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Content

Trunk Balance and Maintaining a Body Position – the Cornerstone of Functional Activities

In rehabilitation practice, mobility limitations such as changing and maintaining body position, carrying and moving objects, walking, and moving are common problems encountered by both patients and rehabilitation professionals. To perform these activities, one needs not only good strength, endurance, flexibility, and coordination of the extremity muscles but also strong functioning trunk muscles. The trunk muscles must first be activated to maintain trunk stability, then only movements of extremities and functional activities are possible. Trunk balance is also represented in the International Classification of Functioning, Disability and Health (ICF) as item d415 - maintaining a body position. It is defined as staying in the same body position as required, such as remaining seated or remaining standing for carrying out a task, in play, work, or school.

Trunk balance is an important component of the rehabilitation process, particularly for persons with stroke, spinal cord injury, and traumatic brain injury. In rehabilitation medicine practice, trunk balance is usually divided into sitting or standing positions, and static or dynamic. It is quite common for rehabilitation practitioners to use qualitative descriptions such as poor, fair, and good to quantify trunk balance when assessing and monitoring patients. A non-standard assessment like this will lead to different interpretations and understanding by different team members. Therefore, it is recommended that a precise and objective assessment tool is used to monitor trunk balance to facilitate group decision-making and identify whether the given interventions are effective.

The Berg balance scale is widely used in rehabilitation practice to assess and train trunk balance. In 2005, a group of researchers from Belgium developed Trunk Impairment Scale or TIS. The TIS measures static and dynamic sitting balance as well as trunk coordination. One interesting feature of TIS is that it points out various compensating movements a patient performs while maintaining a sitting position; therapists who are performing the assessment should be aware of this. Although the TIS was originally developed for stroke patients, some researchers suggested that it could be used in patients with other upper motor neuron lesions. TIS has good reliability, internal consistency, and validity, and is recommended for use for both clinical practice and research. The therapist could learn how to perform TIS by watching instructional video clips which are available online. TIS has been translated into many languages, of which one is the Thai language. In this issue, we present an article on validation and reliability of the Thai version of the TIS version 2.0.

The current issue has interesting and educational articles that could benefit both rehabilitation physicians (physiatrists) and other rehabilitation professionals in their clinical practice and research. I wish you a good read and thank you for your continuous support.

Apichana Kovindha, MD, FRCPhysiatrT
Editor-in-chief

Original Article

Effects of the Self-Ischemic Compression by a T-shaped Wood Stick in Participants with Upper Trapezius Myofascial Trigger Point: A Randomized Controlled Trial

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ABSTRACT

Objectives: To determine the effectiveness of the self-ischemic compression by using a T-shaped wood stick and followed by sustained stretching on pain and quality of life in participants with upper trapezius myofascial trigger point (MTrP).

Study design: Single blinded randomized controlled trial.

Setting: Outpatient rehabilitation clinic at Siriraj Hospital, Thailand.

Subjects: Forty-eight participants (9 males, 39 females), aged 18-55 years old, with moderate pain of unilateral or bilateral upper trapezius myofascial pain syndrome.

Methods: The participants were randomized into two groups. The intervention group received the T-shaped wood stick to perform self-ischemic compression on MTrP followed by sustained stretching, whereas the controlled group was instructed to do sustained stretching. Both groups were asked to perform according to the instruction twice a day for 5 days. The outcomes were assessed before treatment and followed-up on day 8. A visual analog scale as the primary outcome, and pain pressure threshold were used to assess pain intensity. Active cervical lateral flexion range of motion, and the Thai-version of neck disability index was used to measure the quality of life.

Results: There was statistically significant improvement of visual analog scale between groups but no statistically changes in pain pressure threshold and the Thai-version of neck disability index were observed.

Conclusion: Self-ischemic compression with a T-shaped wood stick followed by sustained stretching showed short-term improvement of pain intensity in chronic upper trapezius myofascial pain syndrome with moderate pain.

Keywords*:* self-ischemic compression, myofascial pain syndrome, pain, trigger point, stretching exercise

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Introduction

Myofascial pain syndrome (MPS) is one of the most common causes of pain in general practice. Pongsatornkulpanit et al. reported the prevalence of MPS was 36% in Thai patients with musculoskeletal pain.[1] Higher incidence was noted among office workers and female.[1] Patients with MPS had worse quality of life in terms of pain, energy, physical mobility, sleep, and emotional reactions.[2-5] MPS is characterized by the presence of myofascial trigger points (MTrP) and an active MTrP causes a clinical pain complaint.[6] It is always tender, prevents full lengthening of the muscle, refers a patient-recognized pain on direct compression, mediates a local twitch response of muscle fibers when adequately stimulated, and when compressed within the patient's pain tolerance, produces referred motor phenomena and often autonomic phenomena, generally in its pain reference zone, and caused tenderness in the pain reference zone.[6] Whereas a latent MTrP is a clinically quiescent concerning spontaneous pain; it is painful only when palpated.[6-8] Reviews revealed that trapezius muscle is the most commonly found MTrPs.[9]

The treatments of MPS include symptomatic treatment and correction of precipitating factors. The common treatments are therapeutic exercise, massage, dry needling, and physical modalities.[6-8] For dry needling and physical modalities, the patients have to visit a hospital for the treatment which is time and resource consuming but ischemic compression, one of the effective mechanical treatments of MTrPs, consists of application of sustained pressure for a long enough time to inactivate the MTrPs and can be done by everyone and by themselves anywhere. Ischemic compression can reduce pain by 2 main mechanisms, reactive hyperemia and triggering spinal reflex mechanism producing reflex relaxation.[10-12] There are several ways to apply ischemic compression to MTrP including manual therapy and device created specifically the self-ischemic compression. Hanten et al. reported that a device called 'Thera cane', a plastic J-shaped cane, can be used to deliver self-ischemic compression followed by sustained stretching by patients themselves twice a day for 5 days was effective in reducing MTrP sensitivity and pain intensity in individuals with neck and upper back pain.[13]

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There is a T-shaped wood stick commercially available, which is sold widely as a Thai traditional medicine equipment, to treat muscle pain that people usually use to relieve muscle pain by themselves. This is similar to a J-shaped cane.[13] However, there is no study exploring the effectiveness of this T-shaped wood stick. From personal experience, the T-shaped wood stick used for self-ischemic compression might be effective in relieving pain. Therefore, the purpose of this study was to determine the effectiveness of self-ischemic compression with a Thai T-shaped wood stick followed by sustained stretching exercises in patients with upper trapezius MPS.

Methods

Study design

This single-blinded randomized controlled trial was registered at the Thai Clinical Trials Registry (TCTR 20191110001) and approved (COA 563/2018) by the Medical Ethics Committee of the Siriraj Hospital Human Research Protection, Bangkok, Thailand.

Participants

We recruited participants from Rehabilitation Medicine outpatient clinic, Siriraj Hospital, Mahidol University, from December 2018 to June 2019. They were diagnosed with MPS by a physiatrist who determined active MTrPs in trapezius muscle according to the criteria defined by Travell and Simons.[6] All participants were asked to sign an informed consent form.

Then, those who met the following criteria: having unilateral or bilateral upper trapezius MPS with VAS 50-100 (moderate to severe pain); aged between 18-55 years old; and had to understand written and verbal Thai language, were included. Those with the following exclusion criteria: received upper trapezius MTrP treatment (including massage, physical therapy, dry needling and trigger point injection) in the previous one month; shoulder disorder, cervical spine degeneration, cervical nerve root irritation and severe rheumatic disease); bleeding tendency, received anticoagulants; pregnant, any cancer; and BMI < 18 or > 25 kg/m^2, were excluded from the study.

We conducted a computer-generated block of four randomization by using the web site tool (http://www.randomizer.org/). To test the null hypothesis at significant at level alpha < 0.05 with 80% power and a uniform dropout rate of 20% was assumed. The sample size was calculated total 24 participants in each group.

Intervention

On the first day, a physical therapist with musculoskeletal expertise for 10 years, who was blinded to the participants, performed assessments and collected the following data: age, sex, working hours per week, duration of pain, pain visual analog scale (VAS), involved side active cervical lateral flexion range of motion (ROM), and the Thai-version of Neck Disability Index (Thai-NDI).

To identify possible MTrPs, each participant was asked to point out all painful areas of the neck and upper back, and then lay in prone position. The assessor palpated and marked all MTrPs that matched the inclusion criteria by a nonpermanent marker. Each marked MTrP was measured for pain pressure threshold (PPT). The MTrP with the lowest PPT was designated as the primary MTrP and labeled with semi-permanent henna ink, which could stay on the skin for more than eight days.

Another physical therapist instructed each participant with verbal and written instructions, and a demonstration.

In the intervention group, participants were instructed to perform self-ischemic compression to trapezius MTrP by using a T-shaped wood stick with 2 knobs placed at tips on the stick. The stick which was designed to create sustained pressure in hard-to-reach areas, by holding it over a primary MTrP (Figure 1), then gradually increasing pressure until feeling moderate pain for 60 seconds, and repeating compression steadily until pain was fully dissolved or at least not relieved any further. Thereafter, they were asked to perform self-sustained stretching exercises 10 times each of the following muscles (Figure 2): upper trapezius, posterior neck, middle trapezius, rhomboid, pectoral, and upper back muscles holding each for 30-60 seconds, while sitting near the edge of a stool with both feet firmly on the floor while performing these exercises. Both self-ischemic compression and self-sustained stretching exercises should be done twice a day for 5 days, and stopped on days 6 and 7 to minimize post-compression soreness.

In the control group, participants were instructed to perform only self-sustained stretching exercises of the above-mentioned muscles, 10 times each, twice a day, for 5 days, same as in the intervention group.

All participants were asked not to take any analgesic medication or other physical therapy during the study, They

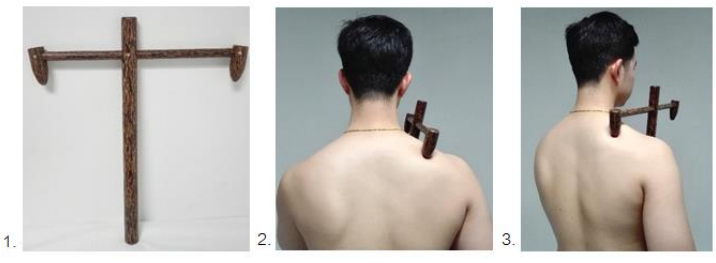

Figure 1. Self-ischemic compression: 1) a T-shaped wood stick, 2) and 3) Holding a T-shaped wood stick over upper trapezius MTrP and pulling the stick to compression

Figure 2. Self-sustained stretching exercises of the following muscles: 1) upper trapezius muscle, 2) posterior neck muscles, 3) middle trapezius and rhomboid muscles, 4) pectoral muscle, and 5) upper back muscles

were informed to report any intolerable soreness and other feelings induced by the instructed treatment, and record their adherence to the instruction in a provided logbook.

On day 2, the instructor therapist made a phone call to all participants to check their performance and on day 5, inform them to stop the treatment.

On day 8, the first blinded therapist re-assessed VAS score for average pain intensity within the last 24 hours, PPT of the primary MTrP, and the Thai-NDI, of all participants. Any medications and complications in the logbook were checked.

Termination criteria were adverse effects (including intolerable soreness and hematoma)

Outcome measurement

The primary outcome was VAS. The VAS scale was 100 mm long, "0" anchored with the words "no pain" and maximum of 100 with "worst pain imaginable" at the opposite end. The test-retest reliability was 0.77 and the validity was 0.51.[14,15]

The secondary outcomes were PPT, active cervical lateral flexion ROM of the involved side, and the Thai-NDI.

PPT was defined as the least amount of pressure needed to provoke pain. The participant was in a prone position. The procedure was performed with an algometer (Force dial FDK20, Wagner), by placing the tip area (1 cm^2) perpendicular to the identified MTrPs and pressing at a rate of 1 kg/sec. The MTrPs were identified with the presence of local or referred pain. The participants were asked to report "yes" as soon as they began to feel pain and then the compression was stopped. Three repetitive measurements at an interval of 30 seconds were performed at the same point, the average value was calculated and used for further analysis.[16-18]

Active cervical lateral flexion ROM of the involved side was measured when the participants were asked to actively lateral flex their heads to the uninvolved side. The angle was measured with a 360-degree goniometer. Three repetitive measurements at an interval of 30 seconds were performed, the average value was calculated and used for further analysis.

The Thai-NDI was used to evaluate the impact of pain on daily activities. This questionnaire has 10 items concerning

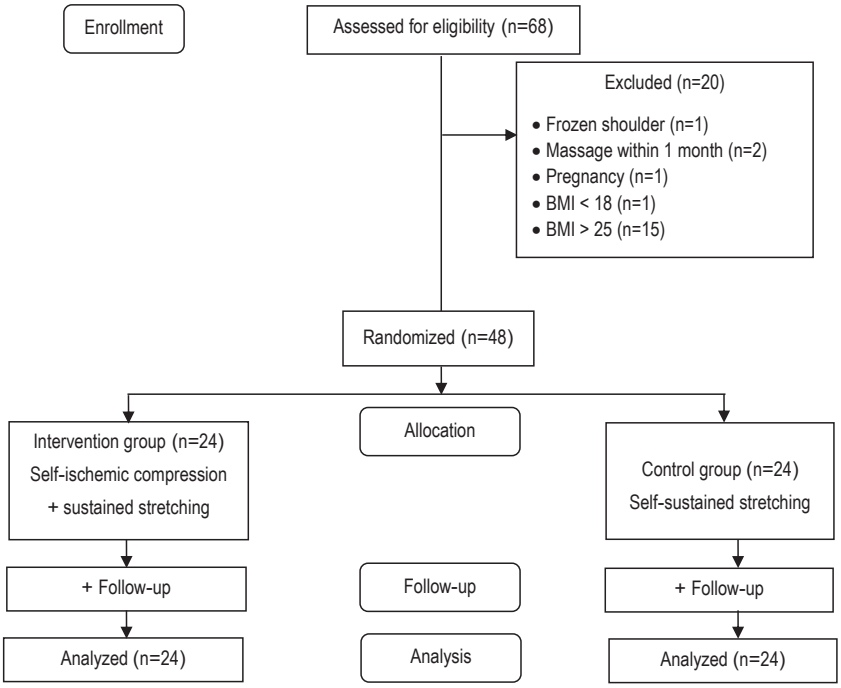

Figure 3. CONSORT diagram outlining the identification, enrollment, and allocation of participants to the two groups: intervention group (self-ischemic compression followed by sustained stretching) and control group (self-sustained stretching).
CONSORT, Consolidated Standards of Reporting Trials.

pain and activities of daily living including personal care, lifting, reading, headaches, concentration, work status, driving, sleeping, and recreation. The Thai-NDI test-retest reliability was 0.986 and validity was 0.886.[29-20]

The minimal clinically important differences (MCIDs) of VAS, PPT, and the Thai-NDI were a 33% decrease in pain,[21] 0.45 kg/cm^2 and 10.5[17] respectively.

Statistical methods

VAS was set to be the primary outcome of this research. The minimal clinically important difference for VAS was a decrease of 33% from a baseline value.[21] Based on Hou et al. study, the baseline VAS was 52.[22] So a reduction in VAS of 23 mm represented a clinically significant difference in pain treatments.[22]

All data were analyzed using SPSS Version 18 for Windows (SPSS Inc, Chicago, IL). The demographic data examined by descriptive statistics, and measurements presented as means (standard deviation, SD). $p < 0.05$ considered statistically significant. Standard comparisons with Student t-test was performed when the data were normally distributed. Descriptive statistics (mean, SD and percentage) were used to calculate all parameters.

Results

Forty-eight participants (39 females, 9 males) participated in this study. There were 17 females and 7 males in the control group whereas 22 females and 2 males in the intervention group. At the baseline, the average age, working hours per week, duration of pain, PPT, ROM, and the Thai-NDI had no statistically significant differences between groups, except VAS (Table 1 and Table 2). Although the participants were randomly allocated by computer-generated block of four randomization into 2 groups, mean VAS of 73.5 (SD 7.1) in the intervention group at baseline was higher than the mean VAS of 68.1 (SD 10.8) in the control group ($p = 0.050$) (Table 2), and might have further room for pain reduction after treatment (Table 2). Therefore, percentage VAS reduction was also analyzed. The percentage of VAS reduction, 38.5% (25.1%) in the intervention group and 24.3% (23.1%) in the control group, were found to be statistically significant difference ($p = 0.048$). In addition, there were 13 participants (54.1%) in the intervention group and 8 participants (33%) in the control group who had a reduction in VAS more than 23 points, and no statistically significant difference between groups ($p = 0.146$). Other parameters including PPT, active cervical lateral flexion ROM, and the Thai-NDI score in pre-, post- and pre-post treatment showed no statistically significant difference between groups (Table 2 and Figure 4).

VAS, visual analog scale; PPT, pain pressure threshold; ROM: range of motion of active cervical lateral flexion of the involved side; Thai-NDI: the Thai-version of Neck Disability Index

Regarding complication, there were 8 participants in the intervention group reporting pain at the pressure point in the first two days and spontaneously resolved. In addition, one participant reported small hematoma at the pressure point.

