneous acquisition and recording of respiratory parameters (TV and RR) and surface electromyographic measurements (muscle activity).

Procedures: Prior to enrollment in the study, all subjects received a training session for PLB. For the quiet natural breathing (QB) maneuver, patients were instructed to breath in their normal habitual comfortable breathing style with no specific training. Breathing maneuvers and sitting postures to be tested were selected by randomized ballots to eliminate any possible test order effect. All subjects felt relaxed and comfortable after a familiarization period of 5 min.

Data analysis: Two-way (2 × 3) analysis of variance with repeated measures was employed for comparing the two breathing maneuvers (QB, PLB) and three different positions (neutral position, WAS position, WAHS position). In the case of significant differences between test positions, Bonferroni's *post hoc* test was performed. In all analyses, P-values <0.05 were deemed to indicate statistical significance.

Results

1. TV and RR

For TV, there was no interaction between breathing pattern and position (F = 0.132, P = 0.877). There was a significant main effect of breathing method (F = 90.017, P < 0.001), but there was no significant main effect of position (F = 0.837, P = 0.446). TV in PLB was significantly greater than that in QB. For RR, there was no interaction between breathing pattern and position (F = 1.462, P = 0.253). There was a significant main effect of breathing method (F = 50.702, P < 0.001), but there was no significant main effect of position (F = 1.387, P = 0.271).

2. Muscle activity

For scalene muscle (SM) activity, there was no interaction between breathing pattern and position (F = 0.830, P = 0.449). However, there were significant main effects of breathing method (F = 19.550, P = 0.001) and position (F = 7.466, P = 0.003). Muscle activity in PLB was significantly greater than that in QB. Bonferroni's *post hoc* test showed that the muscle activity in WAHS was increased significantly compared with that in NP (P = 0.017). Muscle activity was not significantly different between WAHS and WAS (P = 0.070) or between WAS and NP (P = 0.495). For sternocleidomastoid muscle (SCM) activity, there was no interaction between breathing pattern and position (F = 0.650, P = 0.532), but significant main effects of breathing method (F = 5.751, P = 0.035) and position (F = 24.124, P < 0.001) were observed. Muscle activity in PLB was significantly greater than that in QB. Bonferroni's *post hoc* test showed that the muscle activity in WAHS was increased significantly compared with that in NP (P = 0.001), and the muscle activity in WAS was increased significantly compared with that in NP (P < 0.001). No significant difference in muscle activity between WAHS and WAS (P = 0.154) was observed. For pectorals major (PM) muscle activity, the results showed no interaction between breathing pattern and position (F = 1.138, P = 0.359) and no significant main effect of breathing method (F = 3.940, P = 0.073), but a significant main effect of position (F = 4.662, P = 0.037) was observed. Bonferroni's *post hoc* test showed significant muscle activity differences among the three sitting positions used in this study. Muscle activity in WAS was increased significantly compared with that in NP (P = 0.025) and in WAHS (P = 0.029). Muscle activity in WAHS was increased significantly compared with that in NP (P = 0.039).

Discussion

The findings of this study showed that TV was significantly greater in PLB than in QB and that RR was significantly lower in PLB than in QB, supporting the research hypothesis. The increased TV during PLB was probably due largely to the increased pressure in extra-thoracic airways and thus to a reduced cost of breathing due to decreased intrinsic positive end-expiratory pressure (PEEP). Many patients with COPD use PLB in an attempt to produce extrinsic PEEP to reduce lung hyperinflation and dyspnea [4]. The increased TV observed in our study may be explained by a recent study that described that deflation of the abdomen and inflation of the rib cage contributed to increased tidal volume of the chest wall during PLB [5].

In contrast to PLB, TV and RR did not differ significantly with sitting position. Thus, the research hypothesis regarding breathing position was not supported by the results of this study. These findings are consistent with a recent study by Bhatt *et al.* [6], who found no significant differences in FEV_1, the ratio of forced expiratory volume to forced vital capacity (FEV_1/FVC), maximum inspiratory pressure (MIP), maximal expiratory pressure (MEP), diaphragmatic movements during tidal breathing, or forced breathing in the sitting, supine, or sitting leaning forward with the hands supported on the knees (tripod position) in patients with COPD.

Patients with severe COPD frequently lean forward, bracing their arms. A position bracing the elbows on a table increased ventilatory capacity significantly in four healthy men, and this effect could be helpful information for COPD patients, whose diaphragms are flattened and ineffective, as such patients depend more on the inspiratory muscles of the rib cage [7]. TV and RR did not differ significantly in relation to sitting position in this study. We had no data on inspiratory duty cycle or FRC according to different sitting posture; thus, our results do not provide complete information about postural changes in lung volumes.

The muscle activities of the SM and SCM in PLB were significantly greater than those in QB in this study. Given that the SM and SCM attach between the cervical spine and the upper two ribs, increased muscle activity in these muscles during inspiration in patients with COPD can be interpreted as an attempt to increase intrathoracic volume by elevating the upper ribs and sternum [8]. Increased SCM activity in PLB compared with QB is consistent with the results of a previous study indicating increased inspiratory rib cage expansion and recruitment of respiratory accessory muscles and reduced diaphragm recruitment during inspiration of PLB compared with tidal breathing [9].

In this study, muscle activities of the SM and SCM in a forward-leaning position, both WAHS and WAS, were greater than those in NP, even though the increased muscle activity of the SM in WAS relative to NP failed to reach statistical significance. Several mechanisms may explain these results. First, it is possible that increased activity of the SM and SCM overcame restricted downward movement of the diaphragm. The forward-leaning position results in increased intra-abdominal pressure by approximating the ribs to the pelvis, making it difficult for the diaphragm to descend caudally during inspiration [10, 11]. A second possibility is the reversal of muscle action by the stabilizing force of the hand on the face in WAHS and of the forearm on the thigh in WAS. As the hands or forearms are stabilized, the sternum, clavicle, and rib cage can be pulled upward by the SM and SCM.

In this study, the PM showed the greatest muscle activity in WAS, followed by WAHS, and the lowest PM activity was observed in NP. These results may be explained by reversal of muscle contraction. When the distal limb segment is stabilized, the proximal limb segment can be mobilized. Decreased activity of the PM in WAHS, compared with that in WAS, may be attributable to increased SM and SCM activity in WAHS. However, muscle activities of the major muscles of respiration, including the diaphragm and intercostal muscles, were not measured, so the effects of changes in the activity of accessory muscles during different breathing maneuvers and of various positions on major muscle activity could not be determined in this study.

Conclusions

The results suggest that in COPD, PLB induced a favorable breathing pattern (increased TV and reduced RR) compared with QB. Additionally, WAS and WAHS positions induced increased muscle activity of the inspiratory accessory muscles during inspiration versus NP. Differential involvement of accessory respiratory muscles can be readily studied in COPD patients, allowing monitoring of respiratory load during pulmonary rehabilitation.

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