Table 1. Comparison between intervention and control demographic data of 48 participants

Characteristics	Intervention (N = 24)	Control (N = 24)	*p*-value
Age[1] (year)	40.2 (8.9)	38.9 (8.7)	0.627
Sex[2] (female)	22 (91.7)	17 (70.8)	0.137
Working hours per week[1] (hr)	44.2 (11.3)	47.0 (11.7)	0.398
Duration of pain[2] (> 6 months)	17 (70)	15 (62)	0.848
Involved side MTrP[2] (right)	14 (58)	17 (70.8)	0.194

[1]Mean (SD), [2]number (%)

Table 2. Comparison of pre-treatment, post-treatment, and pre-post difference between groups

Parameters	Intervention Mean (SD)	Control Mean (SD)	*p*-value
Pre-treatment			
VAS	73.5 (7.1)	68.4 (10.3)	0.050
PPT	4.3 (1.6)	4.3 (1.0)	0.954
ROM	31.7 (7.1)	31.0 (8.0)	0.756
Thai-NDI	18.4 (7.3)	15.1 (6.3)	0.101
Post- treatment			
VAS	44.8 (18.1)	50.6 (15.6)	0.240
PPT	4.3 (1.2)	4.6 (1.1)	0.318
ROM	33.4 (7.1)	32.0 (9.2)	0.585
Thai-NDI	8.4 (4.2)	8.8 (4.4)	0.740

Pre-Post difference

VAS, visual analog scale; PPT, pain pressure threshold; ROM, range of motion; Thai-NDI, Thai-version of Neck Disability Index

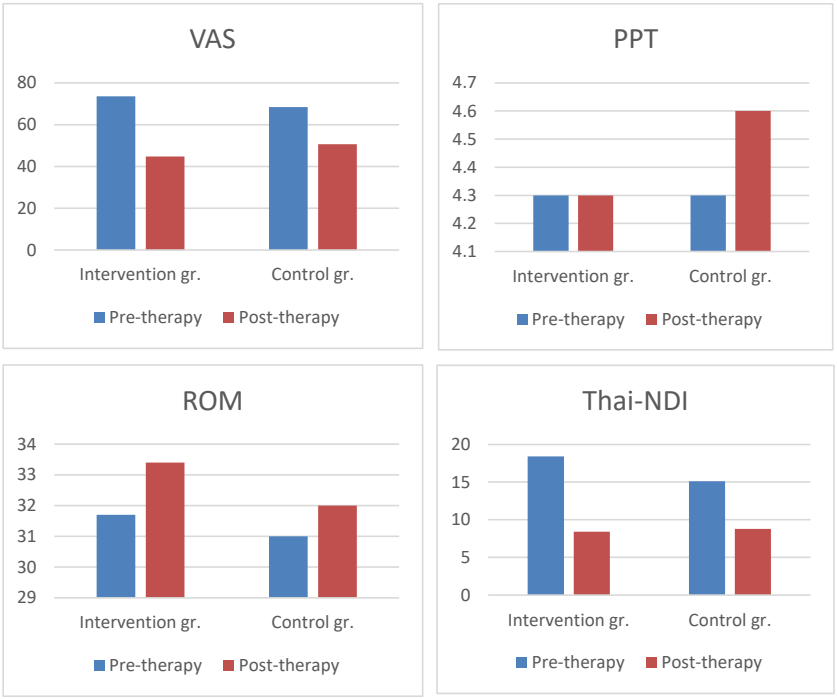

Figure 4. Comparison of values within the same group and between groups pre-therapy, post-therapy
VAS, visual analog scale; PPT, pain pressure threshold; ROM, range of motion; Thai-NDI, Thai-version of Neck Disability Index

In the control group, there were 3 participants reporting increased pain in their neck in the first few days and also spontaneously resolved. The log books showed 100% adherence. None of the participants received other treatment for upper trapezius MTrP.

Discussion

This study demonstrated that decrease in VAS pain intensity within the last 24 hours was found in both intervention and control groups. However, there was a statistical significance of pre-post difference in VAS between groups. Therefore, using a T-shaped wood stick for self-ischemic compression for 5 days as an additional treatment of trapezius MTrP to stretching exercises resulted in better improvement in pain intensity.

A previous study by Hanten et al. proved that self-ischemic compression with a Thera cane was effective in reducing trigger point sensitivity and pain intensity in individuals with neck and upper back pain.[13] The effectiveness of self-ischemic compression with this T-shaped wood stick resulted in pain relief same as Thera cane.

Secondary outcomes including PPT, active cervical ROM-lateral flexion, and the Thai-NDI score showed no statistically significant difference between groups. Barbara et al. examined the effect of ischemic compression on disability confirm our results.[23] There are two explanations, firstly this study did not calculate sample size for detecting MCID of the secondary outcomes. Therefore, calculating the sample size for the detect difference in PPT, ROM, and the Thai-NDI could be investigated in future studies. Secondly the baseline of secondary outcomes was low, so there was small room for change.

We unexpectedly found increased PPT changes of post-treatment in the control group. Possibility is the control group subjects psychologically concerned about the outcome of the treatment that did not improve as expected. Another rare possibility is the PPT measurement stimulates a latent MTrP to become an active MTrP. In accordance with this finding, Walton et al. reported that repetitive mechano-nociceptive stimulations of the trapezius muscle in healthy females evoked moderate and temporary changes in PPT that lasted for at least 35 minutes after cessation of stimulation.[24]

It is important to note that this study faced some limitations. Firstly, this study cannot blind the participants, which might result in biased estimates of treatment effects with VAS which is subjective. This current research investigated just a short-term effect of self-ischemic compression with a T-shaped wood stick on pain. Future studies should evaluate the long-term effects.

In conclusion, this study demonstrated that a daily treatment for 5 days of self-ischemic compression with a T-shape wood stick followed by sustained stretching resulted in a significant improvement in VAS in the short-term in participants with moderate chronic pain of upper trapezius myofascial pain syndrome; and could be one effective home program to reduce pain from upper trapezius myofascial pain syndrome.

Disclosure

All authors declared no personal or professional conflicts of interest, and no financial support from the companies that

produce and/or distribute the materials described in this study.

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Original Article

Long Term Effects of 5-Hz rTMS over M1 Cortex in Spastic Cerebral Palsy: A Pilot Randomized Controlled Trial

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ABSTRACT

Objectives: To determine long term effect of repetitive transcranial magnetic stimulation (rTMS) on muscle tone reduction and mobility in children with spastic cerebral palsy (CP).

Study design: A pilot randomized controlled trial.

Setting: Southern Rehabilitation Center, Songklanagarind Hospital.

Subjects: Spastic CP aged 5-18 years old with modified Ashworth Scale (MAS) of extremities graded 1 to 3.

Methods: Participants were randomized into 2 groups, rTMS and sham groups. The rTMS group received 1500 stimuli of 5-Hz stimulation, 90% resting motor threshold stimulation over the primary motor cortex for 10 consecutive working days. The sham group received 10% resting motor threshold intensity over the same area and duration of stimulation. Both groups received a standard rehabilitation program during experimental periods. Outcome measurements included MAS of extremity muscles and joint range of motion (ROM) at angle of catch (Tardieu's R1) for muscle tone and the Gross Motor Function Classification System - expanded and revised (GMFCS-ER) Thai version for mobility, were assessed before intervention, immediately after intervention, and follow up at 1, 2, 4 and 8 weeks after the last treatment session.

Results: Eighteen children were recruited, mean age (SD) was 95.9 (31.7) months in the rTMS group and 93.8 (20.4) months in the sham group. Their GMFCS-ER was classified as level 3 to 5. After completion of 10 sessions, there were no significant changes in MAS. ROMs at angle of catch tended to increase post intervention and during follow up period in the rTMS group. Mobility levels according to GMFCS-ER were constant within group and no difference between groups. No serious adverse event was reported entire this study.

Conclusion: 5-Hz rTMS over the primary motor cortex for 10 days had no additive effects of spasticity or muscle tone reduction or functional improvement in children with spastic cerebral palsy.

Keywords: cerebral palsy, spasticity, repetitive transcranial magnetic stimulation

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Introduction

Cerebral palsy (CP) is a static brain lesion, which occurs in a child's developing brain and results in delayed development,[1] especially as it regards gross and fine motor functions, muscle tone, and primitive and postural reflexes. One common positive symptom of motor function is spasticity; it can be found in 60-80 percent of all cerebral palsy children.[2,3] Spasticity is defined as a velocity-dependent increase in tonic stretch reflex with exaggerated tendon jerk resulting from the hyperexcitability of the stretch reflex.[4] On the positive side of things, spasticity helps children maintain muscle mass, improve standing balance, etc; on the other hand, it could disturb hand functions or ambulation as well as cause pain or joint contracture.[5] In cases when it is disadvantageous, patients need some treatment to reduce spasticity. There are many options to reduce spasticity including pharmacological therapy, physical therapy, chemical neurolysis, selective dorsal rhizotomy, etc.[6] Treatment selection depends on multiple factors such as regional or total body involvement and severity of symptoms. However, these therapies are associated with side effects like drowsiness from medication or pain on passive stretching, which can be a limitation to treatment continuation. New interventions have been tried to alleviate these problems, one of them is transcranial magnetic stimulation (TMS).

TMS is a procedure which utilizes a non-invasive machine to stimulate the brain and expecting brain plasticity; it is typically combined with standard therapy in a rehabilitation program. TMS has been used to study children suffering from multiple neurological disorders, e.g., stroke, CP, and neuropsychiatric disorders.[7] In comparison to other forms of treatment, the advantages of TMS consist in the fact that it is less invasive, less pain and less complicated procedure for clinical applications. So, its most important advantages are safety and well-tolerable in children.[8] TMS has been studied in children for many years; only a few benign complications have been reported. A systematic review of TMS studies involving more than 1,000 children reported adverse events

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at a rate of around 3-6 percent, and such incidences were mainly minor and resolved spontaneously.[9]

Applications of TMS in treatment of spasticity in patients with stroke and spinal cord injury have been studied.[10] The effectiveness of TMS in the treatment of spasticity in CP was reviewed in 2014; they reported that 5 sessions of high-frequency repetitive transcranial magnetic stimulation (rTMS) over the primary motor cortex was effective in reduction of spasticity in upper extremities.[11] Another study in 2016, researchers found a similar outcome concerning spastic reduction after 20 sessions of 5-Hz frequency rTMS, and also demonstrated effective outcomes in motor function improvement.[12] However, both studies evaluated only the post-interventions effects of rTMS.

Although many researches have reported positive effects of rTMS on spasticity, most of them have shown only immediate effects. Our study was conducted to investigate any additional and long-term effects of high-frequency rTMS over the M1 cortex on reduction of spasticity in cerebral palsy children. We also assessed the benefit of rTMS combined with a standard rehabilitation program on functional ambulation level.

Methods

Study design

This randomized controlled trial (RCT) was approved by the Ethical Committee of Faculty of Medicine, Prince of Songkla University (EC No: 55-195-11-1-2).

Participants

Spastic CP children between 5 and 18 years old with modified Ashworth Scale (MAS) of extremity muscles graded 1 to 3 were invited to enter the study. The recruitment process was conducted between early 2013 and the end of 2016 at Songklanagarind Hospital, Faculty of Medicine, Prince of Songkla University, Thailand. The parents of eligible participants were informed about the study details and then asked to sign the informed consent. All participants had to be able to participate in the treatment program for 2 consecutive weeks. We excluded other types of CP, e.g., athetoid and hemiballismus types, and those who had received botulinum toxin injections or chemical neurolysis within 6 months prior to the study. Patients with contraindications for rTMS therapy, uncontrolled seizures, metallic implants in the head and neck areas, implanted pacemaker or programmable VP shunt, and medication to reduce seizure threshold (bupropion, clomipramine, maprotiline, chlorpromazine, clozapine, methylphenidate), were also excluded due to safety reasons.[13]

Randomization

Eligible participants were randomized into either the intervention (rTMS) or sham group using the block-of-4 method. Regarding sample size calculation for RCT based on the study of Valle, et al.,[14] each group should have 37 subjects recruited.

Intervention

All participants were requested to stop all antispastic drugs at least 2 weeks prior to the commencement of the intervention. Thereafter, muscle tone of extremity muscles and mobility level were assessed by the investigator (ST) throughout the study period. Both the assessor and all participants were blinded as what group they belonged.

A Magstim®, model rapid,[2] magnetic stimulation machine was employed in this study. An air-cooled coil consisting of two 92-mm diameter coils was used in the entire study. This type of coil has a peak magnetic field of 0.93 Tesla. During intervention, a registered nurse who was trained for TMS application, performed the brain stimulation for all participants. The primary motor (M1) cortex was stimulated to identify hotspot and the resting motor threshold (RMT) of the lesioned side of the brain or the more severe cortex; the motor evoked potential (MEP) of abductor pollicis brevis muscle was also recorded. If we could not detect the MEP of the lesioned side, we used the RMT of the contralateral cortex instead.

In the intervention group, the M1 cortex was stimulated with 90.0% RMT, at a 5-Hz frequency, 300 stimuli per train, an intertrain interval of 2 minutes, for 5 trains, and a total of 1500 stimuli per session. The sham group received 10.0% resting motor threshold intensity over the M1 cortex area with the same duration of stimulation. Following each rTMS therapy, all participants received the same rehabilitation program which consisted of physical therapy and occupational therapy twice a week for 2 weeks then they received home program during follow up period. All had rTMS therapy for 10 consecutive working days. Following the risk mitigation guide, all participants were provided earplugs for hearing protection at every rTMS session.[15] During the study period, all parents were informed not to give any antispastic and sedative medication, receive other rehabilitation program at other medical facilities, or apply a new orthosis, to their children.

Outcome measurements

The outcome measurements were recorded immediately post-intervention and at 1 week, 2 weeks, 4 weeks, and 8 weeks after the last day of the intervention. The primary outcome measure was the MAS grade. The secondary outcomes were range of motions (ROMs) at the first catch of sensation, Tardieu's R1, which is a joint angle where examiner can feel a "catch" as an increase in muscle tone reflex is elicited during fast stretch of tested joint.16 The following muscles: elbow flexors, elbow extensors, wrist flexors, finger flexors (flexor digitorum superficialis, FDS of middle finger), hip adductors, knee extensors, and ankle plantar flexors, were assessed for MAS. Joint ROMs at the first catch of sensation were measured using a manual goniometer. Another secondary outcome was mobility level according to the Gross Motor Function Classification System - Extended and Revised, Thai version (Thai GMFCS-ER).[17]

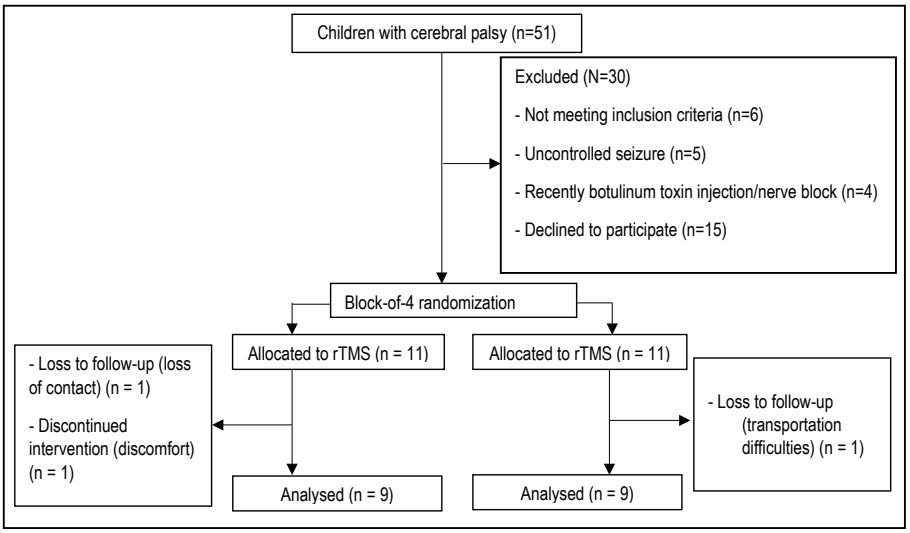

Figure 1. CONSORT flow diagram of the study
rTMS = intervention group, received repetitive transcranial magnetic stimulation
Sham = sham group, received sham magnetic stimulation

Table 1. Baseline characteristics

	rTMS (N = 9)	Sham (N = 9)	*p*-value
Age (months)			0.869
Mean (SD)	95.9 (31.7)	93.8 (20.4)	
Median [Min, Max]	84.0 [64.0, 168]	96.0 [72.0, 124]	
Sex			1
Male	5 (55.6)	6 (66.7)	
Female	4 (44.4)	3 (33.3)	
Causes			0.801
Perinatal	3 (33.3)	3 (33.3)	
Postnatal	1 (11.1)	2 (22.2)	
Prenatal	5 (55.6)	4 (44.4)	
Types			0.856
Diplegia	2 (22.2)	3 (33.3)	
Hemiplegia	2 (22.2)	2 (22.2)	
Tetraplegia	5 (55.6)	4 (44.4)	
GMFCS-ER			1
Level 1, n (%)	0	0	
Level 2, n (%)	0	0	
Level 3, n (%)	1 (11.1)	2 (22.2)	
Level 4, n (%)	2 (22.2)	1 (11.1)	
Level 5, n (%)	6 (66.7)	6 (66.7)	

rTMS, repetitive transcranial magnetic stimulation; SD, standard deviation; GMFCS-ER, Gross Motor Function Classification System - Extended and Revised, Thai version;

Statistical methods

The statistical data was analyzed via R program version 3.2.2. The baseline characteristics data are reported as mean and percentage. T-test and Chi-square test were used to compare the baseline data. A comparison between the MAS scores and the ROMs pre- and post-intervention was carried out, and the level of statistical significance was set at a *p*-value less than 0.05. For the in-between group data analysis, the MAS grades were classified into two groups; non-spastic (MAS gr 0 to 1+) and spastic (MAS gr 2 to 4). The Generalized Linear Mixed Effects Model (GLMM) was selected to analyze the repeated measures of MAS and ROMs between the groups (rTMS and sham) over time. The pre- and the post-intervention Thai GMFCS-ER grades were compared betwen groups using Fisher's exact test.

Results

Fifty-one children with CP were recruited into the screening process (Figure 1). Six did not meet the inclusion criteria, five had uncontrolled seizures, and four had recently received chemical neurolysis/botulinum toxin injections. Thirty-six eligible subjects were informed in details about the study's aims and protocol. Eleven were allocated to the rTMS group; one of them requested to withdraw from the study after 2 sessions of rTMS due to inconvenience to continue

Table 2. Comparison of pre- and post- intervention modified Ashworth Scale (MAS) outcomes between the rTMS and the sham groups

	rTMS (N = 9)						Sham (N = 9)					
	T0	T1	T2	T3	T4	T5	T0	T1	T2	T3	T4	T5
Elbow flexors												
Non-spastic	8 (88.9)	6 (66.7)	9 (100)	8 (88.9)	9 (100)	9 (100)	9 (100)	8 (88.9)	9 (100)	6 (66.7)	9 (100)	9 (100)
Spastic	1 (11.1)	3 (33.3)	0 (0)	1 (11.1)	0 (0)	0 (0)	0 (0)	1 (11.1)	0 (0)	3 (33.3)	0 (0)	0 (0)
Elbow extensors												
Non-spastic	9 (100)	9 (100)	9 (100)	9 (100)	9 (100)	9 (100)	9 (100)	9 (100)	9 (100)	9 (100)	9 (100)	9 (100)
Spastic	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Wrist flexors												
Non-spastic	7 (77.8)	8 (88.9)	9 (100)	8 (88.9)	9 (100)	9 (100)	6 (66.7)	6 (66.7)	9 (100)	6 (66.7)	9 (100)	9 (100)
Spastic	2 (22.2)	1 (11.1)	0 (0)	1 (11.1)	0 (0)	0 (0)	3 (33.3)	3 (33.3)	0 (0)	3 (33.3)	0 (0)	0 (0)
Finger flexors												
Non-spastic	8 (88.9)	8 (88.9)	8 (88.9)	8 (88.9)	6 (66.7)	8 (88.9)	6 (66.7)	6 (66.7)	6 (66.7)	6 (66.7)	6 (66.7)	6 (66.7)
Spastic	1 (11.1)	1 (11.1)	1 (11.1)	1 (11.1)	3 (33.3)	1 (11.1)	3 (33.3)	3 (33.3)	3 (33.3)	3 (33.3)	3 (33.3)	3 (33.3)
Hip adductors												
Non-spastic	1 (11.1)	8 (88.9)	5 (55.6)	8 (88.9)	8 (88.9)	5 (55.6)	6 (66.7)	7 (77.8)	7 (77.8)	7 (77.8)	8 (88.9)	7 (77.8)
Spastic	8 (88.9)	1 (11.1)	4 (44.4)	1 (11.1)	1 (11.1)	4 (44.4)	3 (33.3)	2 (22.2)	2 (22.2)	2 (22.2)	1 (11.1)	2 (22.2)
Knee extensors												
Non-spastic	8 (88.9)	8 (88.9)	8 (88.9)	8 (88.9)	8 (88.9)	8 (88.9)	6 (66.7)	6 (66.7)	6 (66.7)	6 (66.7)	6 (66.7)	6 (66.7)
Spastic	1 (11.1)	1 (11.1)	1 (11.1)	1 (11.1)	1 (11.1)	1 (11.1)	3 (33.3)	3 (33.3)	3 (33.3)	3 (33.3)	3 (33.3)	3 (33.3)
Ankle plantar flexors												
Non-spastic	1 (11.1)	3 (33.3)	1 (11.1)	0 (0)	2 (22.2)	2 (22.2)	3 (33.3)	3 (33.3)	3 (33.3)	3 (33.3)	3 (33.3)	3 (33.3)
Spastic	8 (88.9)	6 (66.7)	8 (88.9)	9 (100)	7 (77.8)	7 (77.8)	6 (66.7)	6 (66.7)	6 (66.7)	6 (66.7)	6 (66.7)	6 (66.7)

Non-spastic, MAS gr 0 to 1+; spastic, MAS gr 2 to 4; rTMS, repetitive transcranial magnetic stimulation;
T0, pre-intervention; T1, immediate post-intervention; T2, 1-week post-intervention; T3, 2-week post-intervention, T4, 4-week post-intervention; T5, 8-week post-intervention

Table 3. Generalized linear mixed effects models (GLMM) for modified Ashworth Scale (MAS) and angle of catch

Muscles	MAS	*p*-value	Angle of catch	*p*-value
Elbow flexors	0.248 (-1.142, 1.639)	0.73	-24.3 (-53.4, 6.0)	0.14
Elbow extensors	0.725 (-1.905, 1.346)	0.25	-18.0 (-35.5, -0.3)	0.06
Wrist flexors	-1.866 (-6.012, -1.866)	0.38	-14.2 (-31.1, 1.8)	0.11
Finger flexors	-0.545 (-4.303, 3.213)	0.78	7.2 (-17.5, 31.9)	0.58
Hip adductors	2.047 (-0.413, 4.506)	0.10	1.9 (-6.1, 9.4)	0.65
Knee extensors	-3.262 (-15.542, 9.017)	0.60	-22.3 (-42.2, -0.7)	0.05
Ankle plantarflexors	1.088 (-6.889, 9.064)	0.79	2.6 (-7.1, 11.8)	0.58

the program. Another two, one in each study group, were lost to follow-up after the last rTMS session. Nine from the rTMS and nine from the sham group, completed the study, and their data underwent statistical analysis. The participants' baseline characteristics are shown in Table 1; there was no statistical different in terms of age, gender, cause and type of CP, and mobility between the groups.

The primary outcome, MAS, was assessed and graded immediately post-intervention and followed over an 8-week period. The participants were divided into the spastic and the non-spastic groups for statistical analysis as shown in Table 2. The GLMM of MAS scores for each muscle over time are shown in Table 3. Some reduction of MAS in rTMS group by time with GLMM of the wrist flexors, hip adductors and knee extensors was observed, but was not statistically significant.

Figure 2 shows the first catch ROM values between the pre- and post-intervention (8 weeks) period. No tendency for an increased ROM post-intervention and its maintenance until the last visit of the study was observed. Meanwhile, the differences in the GLMM of the first catch ROM for each muscle did not reach statistical significance as shown in Table 3. The GMFCS-ER scores were constant immediately post-intervention and during the follow-up period.

There were only minor complications related to the intervention employed in this study. Only two participants in the rTMS group reported mild headache and dizziness after rTMS (22.2%); none of the participants in the sham group experienced these side effects. In both cases, the symptoms resolved spontaneously within a day without any medication or treatment. No other adverse events or serious complications like seizure or loss of conscious were reported.

Discussion

After ten sessions of high-frequency rTMS over the M1 cortex in combination with the standard rehabilitation program, no statistically significant differences in muscle tone or

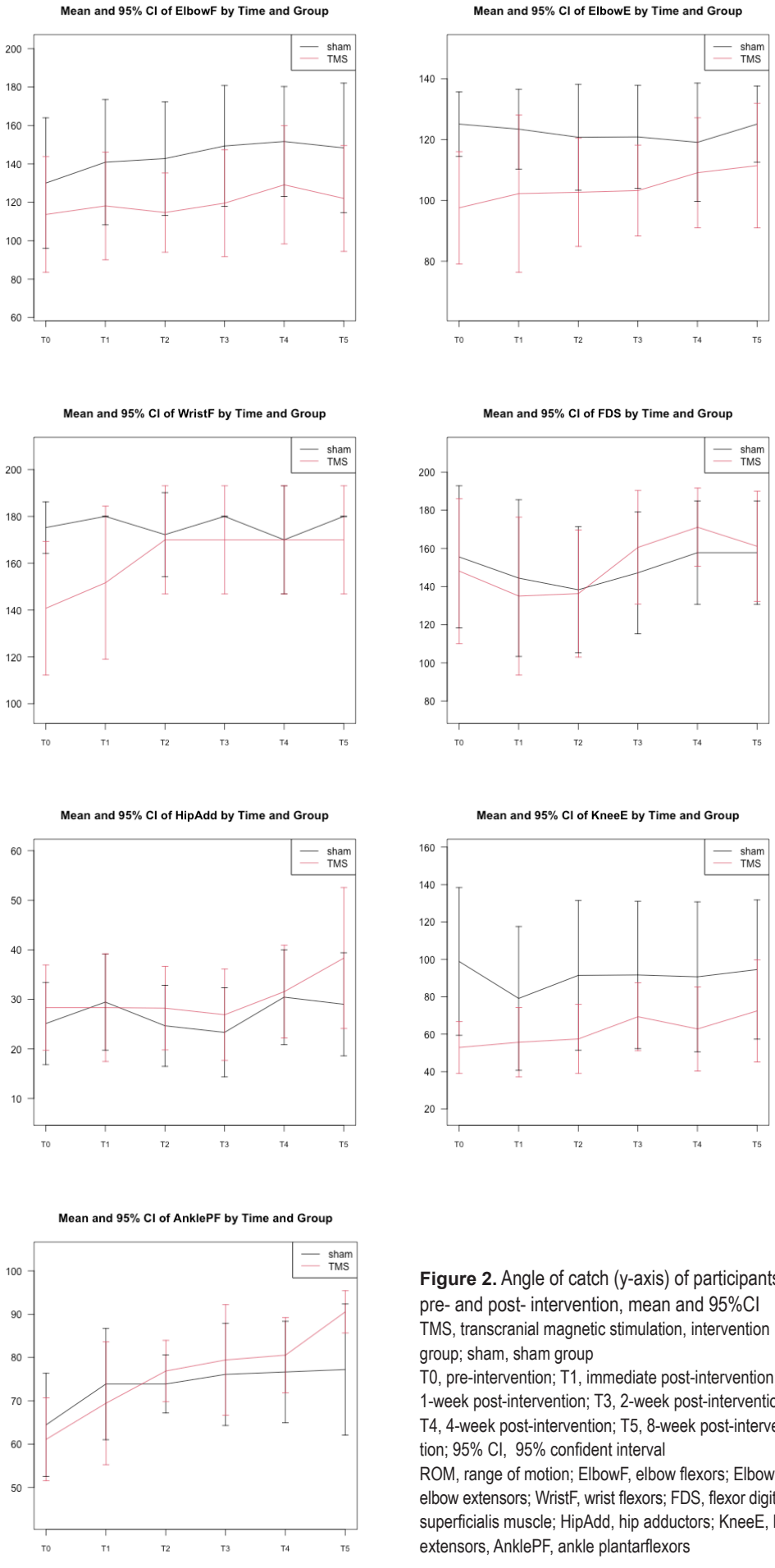

Figure 2. Angle of catch (y-axis) of participants pre- and post- intervention, mean and 95%CI
TMS, transcranial magnetic stimulation, intervention group; sham, sham group
T0, pre-intervention; T1, immediate post-intervention; T2, 1-week post-intervention; T3, 2-week post-intervention, T4, 4-week post-intervention; T5, 8-week post-intervention; 95% CI, 95% confident interval
ROM, range of motion; ElbowF, elbow flexors; ElbowE, elbow extensors; WristF, wrist flexors; FDS, flexor digitorum superficialis muscle; HipAdd, hip adductors; KneeE, knee extensors, AnklePF, ankle plantarflexors

spasticity (MAS grade and first catch ROM) of the tested muscles or the mobility levels (GMFCS-ER) were detected. However, we found a tendency of an increase in the first catch ROM in the intervention group during the 8-week follow-up period as it regards the wrist flexor, hip adductor, and ankle plantar flexor muscles.

Our results were different from those of the 2007 study by Valle, et al.[14] They found an immediate reduction of spasticity in upper extremity muscles after a single session following the 5-Hz rTMS protocol. They did not compare the treatment outcomes with those obtained from standard physical and occupational therapy.[14] Our study, which simulated the routine clinical practice by combining brain stimulation and physiotherapy program, showed similar outcomes for both the standard rehabilitation program and the rTMS therapy in spastic reduction. In another study by Gupta,[18] an experimental study in children with spastic CP, the subjects received rTMS over the motor cortex followed by standard therapy for 20 consecutive days; after that, they compared MAS and functional outcomes. They found a significant change in both parameters, but the magnitude of change was small; the MAS scores reduced by 0.13-0.63, and the GMFM scores leveled up to 0.6%-2.6%. Meanwhile, a minimal detectable change (MDC) in the MAS score, defined as a change of one point,[19] reflects a real change, not only a statistically significant change. Moreover, similar to our results, positive outcomes could have been a result of standard therapy (20 to 40 sessions along with rTMS).

During statistical analysis, we divided the MAS grades into two categories based on clinical application. An MAS grade between 0 and 1+ impacts minimal disadvantage; this severity does not disturb most functional activities. According to the results of this study, the combined rTMS protocol could not add on any positive effect in spastic reduction. More than 10 treatment sessions may be required in order to obtain any benefit because the proposed mechanism of rTMS in spastic CP has been described in light of the cortical plasticity and central motor reorganization theory,[20] which takes time to initiate. In addition, high-rate rTMS could enhance the descending control pathway via the cortico-spinal and the cortico-reticulo-spinal tracts,[21] which results in spasticity reduction and voluntary motor improvement.

Another reason for the negative outcomes of this protocol could be the site of brain stimulation due to differences in pathology in spastic CP brains. For example, hemiplegic CP mostly involves one side of the brain, but diplegic and tetraplegic CP may have bilateral cortical lesions.[22,23] Hence, single ipsilesional brain stimulation may not be enough when bilateral cortical lesions are at play, especially in tetraplegic or diplegic CP. Even in hemiplegic CP, there is evidence that contralesional brain stimulation with rTMS can improve hand function.[24] Thus, the rTMS protocol should be adjusted according to the specific type of patient.

Severity of brain lesion and neural system in our participants might be affect outcomes of the study. More than half of participants had GMFCS-ER level 5, this finding reflected more severe neural damage and poor integrity of corticospinal tract. Our TMS protocol aim to enhance neural plasticity through corticospinal tract via M1 cortex and surrounding connected areas. This reason could explain an insignificance improvement of motor functions. Future study should be conducted with subgroup study of less severity of CP or alternative TMS protocol.

Major limitation of this study was its small numbers of population, only one-fourth of the calculated sample size were recruited into an experiment. As our pilot study results indicated non-superior effects of rTMS over standard rehabilitation program, we decided to discontinue our study. In addition, other factors supported premature termination including many eligible participants refused to stop antispastic drugs, uncontrolled seizure subjects, too long recruitment period. Other limitations were varying types of spastic cerebral palsy and the non-specific functional assessment employed. Further research might focus on specific stimulation protocols for each type of CP, especially as it regards both site and side of stimulation. Multiple-site brain stimulation, such that of a neural network, has been proposed by a recent study in order to achieve better brain plasticity.[25] Finally, the assessment tools, e.g., “box and blocks test” for hand muscles, “reaching time” for the elbow flexors, etc., should be specific to the targeted muscle involvement.

Conclusion

The combination of high frequency repetitive transcranial magnetic stimulation (rTMS) on the primary motor cortex and rehabilitation therapy over 10 sessions had no additive effects on spasticity reduction or functional improvement over rehabilitation program only in children with spastic cerebral palsy.

Disclosure

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Original Article

A Comparison of Gait Analysis and Amputee Satisfaction and Acceptability between the CU Polycentric Knee Unit and the Four-Bar Linkage Knee Unit in Transfemoral Amputees: A Pilot Randomized Crossover Study

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ABSTRACT

Objectives: To compare the spatiotemporal gait parameters and satisfaction of transfemoral amputees using a prosthesis with Chulalongkorn University (CU) polycentric and four-bar linkage knee units.

Study design: A pilot randomized, crossover design.

Setting: Department of Rehabilitation Medicine, King Chulalongkorn Memorial Hospital, Thailand.

Subjects: Transfemoral amputees using a prosthesis in daily life

Methods: Participants were randomly allocated by block randomization into 2 groups. The knee unit of prostheses used in both groups was changed to the CU polycentric and four-bar linkage knee units but in different sequences. Gait parameters were analyzed by using gait analysis when walking at a comfortable speed.

Results: Of the 10 participants, 80 percent were classified as K3 level of functional classification. The mean duration of amputation was 24 years (SD 16) years and mean daily prosthesis use was 6.8 (SD 2.1) hours. There was not a significant difference in gait speed, step length, and cadence of prosthesis side and contralateral side ($p > 0.05$) between the two knee units. However, double limb support time when using the CU polycentric knee unit was statistically significant longer than using the four-bar linkage knee unit (mean difference 0.05 second, 95%CI 0.003-0.100, $p = 0.04$). Amputee satisfaction level and perception of knee stability showed no significant difference between knee units.

Conclusion: Using the CU polycentric knee unit seems feasible and acceptable for K2-K3 transfemoral amputees. However, further development and testing are required before use in clinical practice.

Keywords: gait analysis, amputees, artificial limbs, knee prosthesis

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Introduction

Major components of transfemoral prostheses consist of a socket, a suspension, a knee unit, a pylon and an ankle/foot assembly.[1] The prosthetic knee joint is an essential component to improve transfemoral amputees' mobility functions during stance to prevent the knee buckling and to control the knee motion during the swing phase of a gait cycle.[2] According to prosthetic technological advancement, there are more than two hundred designs of prosthetic knees, ranging from a simple mechanical-controlled single-axis knee unit to a complex microprocessor-controlled knee unit. However, most transfemoral amputees still have gait abnormality because of a lack of active torque generation, loss of somatosensory feedback and limb position awareness, mobile interface between an amputee's stumps and prostheses, pain, contralateral limb problems, and a limit to prosthetic components that fit for the amputee's gait performance.[3]

In Thailand, four-bar linkage polycentric knee units are commonly used due to several advantages including good knee stability, desirable appearance especially while bending the knee, and more foot clearance during swinging when compared with the single-axis knee unit.[4] Their costs are high which limits their usage. Therefore, to lower the cost, the Department of Mechanical Engineering, Faculty of Engineering, Chulalongkorn University (CU) has developed a new knee unit for transfemoral amputees called the "CU polycentric knee unit" (Figure 1), which costs one-half times less than an imported knee unit.[5]

The CU Polycentric knee unit is a prismatic two linkage joint designed from natural knee motion analysis. It can create the same degree of freedom like the 4-bar linkage knee unit does but has fewer components. Knee stability is achieved by setting its alignment to facilitate ground reaction force to be posteriorly to the knee axis. Its adjustable friction ability is comparable with other available knee unit designs.[5] Moreover, assembly and maintenance is easy to perform.[5] For this reason, the CU polycentric knee unit could be a new optimal choice for transfemoral amputees in Thailand.

Since safety is the most important concern for new medical devices, the CU polycentric knee unit passed the stress

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Figure 1. The Chulalongkorn University (CU) polycentric knee unit

test by finite element methods before it was finished,[6] and received ISO 10328, which is a standard structural test of lower-limb prostheses. The strength and endurance of prostheses was tested by a hydraulic simulator that was equivalent to three million strides with a one hundred- and twenty-kilogram load during the heel strike and toe off phase of the gait cycle. Thus, it has adequate knee stability theoretically and mechanically, and is durable for use in transfemoral prosthesis. However, it has had no clinical data to support it in practice; therefore, the objective of this study was to investigate gait parameters and transfemoral amputees' satisfaction when using a prosthesis with the CU polycentric knee unit and comparing it with a 4-bar linkage knee unit.

Method

This was a pilot study of a randomized crossover design which was approved by Faculty of Medicine, Chulalongkorn University Review Board. (Approval number 249-60).

Participants

Amputees with unilateral transfemoral amputation who used a transfemoral prosthesis were recruited and were asked for informed consent. The inclusion criteria consisted of participants had to be aged more than 18 years, have used a prosthesis with a four-bar linkage knee unit at least five hours/day for more than 1 year, have a lower limb prostheses Medicare functional classification level K2 - K4,7 have independent community ambulation without gait aid and be able to complete the study.

Exclusion criteria were inappropriate stumps including a wound, infection, inflammation, the length of stump was too short or too long, a body weight more than 120 kilograms and any underlying problems that obviously affected their walking ability e.g., osteoarthritis of knee, hemiplegia, balance instability, etc.

Materials

Participants' prostheses with standard 4-bar linkage knee units and the CU polycentric knee unit invented and manufactured by the Department of Mechanical Engineering, Faculty of Engineering, Chulalongkorn University, were used during the gait motion analyses. The analyses were performed at the Center of Excellence in Gait & Motion Analysis, King Chulalongkorn Memorial Hospital, by using a Qualisys Motion Capture System (Qualisys AB, Sweden), 6 Oqus cameras, 45 reflective markers capture frequency 120 Hz, Qualisys Track Manager, Visual-3D basic/RT version 3.99.25.6, and Bertec Force Plate.

Procedure

After receiving informed consent, participants' demographics, cause and duration of amputation, duration of prosthesis usage, components of prosthesis and the lower limb prosthesis Medicare Functional Classification level (K-level), were recorded by interviewing and reviewing their medical records.

Using block randomization, the recruited participants were divided into two groups based on sequences of knee unit used for gait motion analysis. Group 1 used the CU polycentric knee unit followed by the 4-bar linkage knee unit and group 2 used the opposite sequence (Figure 2).

All participants were informed to walk at a comfortable speed for 6 trails for each knee unit for gait motion analysis and to stand still on the force plate while eyes opened for 30 seconds and closed for another 30 seconds to record center of pressure (COP) path length for checking stability.

One certified prosthetist-orthotist (CPO) was assigned to change only the knee unit of the participants' prosthesis and maintain the same prosthetic length and alignment by using a prosthetic alignment device. Knee friction adjustment was permitted to achieve participants' familiarization with their prosthesis and walking pattern. After achieving the participants' most comfortable walking ability, they were allowed to have 1-2 days for better familiarization with the changed knee unit before gait motion analysis.

Following the gait motion analyses, they rated their overall satisfaction with the knee units and their feeling of knee stability with a five-point Likert scale of very satisfied, satisfied, neutral, unsatisfied, and very unsatisfied before lastly rating their preference.

Outcome measures

The primary outcomes were spatiotemporal gait parameters including gait speed, step length and cadence, double limb support time and percentage, and center of pressure (COP) path length; and participants' satisfaction with the CU polycentric knee unit and feeling of stability while walking.

The secondary outcomes were other lower limb kinematic and kinetic parameters, and participants' preference.

Statistical analysis

Gait parameters from motion analysis of both groups were gathered and combined according to types of the knee units, the CU polycentric and the 4-bar linkage knee units. The quantitative data were showed in means and standard

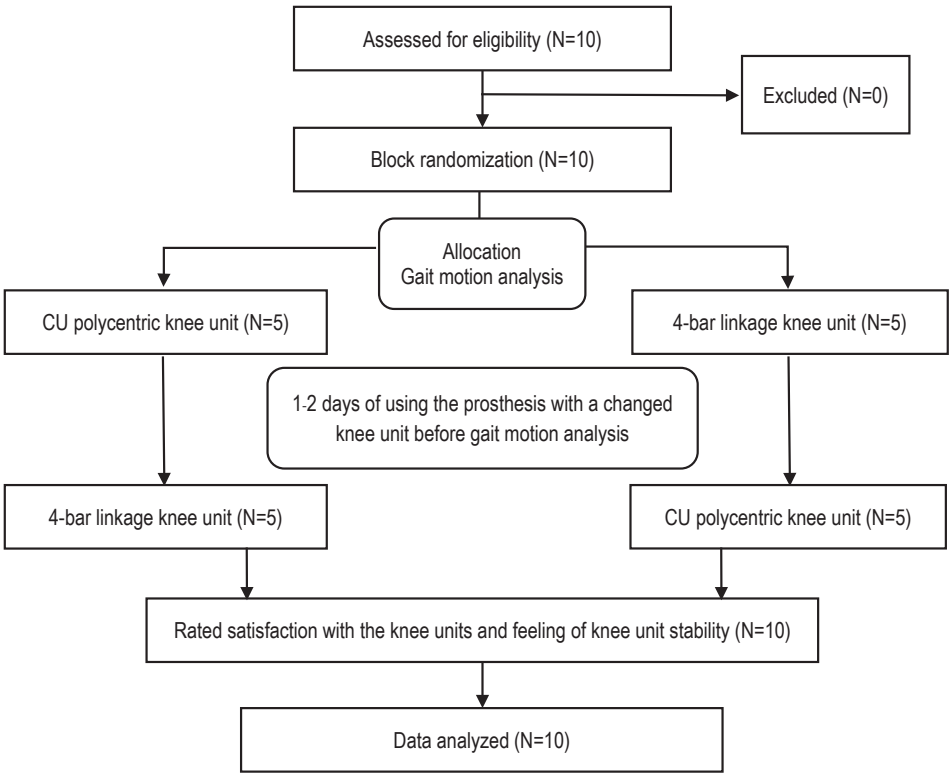

Figure 2. Schematic flow diagram of the study

deviations. The qualitative data were showed in frequencies and percentages. The SPSS version 22 was used for statistical analysis. Mean differences of recorded gait parameters between groups values were analyzed using a paired t-test for parametric data and a Wilcoxon signed-ranks test for paired ordinal data with a confidence limit of $p < 0.05$. The satisfaction score was analyzed using a Chi-square test.

Results

All ten participants completed the study (Figure 2). All participants in the study were males with a mean age of 55 years and a mean duration of amputation of 24 years. Traffic accidents were the causes of amputation. Seven participants used prostheses with a SACH foot and others with a single-axis ankle and foot assembly. The mean duration of current prostheses used was 1.6 years and the daily use of prosthesis was 6.8 hours per day. Eight were classified as K3 level. Some reported underlying diseases such as hypertension and dyslipidemia (Table 1).

A comparison of the spatiotemporal gait parameters between walking with the CU polycentric and the 4-bar linkage knee units is presented in Table 2. There were no statistical differences in gait speed, step length and cadence of the prosthetic leg and sound leg, as well as the COP path length when standing with eyes closed and eyes open for 30 second between the two knee units. Double limb support time was the only parameter that showed a statistically significant difference between the two knee units. The CU Polycentric had a longer double limb support time than the four-bar linkage knee unit had (mean difference = 0.05 seconds or 2.74% of gait cycle, $p = 0.04$).

Table 3 shows a comparison of kinematic parameters while walking between the two knee units. There was signifi-

Table 1. Demographic, medical, amputation-related and prosthetic-related data of the 10 participants

	Mean (SD)	N
Demographic data		
Age (years)	55 (12)	
Gender (male/female)		10 / 0
Underlying diseases		
- Hypertension		3
- Dyslipidemia		3
Amputation-related data		
Cause of amputation, traffic accident		10
Duration of amputation (years)	24 (16)	
Stump length (percentage)	69 (11)	
Prosthetic-related data		
Ankle/foot assembly		
- SACH foot		7
- Single axis		3
Duration of current prosthesis used (years)	1.6 (1.0)	
Duration of daily prosthesis used (hour)	6.8 (2.1)	
K-level		
- K2		2
- K3		8
- K4		0

SACH, solid ankle cushion heel; K-level, the lower limb prosthesis Medicare Functional Classification level

Table 2. Comparison of spatiotemporal gait parameters between the two knee units

Spatiotemporal parameter	CU polycentric	4-bar linkage	Mean difference	95%CI	*p*-value
Gait speed (m/s)	0.70 (0.18)	0.76 (0.20)	-0.06	-0.16 to 0.04	0.22
Step length (m)					
Prosthetic leg	0.57 (0.10)	0.60 (0.09)	-0.03	-0.07 to 0.01	0.11
Sound leg	0.47 (0.11)	0.50 (0.11)	-0.03	-0.08 to 0.01	0.13
Cadence (step/min)					
Prosthetic leg	71.49 (11.48)	74.09 (10.35)	-2.60	-8.27 to 3.07	0.33
Sound leg	90.85 (13.32)	90.19 (12.29)	0.67	-4.4 to 5.76	0.77
Double limb support (s)	0.47 (0.19)	0.42 (0.16)	0.05	0.003 to 0.10	0.04
Double limb support (%)	29.75 (7.87)	27.04 (7.06)	2.71	0.16 to 5.45	0.04
COP path length (m)					
Open eyes	2.615 (0.309)	2.628 (0.372)	-0.013	-0.103 to 0.077	0.75
Close eyes	2.723 (0.386)	2.751 (0.373)	-0.028	-0.128 to 0.072	0.54

Mean (SD); CU, Chulalongkorn University; m, meter; s, second; min, minute; COP, center of pressure

Table 3. Comparison of kinematic parameters while walking between the two knee units

	CU polycentric	4-bar linkage	Mean difference	95%CI	*p*-value
Peak hip flexion (degree)					
Prosthetic leg	30.73 (9.32)	31.05 (9.87)	-0.32	-4.43 to 3.79	0.86
Sound leg	34.99 (9.40	32.82 (7.73)	2.16	-1.89 to 6.21	0.26
Peak hip extension (degree)					
Prosthetic leg	7.76 (7.65)	6.83 (6.21)	0.93	-1.80 to 3.65	0.46
Sound leg	6.69 (3.12)	6.57 (6.19)	0.12	-4.4 to 4.77	0.96
Peak knee flexion (degree)					
Prosthetic leg	40.04 (21.85)	57.17 (21.56)	-17.13	-30.27 to -3.99	0.02*
Sound leg	59.08 (9.84)	60.38 (5.59)	-1.30	-8.83 to 6.24	0.71
Minimum toe clearance (cm)					
Prosthetic leg	3.82 (1.83)	4.27 (2.02)	-0.45	-1.21 to 0.31	0.21
Sound leg	4.89 (1.04)	4.78 (1.98)	0.10	-1.00 to 1.21	0.83

Mean (SD); CU, Chulalongkorn University; cm, centimeter

Table 4. Comparison of kinematic parameters while walking between the two knee units

	CU polycentric	4-bar linkage	Mean difference	95%CI	*p*-value
Peak hip extension moment (Nm/kg)					
Prosthetic leg	0.17 (0.14)	0.18 (0.14)	-0.01	-0.18 to 0.15	0.85
Sound leg	0.50 (0.28)	0.32 (0.09)	0.18	-0.02 to 0.37	0.07
Peak hip flexion moment (Nm/kg)					
Prosthetic leg	0.30 (0.15)	0.35 (0.16)	-0.06	-0.17 to 0.05	0.25
Sound leg	0.25 (0.21)	0.25 (0.15)	0.01	-0.09 to 0.10	0.89
Peak knee extension moment (Nm/kg)					
Prosthetic leg	0.17 (0.14)	0.18 (0.14)	-0.01	-0.18 to 0.15	0.85
Sound leg	0.50 (0.28)	0.32 (0.09)	0.18	-0.02 to 0.37	0.07
Peak knee flexion moment (Nm/kg)					
Prosthetic leg	0.30 (0.15)	0.35 (0.16)	-0.06	-0.17 to 0.05	0.25
Sound leg	0.25 (0.21)	0.25 (0.15)	0.01	-0.09 to 0.10	0.89

Mean (SD); CU, Chulalongkorn University; Nm, Newton-meter; kg, kilogram

cant difference of peak knee flexion angle during the swing phase of the prosthetic leg. The CU-Polycentric knee unit had a lower peak knee flexion angle during the swing phase than the four-bar linkage knee unit [40.04 (SD 21.85) vs 57.17 (SD 21.56) degrees, mean difference 17.13, $p = 0.02$]. Other kinetic parameters including peak hip flexion angle, peak hip extension angle and minimum toe clearance were not significantly different between the two knee units (Table 4). Figure 3 and Figure 4 demonstrate the average of the hip and knee angles and moments from all participants comparing the CU polycentric and the 4-bar linkage knee units. Table 5 reveals that there were no statistical differences of participants' overall satisfaction and feeling of knee stability while walking between the two knee units. Regarding participants' preference based on overall satisfaction, 5 preferred the 4-bar linkage knee unit, 2 preferred the CU-polycentric knee unit, and 3 preferred both equally; finally, based on knee stability, only 1 preferred the former but 5 preferred the latter and the rest preferred both equally.

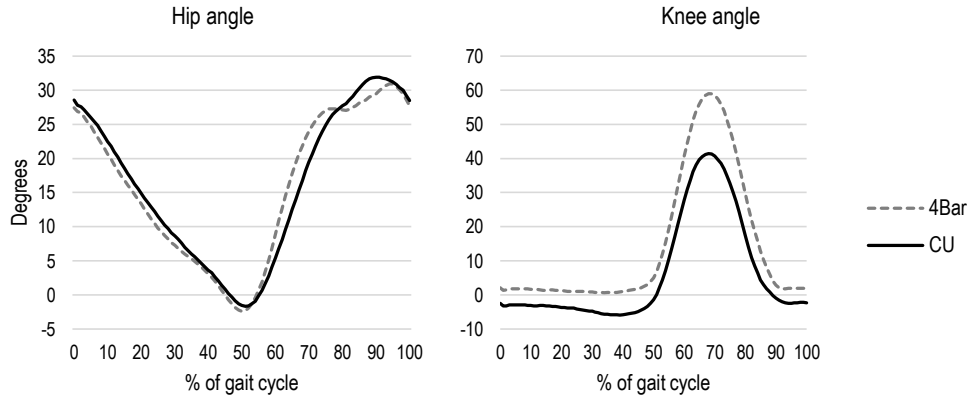

Figure 3. Average hip and knee angles during the gait cycle of the CU polycentric and 4-bar linkage knee units

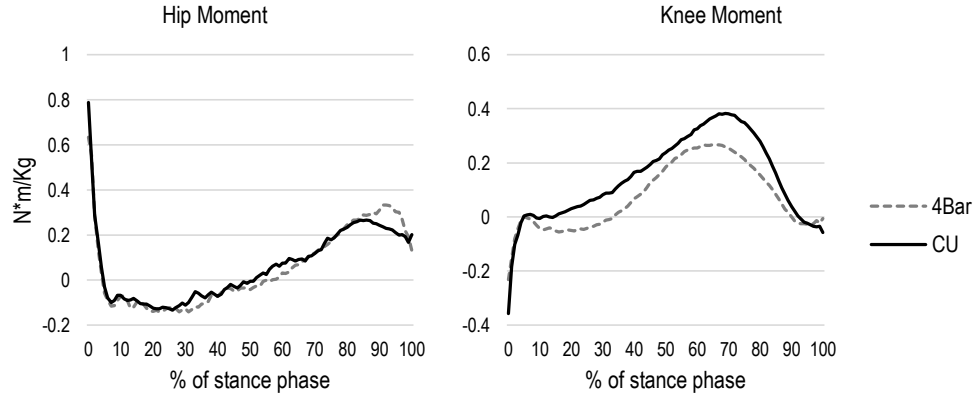

Figure 4. Average hip and knee moments during the gait cycle of the CU polycentric and 4-bar linkage knee units

Table 5. Comparison of the overall satisfaction and feeling of knee stability while walking between the two knee units

	CU Polycentric	4-bar Linkage	*p*-value
Overall satisfaction			0.161
Very satisfied	1	3	
Satisfied	3	3	
Neutral	5	4	
Unsatisfied	0	0	
Very unsatisfied	1	0	
Feeling of knee stability			0.084
Very satisfied	1	4	
Satisfied	3	2	
Neutral	5	4	
Unsatisfied	0	0	
Very unsatisfied	1	0	

Number: Wilcoxon signed-ranks test; CU, Chulalongkorn University

Discussion

This is the first report on comprehensive biomechanical evaluation with spatiotemporal, kinetic and kinematic data in amputees with transfemoral amputation who have experience with the new CU polycentric knee unit. All participants were experienced prosthesis users. In this study, we gave priority to participants' walking ability, thus knee friction and extension assist properties could be adjusted during the fitting process to maximize their walking ability and satisfaction. According to previous studies, a higher gait speed is associated with greater functional independence[8] whereas a comfortable speed is a gait speed that amputees consume with a minimum energy per walking distance,[9] and in the gait analytic study, gait speed is the first parameter that should be concerned not only because of energy expenditure but also kinematic and kinetic gait parameters deviations.[10]

In this study, all participants were used to a transfemoral prosthesis with a 4-bar linkage knee unit and their mean gait speed was 0.76 m/s while walking comfortably. When using the CU polycentric knee unit, the mean gait speed was 0.70 m/s, which was slower. However, according to a prior systematic review, minimal clinically important differences of gait speed ranged from 0.1 to 0.17 m/s.[11] Therefore, a slower gait speed of 0.06 m/s was not clinically significant. Most of transfemoral amputees have gait deviations with decreased self-selected gait speed, short intact limb step length and decrease cadence.[12] These spatiotemporal gait parameters deviations were demonstrated in both groups, the CU Polycentric and the four-bar linkage knee units, without a significant difference. The shorter double limb support time in gait cycles is caused by better stability and less balance concern during walking.[8] Although the CU polycentric had a statistically significant longer double limb support time than the four-bar linkage, the mean difference of 0.05 seconds was clinically insignificant. In addition, COP path length had a difference of less than 2 cm between the two knee units, which did not reach a level of statistical significance. The self-reported feeling of prosthetic/knee stability showed statistically insignificance but there was a trend that the 4-bar linkage knee unit was preferable to the CU polycentric.

The peak knee flexion angle during the swing phase is caused by a ground reaction force while toe-off generated the knee flexion moment, and the knee flexion motion from this force is controlled by proper friction of the knee unit.[3] In this study, the CU polycentric had a smaller peak knee flexion angle during the mid-swing phase than the 4-bar linkage had, as shown in Figure 1. This might be a result of the CU Polycentric knee unit having a different path of instantaneous center of rotation whereas the 4-bar linkage might enhance the apparent ankle dorsiflexion and shank shortening translation.[13] Hence, the CU Polycentric showed a smaller peak knee flexion angle during the swing phase while the minimum toe clearance was not significantly different. However, the assumptions should be further investigated in a mechanical study.

This study had some limitations. Firstly, it was a pilot cross-over study with 10 participants. The results of analytic statistics should be interpreted cautiously due to the small sample size. Secondly, this study focused on comparing the knee units, not correcting participants' gait deviation. We allowed them to have 1-2 days for familiarization with the new knee unit due to ethical reasons, which might not be long enough. We believed that experienced prosthesis users could easily adapt to the new knee unit to the point that waiting for another week or month would not change the walking parameter significantly. Additionally, we used the cross-over design in which both knee units were used first or second equally during the gait analysis. Thirdly, all participants were male, active, and amputated by reason of accident. Recruitment of amputees with different characteristics should be considered. Lastly, there were no clinical data such as complications as gait analysis was done in a short period of time and we did not expect any complications during such. Further study should be done with a larger sample size, a longer training period of at least three weeks[15] and adding a physical therapy program to maximize long-term outcomes. In addition, further study is needed to explore clinical outcomes over the long-term use of the CU polycentric knee unit.

In conclusion, this is the first pilot study comparing the CU Polycentric and the 4-bar linkage knee units, there were no significant differences of gait parameters in terms of gait speed, step length, cadence, peak hip extension and flexion angle, minimum toe clearance, hip extension and flexion moment, overall satisfaction and feeling of stability. Nevertheless, the CU Polycentric knee had a 0.05 second longer double limb support time (2.71% of gait cycle) and a smaller peak knee flexion angle in the prosthesis leg than the 4-bar linkage knee unit had. Further research is needed for further development of the CU polycentric knee unit before use in clinical practice.

Disclosure

The authors certify that there is no conflict of interest with any financial organization regarding the materials discussed in the manuscript.

Acknowledgement

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Original Article

Translation, Cross-Cultural Adaptation, Reliability and Validity of the Thai Version of the Trunk Impairment Scale 2.0

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ABSTRACT

Objectives: This study aimed to translate the Trunk Impairment Scale 2.0 (TIS-2.0) into Thai language and to test its reliability and validity.

Study design: Descriptive cross-sectional design.

Setting: The Thai Red Cross Rehabilitation Center, Thailand.

Subjects: Forty-seven stroke patients (33 males and 14 females) who received rehabilitation.

Methods: A cross-cultural adaptation process was used to translate TIS-2.0 to Thai version (TIS-TH). Four assessors with differing years of work experience scored the patients using the TIS-TH, evaluating from the video record 2 times with a 2-week interval. The results were analyzed by Cronbach's alpha for internal consistency. Testing of intra-rater and inter-rater reliability was analyzed by Intraclass Correlation Coefficient (ICC). Spearman's Rank Correlation Coefficient was used to test validity between the TIS-TH and the Berg Balance Scale (BBS), the Motor Assessment Scale (MAS, sitting balance subscale), and the Functional Reach Test (FRT).

Results: The TIS-TH had good internal consistency. Cronbach's alpha was 0.823. The reliability of inter-rater and intra-rater were 0.885 (95% CI: 0.763-0.941) and 0.951 (95% CI: 0.927-0.971), respectively. Spearman's Rank Correlation Coefficient between the TIS-TH and the three other measures the BBS, the MAS and the FRT were 0.800, 0.710 and 0.731, respectively.

Conclusion: The TIS-2.0 Thai version was acceptable, reliable and valid for evaluating trunk control in stroke patients. It could be one of disability evaluations that health care personnel in Thailand can apply in clinical practice.

Keywords: trunk assessment, stroke, reliability, validity, disability evaluation

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Introduction

Stroke is a non-communicable disease which impacts on health and quality of life. Most stroke survivors suffer from abnormal gait pattern and impaired functional mobilities. These problems commonly associate with muscle weakness, sensory deficit and spasticity of limbs. In addition, trunk control also plays an important role in gait ability and mobility.[1] Impairment of trunk muscle activities can lead to poor dynamic balance and falling in patients with stroke.[2] Therefore, assessment of trunk performance in post-stroke patients is valuable and necessary in clinical evaluation.

A systematic review of Sorrentino, et al (2018)[3] showed that there are 10 tools which are used to assess trunk performance after stroke. Numerous clinical tools have been validated to assess trunk performance after stroke, including: Trunk Impairment Scale (TIS), Trunk Control Test (TCT), Postural Assessment Scale for Stroke (PASS), Ottawa Sitting Scale (OSS), Modified Functional Reach Test (MFRT), Function In Sitting Test (FIST), Physical Ability Scale (PAS), Trunk Recovery Scale (TRS), Balance Assessment in Sitting and Standing Positions (BASSP) and Sitting-Rising Test (SRT). The Trunk Impairment Scale (TIS) is a tool which has been developed to assess trunk control in a sitting position. The American Physical Therapy Association Neurology Section Task Force recommends this tool be applied in physical evaluation.[4] The TIS consists of static and dynamic sitting balance tests, and a trunk coordination test.[5] Verheyden, et al. (2004)[5] showed that this scale has good intra-rater and inter-rater reliability, and excellent validity correlation to the Barthel Index and the Trunk Control Test. Further Verheyden and Kersten (2010)[6] introduced the TIS version 2.0 (TIS-2.0), which deleted the static sitting balance item from the origi-

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nal version because the internal validity this dimension was unable to be shown. The study demonstrated that dynamic and coordination domains have shown a relation between trunk muscle activity and functional performance.

In Thailand, stroke is a major cause of death and disability.[7] The use of the TIS in disability evaluation may be beneficial for treatment planning. However, a language barrier from using the English version of this tool may lead to misconception in a clinical practice and may cause evaluation error. Both versions of the TIS have been translated into other languages, but not yet into Thai. This study aimed to translate the TIS-2.0 into Thai language, and also to examine intra-rater reliability, inter-rater reliability and validity of the TIS in the Thai version in order to apply this measurement in stroke assessment.

Methods

Study design

This descriptive cross-sectional study was approved by the Research Ethics Review Committee, Faculty of Medicine, Chulalongkorn University (IRB No.255/61). There were two parts of this study. The first part was the process of translation and cross-cultural adaptation of the TIS-2.0 into Thai, and the second part was the process of testing its psychometric properties that is, the reliability and validity of the TIS-TH in Thai patients with stroke.

Participants

Participants were inpatients with subacute and chronic stroke who were referred to physical therapy services at Thai Red Cross Rehabilitation Center (TRCR) in Thailand from September 2018 to July 2019. They were included if they met the following conditions: 1) between 45 and 80 years old, 2) able to sit independently for 10 seconds, 3) scored above 23 on the Mini-Mental State Examination (MMSE) Thai version, and 4) able to provide informed consent. Those who did not understand Thai language were excluded. The calculated sample size of 47 was based on an expected correlation of 0.4, an alpha value of 0.05 and a power of 80%.

Outcome measures

The TIS was first introduced in 2002 for the purpose of measuring motor activity of trunk muscles in patients with stroke, consisted of 3 main dimensions, including static, dynamic and coordination subscales, and the total score ranged from 0 to 23.[5,8] Later, a second version of this tool was developed, which was called the TIS-2.0.[6,8] In this version, the static dimension was removed because its internal validity could not be demonstrated and the scale consists of 14 items. Therefore, the total score of the TIS-2.0 ranges from 0 to 16, and a higher score indicates better trunk control.[6,8] The Test-retest reliability and inter-rater reliability (ICC) were 0.96 and 0.99, respectively.[6,8] There were high correlations between the TIS and the Barthel Index (r = 0.86) and the trunk control test (r = 0.83), which showed evidence of construct and concurrent validity, respectively.[6,8]

The sitting balance subscale of the motor assessment scale (MAS) is a six-point ordinal scale that ranks tasks by difficulty.[8] In the Functional Reach Test (FRT), the recorded measure (centimeter) is the distance forward that the finger reaches while the subject lifts his or her arm to 90 degrees while the subject is in the most forward leaning position in order to avoid the trunk from rotating.[4] The Berg Balance Scale (BBS) is a list of 14 items, with each item being measured on a five-point ordinal scale ranging from 0 to 4, with 0 indicating the lowest level of function and 4 indicating the highest level of function.[4]

Translation and cross-cultural adaptation process

The process was performed following the recommended guidelines.[9-10] Firstly, permission to translate the TIS-2.0 was kindly given by the original developer, Verheyden. Secondly, forward translation of the TIS-2.0 from English to Thai language was performed by two native Thai speakers with a good command of English. One is a clinician who understands the purpose of this instrument, and the other is a person who does not have a medical background. Each English expert translation was performed independently. The two drafts from the translators were identified as T1 and T2 respectively. Thirdly, T1 and T2 were synthesized in order to reduce bias from the translation. This stage was done by both translators and one member of the research team working together. Each sentence of the translated T1 and T2 versions was analyzed and rearranged. A consensus was reached by both translators for any initial difference in translation. This “consensus” Thai version was named T12, and was translated back to English by two bilingual individuals who use English language in their daily living and who do not have medical backgrounds. The comparison of the original version and all the translated versions were performed by three reviewers: a physiatrist and two physical therapists who are expert lecturers in rehabilitation medicine at two leading universities, and a physical therapist who carries out daily clinical work with stroke patients. The content validity of the Thai version was checked by analyzing the index of item-objective congruence (IOC).[11]

Next, a pre-test with two experienced physical therapists was undertaken at the TRCR. The instrument was applied to thirty patients with stroke who consented to participate in the study. The objective of this session was to check accuracy and language understanding. Lastly, the translation and cross-cultural adaptation process were sent to the original developer for consideration.

Testing psychometric properties

Reliability

Four physical therapists (A, B, C and D) with different years of work experience were trained to score the TIS-TH by using an instructional video produced by the original

developer.[12] Participants were able to repeat the video until they felt completely comfortable with the test administration and its uniform application. The physical therapists' assessments were recorded as videos in all studied patients. All stroke patients were given the same clear instructions regarding the movements that they had to perform. The starting positions for all items were the same to prevent any error from the observation. Then, to assess the inter-rater reliability of this test, all assessors scored patients from the recorded videos by using the TIS-TH. For the intra-rater reliability, a second assessment was performed 15 days after the first observation to limit the degree to which raters would recall the data from the initial observations.[12] The use of recorded video was intended to prevent patient fatigue and minimize the error from each performance which could have an impact on the scoring of the test.[12] Video recordings were kept confidentially at the TRCR, to be deleted one year after completion of the study.

Validity

The TIS-2.0 was validated with well-established outcome measurements, including sitting balance subscale of the MAS, FRT and BBS. Prior to the validity study, Rater A also received additional training in the use of these tests. The sequence of the tests was random. The test administration was performed in the same laboratory setting and all participants received the same verbal instructions. During the tests, the patients were allowed to rest as much as they wished.[12] The whole testing performance was videotaped so that rater A could score the patients' test performance from videotape again in order to verify the accuracy of the scoring.

Statistical methods

Descriptive statistical analysis of demographic and baseline clinical characteristic of participants was conducted before proceeding to analyzing reliability and validity. Cronbach's Alpha was used to assess the internal consistency of the total and sub-total scales. Inter-rater and intra-rater reliability were calculated by Interclass Correlation Coefficient (ICC). ICC model 2, k was used for inter-rater reliability and model 3, k was used for intra-rater reliability.[13] An ICC value of 0.75 or above indicates excellent reliability; below 0.40 indicates poor reliability, and results between these two values indicate moderate to good reliability.[14] The Standard Error of Measurement (SEM) and Minimal Detectable Change (MDC) were also calculated. The Pearson and Spearman rank-order correlations were used to determine the convergent validity of the TIS-TH and other clinical assessments.

Results

In the process of translation from English to Thai, it was found that some translated words from English to Thai were too formal, affecting the understanding of patients. Therefore, a discussion was carried out to adapt some translated words to be easier to understand while maintaining the same meaning as the original tool. In fact, the Thai version of the TIS has been revised twice. The first revision was made as per the suggestions given by the experts. After that, a pilot test was conducted which provides feedbacks from two assessors, and the addition of footnotes was recommended in order to clarify the rating criteria. Then, the final draft of the TIS-TH was completed (see Appendix). An IOC value in the range from 0.67 to 1.00 indicates good content validity. The average IOC of TIS-TH was 0.86, as shown in Table 1.

Demographics

Forty-seven stroke patients consented to participate in the study. The participants consisted of 33 males and 14 females; the mean age was 55.85 (SD 13.85) years. The mean MMSE score was 25.21 (SD 3.49), which indicates normal cognitive function. A summary of patient characteristics and outcome measurement scores is shown in Table 2.

Reliability

The total score of TIS-2.0 ranged from 0 to 9, with an average of 4.57. The dynamic sub-score of TIS-2.0 ranged from 0 to 8, with an average of 3.38. The coordination subscore of TIS-2.0 ranged from 0 to 3, with an average of 1.19. The analysis of the floor effect demonstrated that 19.15% (n = 9) received a zero score on the coordination sub-scale. None of the participants received the maximum score from the total score, dynamic sub-score or coordination sub-scale. Cronbach's Alpha of the total score was 0.823, which indicates good internal consistency. For sub-scores, the dynamic dimension was 0.808 and co-ordination dimension was 0.328, which indicates good and poor reliability, respectively (Table 3).

The study showed excellent intra-rater reliability with regard to the total score and sub-score (dynamic dimension) of the TIS-TH, with ICC values of 0.951 (95% CI: 0.927-0.971) and 0.969 (95% CI: 0.978-0.993), respectively. The intra-rater reliability of the co-ordination dimension was moderate, with ICC value of 0.638 (95% CI: 0.458 to 0.776). The standard error of measurement (SEM) of the total TIS-TH score was more than the dynamic or coordination dimension, indicating more measurement error on individual results of this tool when using the two dimensions together. The minimal detectable change, at 95% confidence level (MDC95), of the TIS-TH was 2.245 (Table 4).

Table 1. Item-objective congruence (IOC) of each item

Item	IOC	Item	IOC
Dynamic item 1	1.00	Dynamic item 8	1.00
Dynamic item 2	0.67	Dynamic item 9	0.67
Dynamic item 3	0.67	Dynamic item 10	1.00
Dynamic item 4	1.00	Coordination item 1	1.00
Dynamic item 5	0.67	Coordination item 2	1.00
Dynamic item 6	0.67	Coordination item 3	1.00
Dynamic item 7	0.67	Coordination item 4	1.00
Average IOC		0.86	

Table 2. Demographic characteristics of the participants and outcome measurement scores

Characteristics	N = 47
Age (year)[1]	55.85 (13.85) [14-81]
Sex[2]	
Male	33 (70.21)
Female	14 (29.78)
Time since stroke onset (month)[1]	9.55 (10.11) [1-36]
Stage of stroke[2]	
Sub-acute	27 (57.45)
Chronic	20 (42.55)
Types of stroke[2]	
Ischemic	33 (70.21)
Hemorrhagic	14 (29.78)
Side of paresis[2]	
Left	27 (57.45)
Right	20 (42.55)
MMSE[1]	25.79 (2.37) [23-29]
BI (total score 100)[1]	78.19 (16.92) [30-100]
TIS-TH (total score 16)[1]	4.57 (2.97) [0-9]
BBS (total score 56)[1]	29.53 (17.15) [4-53]
Forward FRT (cm)[1]	15.35 (9.99) [0-34]
MAS sitting balance subscale (total score 6)[1]	3.72 (1.31) [2-6]

[1]Mean (SD) [range], [2]number (%)

MMSE, mini-mental stage examination; BI, Barthel index; TIS-TH, trunk impairment scale Thai version; BBS, Berg balance scale; FRT, functional reach test; MAS, motor assessment scale

Table 3. Score of the TIS-TH, floor and ceiling effect, and internal consistency of the test

TIS-TH	Number of items	Mean (SD)	Range	IQR	Floor effect; Number (%)	Ceiling effect; Number (%)	Cronbach's α
Total score: (/16)	14	4.57 (2.97)	0 - 9	6	2 (4.26)	0 (0)	0.823
Dynamic sub-score: (/10)	10	3.38 (2.55)	0 - 8	5	6 (12.77)	0 (0)	0.808
Co-ordination sub-score: (/6)	4	1.19 (0.68)	0 - 3	1	9 (19.15)	0 (0)	0.328

Table 4. Inter-rater and intra-rater reliabilities

	Inter-rater reliability		Intra-rater reliability			
	ICC (95% CI)	*p*-value	ICC (95% CI)	*p*-value	SEM	MDC95
TIS-TH Total score	0.885 (0.763-0.941)	< 0.0001	0.951 (0.927-0.971)	< 0.0001	0.657	2.245
TIS-TH Dynamic score	0.911 (0.838-0.951)	< 0.0001	0.969 (0.978-0.993)	< 0.0001	0.447	1.850
TIS-TH Coordination score	0.538 (0.277-0.720)	< 0.0001	0.638 (0.458-0.776)	< 0.0001	0.409	1.772

SEM, standard error of measurement; MDC, minimal detectable change

The inter-rater reliability as a whole was good, with an ICC value of 0.885 (95% CI: 0.763-0.941). The ICC of the dynamic and co-ordination dimensions were 0.911 (95% CI: 0.838-0.951) and 0.538 (95% CI: 0.277-0.720), respectively (Table 3).

Validity

Regarding the convergent validity, the TIS-TH showed high correlation (r > 0.70) with the BBS, the MAS and the FRT (Table 5). In addition, correlations between the TIS-TH and these outcome measurements were all statistically significant ($p < 0.0001$).

Discussion

This study found good reliability of the TIS-2.0 Thai version (TIS-TH) (α = 0.823) for measuring trunk performance in stroke patients that is almost equal to the original English version (α = 0.89).[5] Similar results have been reported with other translations; however, Cronbach's Alpha and the

Table 5. Relationships between the TIS-TH total scores and other outcome measurements

Outcome measures	Dynamic TIS-TH	Coordination TIS-TH	BBS	FRT	MAS
Total TIS-TH	0.981* (0.969-0.991)	0.533* (0.309-0.749)	0.800* (0.675-0.981)	0.731* (0.595-0849)	0.710* (0.526-0825)
Dynamic TIS-TH	1	0.800* (0.675-0.981)	0.743* (0.586-0.870)	0.698* (0.551-0.834)	0.658* (0.448-0.800)
Coordination TIS-TH	-	1	0.724* (0.592-0.849)	0.620* (0.355-0.782)	0.666* (0.446-0.798)
BBS	-	-	1	0.861* (0.767-0.924)	0.868* (0.768-0.919)
FRT	-	-	-	1	0.826* (0.683-0.906)

*$p < 0.0001$

BBS, Berg balance scale; FRT, functional reach test; MAS, motor assessment scale

ICC values of the subscale co-ordination in the current study were lower than have been reported with other versions.[12,15-18] Poor internal consistency of the co-ordination dimension (α = 0.328) might relate to non-correlation between the questions. It has been demonstrated that the corrected item-total correlation value of item 2 in the subscale co-ordination cannot be calculated because all of participants received a score of zero. In addition, the value of item 4 was less than 0.20, which indicates that this item may need to be revised.[19] These two items are sequential tasks in the TIS-TH, so the raters can skip the tasks if patients are unable to perform the previous item. It has been suggested that the items in the co-ordination subscale may be too difficult for stroke patients.[9] In fact, the floor effect of greater than 15% implies that a large number of participants were too weak to perform this item.

The SEM of the TIS-TH total in this study was 0.657. Although this is lower than the SEM in other studies, this result cannot be compared with those versions because the static sitting balance dimension was included in their analyses.[5,20] The SEM of both dynamic and co-ordination subscales of the Italian version were slightly higher than this research.[20] Only the study of Cabanas-Valdes et al, (2016) has translated the TIS-2.0 into Spanish, but there was no presentation of the SEM in that study.[9]

The correlation between the TIS-TH and the BBS was evaluated in this study. It has been shown that the TIS-TH total and both subscales have high correlation with the BBS (r > 0.70). The study also investigated the convergent validity of this instrument with the FRT and the MAS, which also demonstrated high correlation coefficients. There were moderate correlations between these two tests and both subscales of the TIS-TH. It has been suggested that moderate convergent validity may indicate inconclusive results for the measurement tool.[21] This might be explained by the fact that performance and patient outcomes from these two tests do not depend solely on trunk activity. The objective of the MAS is to evaluate motor functions which associate with movement of extremities in activity of daily living, while the FRT focuses on mobility based on balance. The original version of the TIS compared relation with the Barthel Index (BI) and the Trunk Control Test (TCT), which had high correlation coefficients.[5] However, Sullivan, et al, (2013)[4] suggested that the TCT is not recommended for evaluation of motor function for patients with strokes. Use of gold standard outcome measurement for assessing trunk activity to compare with the TIS is still required in research area.[9] Electromyography (EMG) has been introduced to evaluate trunk muscle activities in patients with stroke. In the study of Liao et al, (2015),[22] the surface EMG demonstrated an impairment of trunk muscle activities in chronic hemiparesis during performance of symmetrical trunk movement. Further study could benefit from employing the EMG in analysis of the TIS-TH, especially the co-ordination subscale.

One limitation in this study was the restricted performance of the patients. The sample size in the study was acceptable; however, results showed that a large number of the participants found it difficult or were unable to complete the tasks in this tool. The median score of the TIS English version was 14 and 11 points in subacute and chronic stroke, respectively. Although the normative data cannot be compared with the original version, the median score in the current study was extremely low (4 out of 16 points). In future studies, additional participants at different stages of motor recovery may provide a wider range of measurement scores. To gather patients of varying ability levels, the Brunnstrom Recovery Stages (BRS) may be considered in future studies in order to measure and classify levels of motor function between stroke patients.[21]

The TIS-TH requires less than 10 minutes to complete. The American Physical Therapy Association Neurology Section Task Force recommends this tool for use in all stages of stroke. It is also appropriate for use in research studies. Even though learning to administer the TIS is not necessary for physical therapy students, it has been suggested that they should be exposed to the tool.[4] Therefore, translation of this instrument into Thai language is an advantage for students, clinicians, and researchers in order to provide the best possible care for patients.

Conclusion

In summary, the translation of TIS-2.0 into Thai language demonstrated its reliability and validity for use with patients with stroke. Guidelines for the use and interpretation of the TIS-TH would be helpful for clinical practice and research.

Disclosure

The authors declare no conflicts of interest regarding any aspects of the study.

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Appendix

แบบประเมิน Trunk impairment scale ฉบับภาษาไทย

ชื่อผู้ป่วย.....

ด้านของร่างกายที่ได้รับผลกระทบมากที่สุด (ตามที่ผู้ป่วยรับรู้) ☐ ขวา ☐ ซ้าย

วันที่.....

ตำแหน่งเริ่มต้น

ตำแหน่งเริ่มต้นสำหรับแต่ละหัวข้อนั้นเหมือนกัน ผู้ป่วยจะนั่งอยู่บนขอบของเตียง ต้นขาสองข้างสัมผัสเต็มที่กับเตียง เท้าสองข้างวางห่างกันเท่ากับความกว้างสะโพกและวางราบบนพื้น มุมของเข่าสองข้างอยู่ที่ 90 องศา แขนสองข้างวางพักอยู่บนต้นขา หากมีการแสดงภาวะความตึงตัวของกล้ามเนื้อสูง แขนข้างอ่อนแรงจะถูกนับเป็นส่วนหนึ่งของท่าเริ่มต้น ศีรษะและลำตัวอยู่ในตำแหน่งแนวกลางลำตัว

ถ้าผู้ป่วยล้มหรือไม่สามารถรักษาตำแหน่งท่าเริ่มต้นได้เป็นระยะเวลา 10 วินาที โดยไม่ใช้แขนช่วยพยุง คะแนนรวมสำหรับ TIS ฉบับภาษาไทย คือ 0

แต่ละหัวข้อของการทดสอบอาจให้แสดง 3 ครั้ง นับเป็นคะแนนที่ทำได้สูงสุดไม่อนุญาตให้ฝึกซ้อม ผู้ป่วยอาจได้รับการปรับเปลี่ยนท่าในขณะทำการทดสอบ

การทดสอบจะถูกอธิบายเป็นคำพูดให้กับผู้ป่วยและอาจได้รับการสาธิตหากจำเป็น

ความสมดุลในการนั่งขณะมีการเคลื่อนไหว		**คะแนน**
1.	จากตำแหน่งเริ่มต้น ผู้ป่วยได้รับคำสั่งให้สัมผัสเตียงหรือฐานนั่งด้วยข้อศอกข้างที่มีปัญหามากที่สุด (โดยมีการหดสั้นของลำตัวด้านที่ได้รับผลกระทบมากที่สุดและมีการยืดออกของลำตัวด้านที่ได้รับผลกระทบน้อยที่สุด) และกลับสู่ตำแหน่งเริ่มต้น	
	- ผู้ป่วยล้ม จำเป็นต้องใช้แขนช่วยพยุง หรือข้อศอกไม่สัมผัสเตียงหรือฐานนั่ง	0
	- ผู้ป่วยเคลื่อนไหวด้วยตนเองโดยปราศจากการช่วยเหลือ ข้อศอกสัมผัสเตียงหรือฐานนั่ง	1
	ถ้าคะแนน = 0 ข้อที่ 2 และ 3 = 0	
2.	ทำซ้ำข้อที่ 1	
	- ผู้ป่วยแสดงให้เห็นว่าไม่มีหรือมีการหดสั้น/ยืดออกของลำตัวในด้านตรงกันข้าม	0
	- ผู้ป่วยแสดงให้เห็นการหดสั้น/ยืดออกของลำตัวได้อย่างเหมาะสม*	1
	* หมายถึง การเอียงลำตัวไปด้านข้าง โดยปราศจากการเหวี่ยงลำตัว โน้มลำตัว เอนลำตัวไปทางด้านหลัง	
	ถ้าคะแนน = 0 ข้อที่ 3 = 0	
3.	ทำซ้ำข้อที่ 1	
	- ผู้ป่วยเคลื่อนไหวชดเชย การเคลื่อนไหวชดเชยที่เป็นไปได้ ได้แก่ (1) การใช้แขน (2) การกางข้อสะโพกด้านตรงข้าม (3) การงอข้อสะโพก (หากข้อศอกสัมผัสเตียงหรือฐานนั่งทางส่วนปลายมากกว่าครึ่งของส่วนต้นกระดูกต้นขา) (4) การงอเข่า (5) การเลื่อนของเท้าสองข้าง	0
	- ผู้ป่วยเคลื่อนไหวโดยปราศจากการเคลื่อนไหวชดเชย	1
4.	จากตำแหน่งเริ่มต้น ผู้ป่วยได้รับคำสั่งให้สัมผัสเตียงหรือฐานนั่งด้วยข้อศอกข้างที่มีปัญหาน้อยที่สุด (โดยมีการหดสั้นของลำตัวด้านที่ได้รับผลกระทบน้อยที่สุดและมีการยืดออกของลำตัวด้านที่ได้รับผลกระทบมากที่สุด) และกลับสู่ตำแหน่งเริ่มต้น	
	- ผู้ป่วยล้ม ต้องการการช่วยพยุงจากแขน หรือข้อศอกไม่สัมผัสเตียงหรือฐานนั่ง	0
	- ผู้ป่วยเคลื่อนไหวด้วยตนเองโดยปราศจากการช่วยเหลือ ข้อศอกสัมผัสเตียงหรือฐานนั่ง	1
	ถ้าคะแนน = 0 ข้อที่ 5 และ 6 = 0	
5.	ทำซ้ำข้อที่ 4	
	- ผู้ป่วยแสดงให้เห็นว่าไม่มีหรือมีการหดสั้น/ยืดออกของลำตัวในด้านตรงกันข้าม	0
	- ผู้ป่วยแสดงให้เห็นการหดสั้น/ยืดออกของลำตัวได้อย่างเหมาะสม*	1
	* หมายถึง การเอียงลำตัวไปด้านข้าง โดยปราศจากการเหวี่ยงลำตัว โน้มลำตัว เอนลำตัวไปทางด้านหลัง	
	ถ้าคะแนน = 0 ข้อที่ 6 = 0	
6.	ทำซ้ำข้อที่ 4	
	- ผู้ป่วยเคลื่อนไหวชดเชย การเคลื่อนไหวชดเชยที่เป็นไปได้ ได้แก่ (1) การใช้แขน (2) การกางข้อสะโพกด้านตรงข้าม (3) การงอข้อสะโพก (หากข้อศอกสัมผัสเตียงหรือฐานนั่งทางส่วนปลายมากกว่าครึ่งของส่วนต้นกระดูกต้นขา) (4) การงอเข่า (5) การเลื่อนของเท้าสองข้าง	0
	- ผู้ป่วยเคลื่อนไหวโดยปราศจากการเคลื่อนไหวชดเชย	1

ความสมดุลในการนั่งขณะมีการเคลื่อนไหว		คะแนน
7.	จากตำแหน่งเริ่มต้น ผู้ป่วยได้รับคำสั่งให้ยกเชิงกรานด้านที่ได้รับผลกระทบมากที่สุดขึ้นจากเตียงหรือฐานนั่ง (โดยมีการหดสั้นของลำตัวด้านที่ได้รับผลกระทบมากที่สุดและมีการยืดออกของลำตัวด้านที่ได้รับผลกระทบน้อยที่สุด) และกลับสู่ตำแหน่งเริ่มต้น	
	- ผู้ป่วยแสดงให้เห็นว่าไม่มีหรือมีการหดสั้น/ยืดออกของลำตัวในด้านตรงกันข้าม	0
	- ผู้ป่วยแสดงให้เห็นการหดสั้น/ยืดออกของลำตัวได้อย่างเหมาะสม*	1
	* หมายถึง การยกเชิงกราน โดยปราศจากการเหวี่ยงลำตัว โน้มลำตัว เอนลำตัวไปทางด้านหลัง	
	ถ้าคะแนน = 0 ข้อที่ 8 = 0	
8.	ทำซ้ำข้อที่ 7	
	- ผู้ป่วยเคลื่อนไหวชดเชย การเคลื่อนไหวชดเชยที่เป็นไปได้ ได้แก่ (1) การใช้รยางค์แขนสองข้าง (2) การดันด้วยเท้าด้านเดียวกัน (ส้นเท้าขาดการสัมผัสกับพื้น)	0
	- ผู้ป่วยเคลื่อนไหวโดยปราศจากการเคลื่อนไหวชดเชย	1
9.	จากตำแหน่งเริ่มต้น ผู้ป่วยได้รับคำสั่งให้ยกเชิงกรานด้านที่ได้รับผลกระทบน้อยที่สุดขึ้นจากเตียงหรือฐานนั่ง (โดยมีการหดสั้นของลำตัวด้านที่ได้รับผลกระทบน้อยที่สุดและมีการยืดออกของลำตัวด้านที่ได้รับผลกระทบมากที่สุด) และกลับสู่ตำแหน่งเริ่มต้น	
	- ผู้ป่วยแสดงให้เห็นว่าไม่มีหรือมีการหดสั้น/ยืดออกของลำตัวในด้านตรงกันข้าม	0
	- ผู้ป่วยแสดงให้เห็นการหดสั้น/ยืดออกของลำตัวได้อย่างเหมาะสม*	1
	* หมายถึง การยกเชิงกราน โดยปราศจากการเหวี่ยงลำตัว โน้มลำตัว เอนลำตัวไปทางด้านหลัง	
	ถ้าคะแนน = 0 ข้อที่ 10 = 0	
10.	ทำซ้ำข้อที่ 9	
	- ผู้ป่วยเคลื่อนไหวชดเชย การเคลื่อนไหวชดเชยที่เป็นไปได้ ได้แก่ (1) การใช้รยางค์แขนสองข้าง (2) การดันด้วยเท้าด้านเดียวกัน (ส้นเท้าขาดการสัมผัสกับพื้น)	0
	- ผู้ป่วยเคลื่อนไหวโดยปราศจากการเคลื่อนไหวชดเชย	1
	คะแนนรวมความสมดุลในการนั่งขณะมีการเคลื่อนไหว	**..... /10**

การทำงานประสานสัมพันธ์		คะแนน
1.	จากตำแหน่งเริ่มต้น ผู้ป่วยได้รับคำสั่งให้หมุนลำตัวส่วนบนจำนวน 6 ครั้ง (หัวไหล่แต่ละข้างต้องเคลื่อนมาทางด้านหน้าจำนวน 3 ครั้ง) ด้านที่ได้รับผลกระทบมากที่สุดเคลื่อนไหวก่อน ศีรษะควรคงอยู่ในตำแหน่งเริ่มต้น	
	- ด้านที่ได้รับผลกระทบมากที่สุดเคลื่อนไหวไม่ครบ 3 ครั้ง	0
	- การหมุนลำตัวไม่สมมาตรกัน	1
	- การหมุนลำตัวสมมาตรกัน	2
	ถ้าคะแนน = 0 ข้อที่ 2 = 0	
2.	ทำซ้ำข้อที่ 1 ภายใน 6 วินาที	
	- การหมุนลำตัวไม่สมมาตรหรืองานใช้เวลามากกว่า 6 วินาที	0
	- การหมุนลำตัวสมมาตรและงานใช้เวลาน้อยกว่า 6 วินาที	1
3.	จากตำแหน่งเริ่มต้น/ ผู้ป่วยได้รับคำสั่งให้หมุนลำตัวส่วนล่างจำนวน 6 ครั้ง (หัวเข่าแต่ละข้างต้องเคลื่อนมาทางด้านหน้าจำนวน 3 ครั้ง) ด้านที่ได้รับผลกระทบมากที่สุดเคลื่อนไหวก่อน/ ลำตัวส่วนบนควรคงอยู่ในตำแหน่งเริ่มต้น หากผู้ป่วยมีการเคลื่อนตัวมาทางด้านหน้าต่อของขอบเตียงหรือฐานนั่งถือว่าเป็นอนุโลมได้	
	- ด้านที่ได้รับผลกระทบมากที่สุดเคลื่อนไหวไม่ครบ 3 ครั้ง	0
	- การหมุนลำตัวไม่สมมาตรกัน	1
	- การหมุนลำตัวสมมาตรกัน	2
	ถ้าคะแนน = 0 ข้อที่ 4 = 0	
4.	ทำซ้ำข้อที่ 3 ภายใน 6 วินาที	
	- การหมุนลำตัวไม่สมมาตรหรืองานใช้เวลามากกว่า 6 วินาที	0
	- การหมุนลำตัวสมมาตรและงานใช้เวลาน้อยกว่า 6 วินาที	1
	คะแนนรวมการทำงานประสานสัมพันธ์รวม	**...../6**

Slow Reversal-Hold Technique in Treating Radial Nerve Palsy Patient: A Case Report

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ABSTRACT

Objectives: To demonstrate the effectiveness of slow reversal-hold technique in patients with incomplete radial nerve palsy associated with humerus fracture.

Study design: Case report.

Setting: Department of Rehabilitation Medicine, King Chulalongkorn Memorial Hospital.

Subjects: A 28-year-old female patient diagnosed with fracture of upper end of left humerus subsequently developed incomplete radial nerve palsy.

Methods: Not applicable.

Results: The patient presented with wrist and finger drop and intrinsic and extrinsic wrist and finger flexors tightness of her left hand, resulting in difficulties in performing activities of daily living (ADL). Adding to conventional occupational therapy, slow reversal-hold proprioceptive neuromuscular facilitation (PNF) technique was used to treat her conditions. After 12 weeks of therapy, the aforementioned conditions resolved. Her hand function improved significantly and she eventually became totally independent in ADL.

Conclusion: Slow reversal-hold technique PNF technique combined with conservative treatment seemed to facilitate improvement of muscle power, resolving intrinsic tightness and extrinsic finger flexors shortening in a patient with incomplete radial nerve palsy.

Keywords: radial nerve palsy, slow reversal-hold technique, proprioceptive neuromuscular facilitation (PNF), strengthening exercise, occupational therapy

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Introduction

Radial nerve palsy is found in 6-15% of patients with humerus fracture.[1] A radial nerve injury can occur at any point along the nerve. Due to the anatomy of the arm, the nerve is vulnerable to fractures of the humerus shaft and around the elbow. Normally, injuries most commonly occur at the middle to the distal third of the humerus.[2] The classic sequalae of radial nerve injuries are inability to extend the wrist, weakness of finger extensors, thumb extension and abduction.[3] The most concerning problem is weakness or inability to control extensor muscle group around the wrist and fingers which is also known as "wrist and finger drop".[2,3] Wrist drop is the hallmark of a radial nerve injury, whereby the wrist flexors are stronger than the extensor group. The hand cannot maintain the functional position, leading to loss of hand function which affects patients' activities in daily living (ADL).[1]

Conservative treatment plays a crucial role as radial nerve injuries commonly represent neurapraxia or axonotmesis, with a high rate of spontaneous recovery, ranging between 60% to 92%.[2] In contrast, surgical management is indicated in nerve transection cases, open injuries and failed conservative treatment.[2] Non-operative management includes rest, activity modification, vitamin therapy and a period of immobilization with a splint. One of the most important goals is to maintain range of motion (ROM) and improve strength via exercises.[2] In general, such treatment is based on the use of electrical stimulation to retard muscle atrophy while awaiting nerve recovery. Passive movement exercise is used if there is no muscle contraction. On the contrary, active assistive exercise is applied if there is some muscle contraction. Once the muscles become more active, active resistive exercise will be implemented.[4] However, this overall exercise program takes a long time to achieve the goal and has a tendency to cause complications, such as intrinsic muscles tightness, extrinsic finger flexors shortening, extensors elongation or joint stiffness.[1]

Another technique for treating extrinsic flexors shorting and strengthening extensor muscles is the method of slow reversal-hold, one of the proprioceptive neuromuscular facilitation (PNF) strengthening techniques.[5] This slow reversal-hold technique involves isotonic contraction of the agonist followed immediately by an isometric contraction with a hold command given at the end of each active moment, to develop

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strength at a specific joint ROM.[5] In this case, we combined conservative occupational therapy with this slow reversal-hold technique. The consequences after radial nerve injury resolved and the patient resumed their independence in performing activities of daily living (ADL). Therefore, we would like to demonstrate our experience in employing the slow reversal-hold technique as an adjunctive therapy to facilitate motor recovery and treat complications following incomplete radial nerve injury.

Case study

A 28-year-old Thai nurse was involved in a car accident on July 31st, 2017. She suffered from the left proximal humerus fracture, which was treated with open reduction and internal fixation on August 4th, 2017. After the surgery, she still had left wrist drop and finger drop, and was able to grip only light objects. There was evidence of incomplete left radial nerve injury supported by electrodiagnostic study. The study revealed incomplete left radial nerve degeneration with signs of regeneration, up to branches of triceps brachii muscle. Rehabilitation consultation and occupational therapy started after surgery on August 15th, 2017.

The first occupational therapy assessment

The patient came in for the first occupational therapy assessment on August 17th, 2017. She was left-handed. The evaluation of grip and grasp strength for picking and holding objects with a dynamometer found that the patient could not perform all of the functions. The patient was asked to self-report pain and difficulties in performing ADL by completing the Patient Rated Wrist/Hand Evaluation (PRWHE) questionnaire. Table 1 shows high scores of both pain and difficulties in ADL, with 141 points before therapy. Pain was the main limitation of difficulties in using hand. In addition, ADL was assessed with modified Barthel ADL Index and the score was 17 points out of 20. The patient could not take a shower or get dressed by herself, due to the affected dominant hand. She had to use the non-dominant hand for eating, washing her face and brushing her teeth. On the initial assessment, there were other complications such as hand edema, intrinsic finger flexors tightness and extrinsic finger and wrist flexors shortening.

After planning for treatment and goal setting with the patient using the Canadian Occupational Performance Measure (COPM) (Table 2), the first priority for the patient was to improve her wrist and hand movements and then her function performance such as taking objects, showering, getting dressed and working, respectively. The patient rated her satisfaction with the first assessment, 6 out of 50.

Problems-based approach in occupational therapy

The main problems of this patient were muscle weakness, impaired left-hand functions, and difficulties in performing ADL and work-related tasks. All were interrelated to one another and required treatments. According to the problem-based approach, the assigned occupational therapist planned a 90-minute session three times per week over a period of 12 weeks, for a total of 36 sessions. Slow reversal-hold PNF strengthening technique was combined with conventional occupational therapy to facilitate motor neurons of the weak extensor muscles, and improve ROM of wrist and finger,

Table 1. The Patient-Rated Wrist/Hand Evaluation (PRWHE)

Patient rated wrist/hand evaluation	Scores	Before	After
1. Level of pain			
1. While resting	10	7	3
2. While moving hand & wrist repeatedly	10	8	4
3. While lifting heavy objects	10	10	9
4. When the patient felt most painful	10	10	9
5. How often the patient felt pain?	10	6	4
Pain score	50	41	29
2. Work difficulty			
6. Turn door knob with affected hand	10	10	6
7. Using cutleries with the affected hand	10	10	6
8. Buttoning	10	10	5
9. Use affected hand to support when getting up from the chair	10	10	7
10. Lift an object around 5 kg. with affected hand (1 bag of rice)	10	10	10
11. Clean oneself with affected hand	10	10	7
12. Doing daily activities (bathing, dressing etc.)	10	10	3
13. House work	10	10	5
14. Regular job	10	10	5
15. Hobbies	10	10	4
Work difficulty score	100	100	58
Total	150	141	87

Before, 1st occupational therapy assessment; after, after completion of 36 sessions
In pain domain, high score means more pain.
In work domain, lower score means less difficulty or improvement in function.

Table 2. Patient's performance and satisfaction evaluated by COPM

COPM and satisfaction activity	Points	Before			After		
		Imp	Perf	Sat	Imp	Perf	Sat
Movements in hands & wrists	10	10	0	0	10	8	8
Hand function	10	10	0	0	10	8	9
Bathing	10	10	3	3	10	9	9
Dressing	10	10	3	3	10	8	9
Working	10	10	0	0	10	5	7
Total	50	50	6	6	50	38	42
Average	10		1.2	1.2		7.6	8.4

COPM, Canadian Occupational Performance Measure; Imp, important; Perf, performance; Sat, satisfaction
Before, 1st occupational therapy assessment; after, after completion of 36 sessions

together with and hand and arm use in daily life. In this case, the therapist employed the slow-reversal-hold PNF strengthening technique with the flexors group (flexor carpi radialis, flexor carpi ulnaris and flexor digitorum superficialis) first and then with the extensor group (extensor carpi ulnaris, extensor carpi radialis longus, extensor carpi radialis brevis and extensor digitorum). The technique was performed with five repetitions per set with a break between sets. The whole process took approximately thirty minutes and was followed by a 20-minute session of biofeedback training.

Once the weak muscles gained more muscle power, the therapist then continued to the next step of improving the patient's hand function by grasping as well as holding light-weight hand-sized objects such as tennis balls then sizing it down to table tennis balls or beads respectively. Furthermore, strength training was done by grasping objects through various activities with resistance such as turning knots or opening bottle caps. To improve performance of ADL, adaptive devices were recommended to facilitate the affected hand, such as using a larger handled spoon and toothbrush. The patient was also encouraged to use the affected hand to do more challenging daily activities such as rubbing arms, taking food, and moving objects. The last training was performing tasks related to work as a nurse, for instance, using mock-up activities such as opening bottle caps, lifting objects as well as giving injections.

Occupational therapy outcomes

After 12 weeks of combined therapy, according to COPM, the patient's performance improved and satisfaction score increased in every aspect as shown in Table 2. According to the Medical Research Council (MRC) muscle power grading system, the affected arm muscles showed a higher grade as shown in Table 3. Her left-hand grip strength and lateral pinch strength improved to 2.27 kilograms and her tip pinch to 0.45 kilograms. According to PRWHE test, the difficulty in using hand and arm decreased when compared with the first assessment as shown in Table 1. The modified Barthel ADL index scores also increased from 17 to 20 because of improvements in bathing (showering) and dressing.

Table 3. Muscle power according to MRC muscle grading system

Muscle power grading	Before	After
Elbow flexors	4*	5
Elbow extensors	4*	5
Wrist flexors	4*	5
Wrist extensors	2*	4
Finger flexors	3*	5
Finger extensors	2*	4
Thumb flexors	3*	5
Thumb extensors	2*	4

MRC, Medical Research Council
Before, 1st occupational therapy assessment; after, after completion of 36 sessions
*Muscle power assessment was limited by marked pain.

Discussion

Radial nerve palsy results in muscle power impairment of elbow, wrist and hand muscles which are essentially responsible for performing ADL.[6] Although radial nerve palsy has some potential for spontaneous improvement, other complications may occur over time. Therefore, occupational therapists are advised to consider other possible complications in order to prevent them and decide a proper treatment program. We believe that the PNF technique of slow reversal-hold not only strengthens the weak muscles by stimulating its motor neurons but also prevents the intrinsic hand muscles tightness and extrinsic finger flexors shortening in this patient with incomplete radial nerve palsy. According to clinical decision making in therapeutic exercise recommended by Sullivan PE,[5] therapists should start the slow reversal-hold PNF technique with isotonic contraction of the stronger agonist muscle followed by isometric contraction at the end of the session; then a second isotonic contraction of the weaker antagonist muscle and followed immediately with isometric contraction at the end of the session. There is no rest period between contractions. Quick stretch could be applied to facilitate muscular activity which aims to develop strength of antagonist muscle.

In this case study, after the completion of 36 sessions of the 12-week combined therapy of slow reversal-hold PNF technique, conventional occupational therapy training and

biofeedback, muscle power of the wrist and finger extensors improved from grade 2 to 4, the pain level decreased by approximately about half at rest and when moving hand and wrist repeatedly, and performance in activities was markedly improved. We believe that such improvements were facilitated by the slow reversal-hold PNF technique as PRWHE scores decreased similar to the study reported by Keerthi, et al.[7] who conducted a randomized controlled trial in patients diagnosed with distal radius fracture, by comparing between conventional therapy and combination of conventional therapy and slow reversal-hold PNF technique. Significant improvement was found in both groups evaluated by PRWHE, numerical pain scale and ROM but the combined therapy group showed better results.[7] Generally, incomplete radial nerve injury with axonotmesis like in our case, complete motor recovery takes about 12 months.[8] To be noted, our case had nearly complete recovery within 3 months after surgery which lead us to believe that slow reversal-hold PNF technique facilitates motor neurons and enhances motor recovery.

The slow reversal-hold PNF technique employed in this case of incomplete radial nerve injury with intrinsic tightness and extrinsic finger flexors shortening seemed effective. Although the wrist and fingers ROMs of the affected hand were not measured objectively, we observed an increase in ROMs as the patient performed activities with less difficulty. One should be reminded that there are two groups of PNF techniques, strengthening and stretching. Birinci et al. used a structured exercise program combined with the PNF technique of hold-relax stretching in patients with post-traumatic elbow stiffness and reported improvement of elbow flexion ROM and pain.[9] The PNF hold-relax stretching technique aims to gain ROM quicker than static stretching due to reciprocal inhibition.[9] In addition, voluntary contraction of the opposite muscle can lead to reduced activation level in the target muscle through development of reciprocal inhibition.[10]

Lastly, this case report is written to support the idea of treatment for improving muscle power and reducing intrinsic and extrinsic tightness of the hand with the slow reverse-hold PNF technique, which has not been commonly used in conventional occupational therapy, and to raise awareness among occupational therapists and physiatrists about the benefit of this PNF technique. In addition, favorable outcomes in this case are merely the beginning for future research of case series or randomized controlled trial to compare between conventional therapy and the slow reverse-hold PNF technique in patients with radial or other nerve palsy.

Conclusion

Although radial nerve palsy has a potential of spontaneous recovery in some degree, however other complications may occur and affect functional recovery. Therefore, physiatrists and occupational therapists are advised to consider all possible complications in order to prevent or treat them and prescribe the most appropriate treatment. The PNF slow reversal-hold technique employed in this case with incomplete radial nerve palsy not only facilitated the wrist and fingers extensors muscle power but also improved the intrinsic muscle tightness and extrinsic flexor shortening. This technique combined with conventional therapy correspondingly with problem-based approach treatment seems effective in improving patient's independence in daily living.

Disclosure

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Electrophysiological Findings in Human Parechovirus-Associated Acute Flaccid Paralysis: A Case Report

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ABSTRACT

Objectives: This paper aims to describe the electrophysiological findings seen in a young boy diagnosed with human parechovirus-associated acute flaccid paralysis (AFP) in the Philippines.
Study design: Case report.
Setting: Hospital.
Subject: This is a case of a 1-year-old Filipino boy who presented with focal flaccid limb weakness following a prodromal illness, which then progressed asymmetrically and with respiratory paralysis. Lumbar puncture results were normal, nasopharyngeal swab showed enteroviral antigens, and human parechovirus (HPeV) was isolated in stool. Whole spine magnetic resonance imaging (MRI) initially demonstrated inflammatory changes in the C4-C6 cord levels, but was normal on repeat testing after five months. Following the set case definition, findings altogether led to diagnosis of enterovirus-related AFP.
Methods: Electromyography (EMG) and nerve conduction study (NCS) was conducted 6 months into the disease course.
Results: NCS of the upper limbs revealed normal sensory nerve action potential parameters. Compound motor action potentials were likewise normal except for apparent conduction blocks on the left proximal median and peroneal nerves. EMG showed active partial denervation and patchy evidence of reinnervation process on the tested limbs. These findings of a diffuse axonal motor neuropathy are compatible with neurophysiological changes seen in limited published studies on enterovirus-associated AFP.
Conclusion: Electrophysiological studies may be clinically useful as part of the multidisciplinary approach in diagnosing enterovirus-associated AFP. To our knowledge, this is the first electrophysiological description of parechovirus-associated AFP in Asia.

Keywords: human parechovirus, acute flaccid paralysis, non-polio enterovirus, nerve conduction study, electromyography

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Introduction

With the marked decline in the incidence of poliovirus worldwide and its eradication in some industrialized countries, Non-Polio Enteroviruses (NPEVs) including Coxsackievirus, Echovirus and newly discovered Enteroviruses, such as Enterovirus D68 (D68V) have become an emerging concern as a suspected cause of acute flaccid paralysis (AFP).[1,2] These viruses are known to have a worldwide prevalence and are associated with multiple clinical presentations including gastroenteritis, respiratory tract infections, aseptic meningitis, fever of unknown origin and flaccid paralysis, among others.[3-10]

Acute flaccid paralysis represents a wide spectrum of neuromuscular diseases, ranging from acute inflammatory motor polyneuropathy to hypo/hyperkalemic paralysis, poliomyelitis and polio-like infections.[7] Despite the consistent utilization of polio vaccine in many parts of the world, sporadic cases of acute paralysis similar to paralytic poliomyelitis are accounted by other enterovirus serotypes. In particular, a new emerging NPEV is being recognized among different countries as a cause of severe neurodevelopmental complications. In the late 2017, public health warnings were issued about a national epidemic of human parechovirus (HPeV) in young children.

The human parechovirus is a single-stranded, RNA virus from the Picornaviridae family, which includes enteroviruses and poliovirus. HPeVs were first isolated in 1956 and classified as enteroviruses (named echoviruses 22 and 23) but was only reclassified into a separate genus in 1996. EV and HPeV are clinically and genetically similar, with differences in the 5' non-translated region. Both viruses replicate in the gastrointestinal tract, are transmitted via the fecal oral route, and shed from the nasopharynx. Nucleic-acid detection, culture, serology, and antigen detection are the available diagnostic techniques. At present, nineteen genotypes (HpeV-1 to HpeV-19) have been identified based on their complete genome or viral protein 1 (VP1) sequences. HPeV1 and HPeV2 have been associated with mild gastrointestinal and respiratory symptoms, while HPeV3 has been associated with more severe clinical manifestations in the form of sepsis-like and CNS illnesses, particularly in neonates and

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infants. HPeV types 4-8 seem to cause disease similar to those associated with HPeV1 and HPeV2 infections. Young children, particularly infants less than 3 months old, are especially susceptible because of an immature immune system.[3, 9, 11-14]

Parechovirus serotypes 1 and 3 are most commonly associated with human disease.[15] HpeV-1 genome caused an outbreak of AFP in Jamaica in 1986 while HPeV3 infection was first associated with AFP in a young girl in 2004.[3,16] There was only one documented case of HpeV in 2017 in a 4-year-old male presenting as flaccid paralysis of both upper and lower limbs in the United Kingdom.[17] In these patients neuroimaging, particularly MRI, showed spinal cord inflammation, root enhancement, and anterior horn cell involvement. Findings similar with parechovirus and poliovirus infections were the presence of long-segment T2 hyperintensity of spinal cord anterior horn cell, nerve root enhancement as well as anterior horn cell enhancement.

There are a few published reports regarding electrophysiological findings observed in patients with HPeV. Electrodiagnostic testing on a 6-year-old boy in Italy diagnosed with HPeV Type 6 (Pellegrinelli et al, 2018) revealed signs of an axonal motor neuropathy mostly affecting the lower limbs.[18] In a case series of twenty-nine patients who had EV-D68–associated acute flaccid myelitis (AFM) in Europe (Knoester et al, 2018), eleven underwent EMG-NCS which generally showed low amplitude compound muscle action potentials most often with normal conduction velocity without signs of sensory nerve conduction abnormalities.[10] In the said case series, EMG done on varying stages of the disease (ranging from 7 days to 3 months) revealed spontaneous muscle fiber activity in the affected muscles. A report on two Norwegian cases (Pfeiffer et al, 2015) exhibited similar findings of motor axonal involvement (reduced motor amplitudes) with sensory nerve sparing parameters on NCS.[19] Of these 2 patients, only one presented with an abnormal needle study consistent with an axonopathic process.

To date, there are no published reports or studies on cases of human parechovirus infection in Asia recorded. Furthermore, electrodiagnostic findings of HPeV have not been thoroughly described, although the clinical as well as radiologic description have been stated as having similarities with poliovirus infection. We describe in this first reported case the electrophysiological findings of HPeV-induced AFP in a young Filipino boy.

Case presentation

This is the case of a previously-well 15-month-old Filipino boy with complete immunization status, who developed fever, lethargy and dyspnea while on a trip to Spain. There he was admitted at the pediatric intensive care unit of a hospital and was admitted for 6 months before being transferred to the Philippines. While confined in Spain, the boy developed progressive respiratory distress prompting eventual mechanical ventilation. Magnetic resonance imaging (MRI) with contrast of the cervical spine cord revealed an inflammation on the C4 to C6 levels. The medical report from the source hospital stated that lumbar puncture results were normal, however the detailed cerebrospinal fluid (CSF) profile or findings were not included in the endorsed document. Nasopharyngeal swab revealed the presence of an enterovirus whereas stool analysis detected parechovirus. While enterovirus and parechovirus are genetically similar hence possibly the reason for the inconsistency in laboratory result reporting, an EV and HPeV coinfection cannot be entirely ruled-out given the limited test reporting. The parechovirus genotype was also not specifically mentioned in the medical report from the hospital in Spain, as with any mention of subtyping performed. A few days after admission, the patient was observed to have focal right upper limb weakness consequently progressing to involve all extremities. Poor oral feeding necessitated gastrostomy tube and button placement. Motor assessment revealed poor neck control and truncal balance with flaccid limbs and no neck stiffness reported. The initial clinical presentation of the patient was consistent with encephalitis and this condition was entertained early, but was ruled out after normal cranial computed tomography (CT) scan and electroencephalography (EEG) results. The features observed in the patient were consistent with the case definition of EV-related AFM.

The child underwent regular rehabilitation sessions (physical, occupational and speech therapies). He could be propped with support on both his wheelchair and an adapted stroller. Therapeutic standing up to one hour was performed in a pediatric inclined plane.

The child was transferred to a tertiary hospital in the Philippines after six months in Spain. EMG-NCS was done within the first month after transfer (Tables 1, 2 and 3). Repeat cervical spine MRI by this time did not show the previously seen spinal cord lesions. This may signify either an absence of active inflammation at the time of neuroimaging, or that the prior cervical cord damage was not permanent and may have resolved.

On the 3rd month of hospital stay, he experienced episodes of desaturation with cyanosis, and suffered a cardiac arrest but was revived and started on antiseizure medications due to post-arrest focal seizures. Video electroencephalogram (VEEG) revealed abnormal interictal electroencephalography (EEG) patterns due to diffuse cerebral dysfunction, while cranial CT scan showed hydrocephalus ex vacuo. The VEEG and cranial CT scan results likely signify neuropathological complications from brain hypoxia. Multiple tests done over the succeeding months documented other co-existing medical conditions such as poor left hemi-diaphragmatic excursion by ultrasound, right hip subluxation with neuromuscular thoracolumbar levoscoliosis by radiographs, and osteopenia by skeletal survey. The presence of levoscoliosis coupled with the immaturity of the hip, lack of weightbearing

Table 1. Sensory nerve conduction study done within the first month after transfer

Nerve	Peak latency (ms)	Amplitude (μV)	Conduction velocity (m/s)
I. Median nerve			
Left median (palm – wrist)	0.5	82.0	71.0
Right median (palm – wrist)	ND	ND	ND
Normal values for age[1]	≤ 0.9	≥ 12.7	49.7 ± 6.4
II. Ulnar nerve			
Left ulnar (5th digit – wrist)	0.5	16.1	60.0
Right ulnar (5th digit – wrist)	ND	ND	ND
Normal values for age[1]	≤ 0.8	≥ 8.5	56.7 ± 4.8
III. Sural nerve			
Left sural	1.1	22.0	44.0
Right sural	ND	ND	ND
Normal values for age[1]	≤ 1.3	≥ 5.1	48.5 ± 8.7
IV. Superficial peroneal nerve			
Left superficial peroneal	1.4	28.0	46.0
Right superficial peroneal	ND	ND	ND
Normal values age[2]	-	21.90 ± 8.58	48.13 ± 6.24

[1]Reference: Jabre JF, Pitt MC, Smith R. Deriving pediatric nerve conduction normal values in the very young (< 3 years). Clin Neurophysiol. 2020;131:177-182

[2]Reference: Verma S, Pochiraju S. Superficial fibular nerve sensory nerve conduction study in children. Muscle Nerve. 2016;54:808-9.

ND, not done due to intravenous attachments

and abnormal muscle forces around the affected hip likely contributed to the asymmetrical (right) hip subluxation. Orthopedic intervention was done through an application of a hip abduction brace for 2 months. Mechanical ventilation was also continued and episodes of desaturation with cyanosis were addressed. His overall condition continuously deteriorated and he ultimately went into cardiopulmonary arrest leading to his demise 2 years after the onset of symptoms.

Electrodiagnostic findings

EMG-NCS was done (with the patient awake) after transfer. Electrophysiological findings demonstrated normal NCS on the left median, left ulnar, left sural and left superficial peroneal nerves (Table 1). Sensory conduction study of the same nerves on the right was not done due to technical difficulties (i.e., multiple intravenous attachments, positional problems).

Compound motor action potential (CMAP) parameters were likewise normal on all the nerves tested (left median, left ulnar, left common peroneal and left tibial nerves) except for reduced amplitudes of the left median nerve and left peroneal nerve by > 20% upon proximal stimulation (Table 2). Motor NCS of the right upper extremity nerves was not done due to technical difficulties. F-wave latencies of the left median, left ulnar and both tibial nerves were within normal limits.

Needle EMG study revealed increased insertional activities with abnormal spontaneous potentials in the form of positive sharp waves (PSW) and fibrillations in the right biceps (musculocutaneous nerve, C5-C6), left gastrocnemius (tibial nerve, S1) and left tibialis anterior (peroneal nerve, L4), indicating an active denervation process (Table 3). These muscles together with the left rectus femoris and right medial gastrocnemius exhibited markedly reduced recruitment with long-duration polyphasic motor unit action potentials (MUAPs).

Discussion

To the authors' best knowledge, this is the first reported case of AFP caused by human parechovirus in a pediatric patient in the Philippines. In the study by Apostol et al in 2012, a total of 790 NPEVs were isolated from the stool specimen of children < 15 years of age presenting with acute flaccid type of paralysis.[1] Only 47 serotypes of NPEV strains were identified using neutralization test and molecular typing, and there was no mention of an HPeV serotype. They concluded that multiple patterns of circulation of plural NPEV serotypes may have existed in the Philippines over 17 years.

The features observed in the patient are consistent with the case definition of EV-related AFM comprised of the following key components: (1) Acute onset of focal limb weakness, (2) MRI showing spinal cord lesion largely restricted to the grey matter spanning 1 or more spinal segments and (3) Detection of EV-D68 in a respiratory, fecal, blood or CSF specimen using a validated Polymerase Chain Reaction (PCR) assay for EVs in general and subsequent sequencing and typing.[10]

This patient's NCS yielded normal sensory transmission and normal motor amplitude values except for attenuated proximal left median nerve and left peroneal nerve amplitudes by > 20% (stimulated supramaximally), which likely signify conduction block due to axonal loss. The left ulnar motor amplitude dipped by 17% upon stimulation at the elbow

Table 2. Motor nerve conduction study done within the first month after transfer

Nerve	Distal latency (ms)	Amplitude (mV)	Conduction velocity (m/s)	F-waves minimal latency (ms)
I. Median nerve				
Left median (wrist)	2.1	4.0	-	17.0
Left median (elbow)	-	2.7	43.0	-
Right median (wrist)	ND	ND	-	ND
Right median (elbow)	-	ND	ND	-
Normal values for age[1]	<2.5	>3.5	≥ 35	≤ 21
II. Ulnar nerve				
Left ulnar (wrist)	2.0	6.3	-	17.2
Left ulnar (elbow)	-	5.2	52.0	-
Left ulnar (above elbow)	-	5.6	63.0	-
Right ulnar (wrist)	ND	ND	-	ND
Right ulnar (elbow)	-	ND	ND	-
Right ulnar (above elbow)	-	ND	ND	-
Normal values for age[1]	< 2.5	≥ 2.5	≥ 40	≤ 17
III. Common peroneal nerve				
Left common peroneal (ankle)	1.9	2.9	-	-
Left common peroneal (knee)	-	2.0	52.0	-
Left common peroneal (above knee)	-	2.5	54.0	-
Right common peroneal (ankle)	2.2	2.1	-	-
Right common peroneal (knee)	-	2.1	45.0	-
Right common peroneal (above knee)	-	ND	ND	-
Normal values for age[1]	≤ 3.5	≥ 1.5	≥ 35	-
IV. Tibial nerve				
Left tibial (ankle)	2.5	9.9	-	24.5
Left tibial (knee)	-	9.7	47.0	-
Right tibial (ankle)	2.4	10.8	-	22.7
Right tibial (knee)	-	11.2	45.0	-
Normal values for age[1]	≤ 3.0	-	≥ 30	≤ 26

[1]Reference: Kang PB. Pediatric nerve conduction studies and EMG. In: Blum AS, Rutkove SB, editos. The Clinical Neurophysiology Primer. Totowa, NJ: Humana Press Inc; 2007: 369-89.
ND, not done due to intravenous attachments

Table 3. Electromyography findings done at a tertiary hospital in the Philippines after transfer

Muscle	Insertional activity	Abnormal spontaneous activity[1]			Motor unit action potentials
		Fibrillations	Fasciculations	PSW	
A. Upper limbs					
Right biceps	Increased	2+	0	2+	No activated motor units, severely reduced recruitment with paucity of motor unit remodeling
B. Lower limbs					
Right gastrocnemius (medial head)	Normal	0	0	0	Reduced recruitment; large motor units with increased duration, polyphasia, and evidence of motor unit remodeling
Left rectus femoris	Normal	0	0	0	
Left tibialis anterior	Increased	2+	0	1+	Severely reduced recruitment; large motor units with increased duration, polyphasia, and evidence of motor unit remodeling
Left gastrocnemius (medial head)	Increased	2+	0	2+	Severely reduced recruitment; large motor units with increased duration, polyphasia, and evidence of motor unit remodeling

PSW, positive sharp waves
[1]Grading of abnormal spontaneous activity: 0 = None; 1+ = Persistent single runs in > 1 second in 2 areas; 2+ = Moderate runs > 1 second in three or more areas; 3+ = many discharges in most muscle regions; 4+ = Continuous discharges in all areas of the muscle

and 11% above the elbow, which likely resulted from a submaximal stimulation at the elbow, and not fulfilling the description for a conduction block. The needle EMG study evoked abnormal insertional activities in the form of abnormal spontaneous potentials (PSW and fibrillations) along with varying degrees of reduced recruitment patterns of increased duration, some polyphasic MUAPs, and paucity of motor units remodeling in the right biceps, left tibialis anterior and left gastrocnemius. EMG findings seemed to demonstrate electrophysiological evidence of a diffuse motor axonal polyneuropathy consistent with what was observed on the study by Pellegrinelli et al.[18] Fibrillation potentials develop as motor axons degenerate, while the appearance of motor unit potential of large amplitude and long duration are indicative of reinnervation as a result of compensatory collateral sprouting thus remodeling of the motor units.[20-22]

The general finding of low CMAP amplitudes observed on children from the case series by Knoester et al,[10] and Pfeiffer et al,[19] was however not observed in our patient. This is surprising since axonal injury within the nerve bundle will typically result in a dropout of axons actually stimulated and consequently a reduction in the amplitude of the motor action potential. Neurogenic MUAP characteristics (such as seen in this case) and attenuated CMAP amplitudes on NCS (not seen in this case) are stereotypical for a motor axonal polyneuropathy, but can also be expected in an anterior horn cell (AHC) involvement. However, an AHC condition seems less likely to be the circumstance here because of the presence of conduction blocks observed in the patient's left median and peroneal nerves using supramaximal stimulation. Furthermore, flaccid paralysis in the background of anterior horn cell loss would be expected to produce much lower CMAP amplitudes (but depending on severity), contrary to the mostly-normal values observed in this patient. It is possible that in this patient, recovery may have begun on an existing motor axonal neuropathy, with the primary mechanism of early recovery being collateral reinnervation, with resolution of conduction block and nerve regeneration occurring later.[20]

While the spinal cord lesion seen on MRI (C4-C6) may explain the fibrillations and PSW seen on the right biceps (a muscle innervated at the corresponding levels affected) and even the conduction block observed on the left proximal median nerve (stimulated supramaximally), it is unlikely to cause MUAP changes seen on the lower limbs. Furthermore, even if cervical transverse myelitis (TM) as a likely sequela was entertained earlier in the course, a thorough investigation seems to discourage this as it appeared that the patient did not manifest with a rapidly progressing paraparesis or bilateral signs and symptoms, had no identifiable sensory level (cannot be tested), and had no CSF pleocytosis, which are all significant clinical features in the diagnostic criteria of TM.

This report has its own limitations. Electrophysiological evaluation was not done earlier in the course of the disease; hence we cannot definitively conclude that the normal CMAP parameters seen in this patient at the time of testing indeed point to signs of ongoing recovery as postulated. Moreover, repeat testing was not done so we cannot objectively determine if the changes identified will improve over time as might be seen in some cases of motor axonal polyneuropathy, or persist indefinitely as seen in patients with AHC involvement. Lastly, only a limited number of muscles were tested (especially for the upper limbs). More sites tested on needle study might provide more information to support our inferences.

Conclusion

The electrophysiological profile of non-poliomyelitis AFP remains poorly defined despite well-established epidemiological and clinical parameters. After extensive literature search, the authors believe that this is the first electrophysiological description of AFP caused by human parechovirus in a pediatric patient in Asia, revealing changes suggestive of a diffuse motor axonal neuropathy. This report illustrates the importance of including electrophysiology as part of the multidisciplinary approach in the diagnosis of enterovirus-induced flaccid paralysis, especially in situations when clinical judgment is inexplicit.

Disclosure

The authors disclose no potential conflicts of interest, including all relevant financial interests in any company or institution that might benefit from the publication.

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