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Content

Notes from the Editor-in-Chief

Welcome to our first issue of the 2023 ASEAN Journal of Rehabilitation Medicine. This issue has articles relate directly to rehabilitation medicine treatment and diagnostic methods that are becoming popular among rehabilitation physicians. There are also researches on factors related to the therapeutic effects of various diseases. The readers can have more information for decision-making in the practices. In addition, research on medical education topics has also been exciting from residency training programs.

In the first article, Keesukphan A and her colleagues studied the effect of peripheral magnetic stimulation in patients with knee osteoarthritis. The authors looked specifically at the short-term effects of repetitive peripheral magnetic stimulation on pain reduction in knee osteoarthritis. Their findings indicated that adding this treatment intervention provided no significant additional therapeutic effect in a short-term improvement of pain in primary knee osteoarthritis patients compared with sham treatment. They suggested that future studies include multiple treatment sessions and investigate an appropriate treatment protocol.

In the second article, Vorawanthanachai T and her colleagues compared the effects of three soreness reduction methods after dry needling for a patient with upper trapezius trigger points. They suggested that diclofenac spray combined with contract-relax stretching might be the intervention of choice to reduce post-dry needling soreness at the upper trapezius muscle effectively.

In the third article, Eurcherdkul P and her colleagues examined the efficacy of high-intensity lasers combined with muscle training in patients with patellofemoral pain syndrome. They found that, adding these interventions did not yield better outcomes than muscle training alone.

In the fourth article, Poolpipat P and her colleagues carried out their cross-sectional study about thermoplastic ankle-foot orthoses in patients with foot drop to identify factors related to AFO use and develop a more efficient way to determine an appropriate AFO prescription. They found that sixty percent of their patients continued using an AFO after three months. The factors contributing to good compliance are; being unable to do ankle dorsiflexion, wearing clogs, and having practiced walking with a physical therapist.

In the fifth article is about the diagnosis study. Charussuriyong P and Suksathien R found that a shoulder ultrasound by a trained physiatrist showed high sensitivity and specificity for detecting supraspinatus tears diagnosed by MRI. They suggested that trained clinicians new to musculoskeletal ultrasound could use this method to evaluate supraspinatus tendon tears for initial diagnosis and management.

The sixth article, Suksathien R and her colleagues evaluated the reliability and acceptability of using the multiple mini-interview (MMI) for Physical and Rehabilitation Medicine in the residency admission selection process. They found that the MMI was highly accepted among both candidates and interviewers, especially in fairness and decreased bias, allowing efficient evaluation of the candidate's performance and strengths.

In the seventh article, Lewsirirat S and her colleagues evaluated the relationship between evertor muscle function and recurrence of deformity in pediatric idiopathic clubfoot after two years or more after treatment. They found that the severe deformity at presentation was a significant proportion of the recurrence.

The last article is a case report by Pattanasuwanna P. She presented her case about Riche-Cannieu anastomosis in patients with suspected carpal tunnel syndrome. She emphasized that this anastomosis should be excluded if no compound muscle action potential response is obtained from the abductor pollicis brevis with median stimulation without supportive evidence, such as motor weakness and muscle atrophy. Stimulation of the ulnar nerve with recording at the APB muscle can help avoid misdiagnosis.

We continue to invite and welcome works from our rehabilitation medicine field in South East ASEAN countries colleagues. We look forward to your submissions of individual papers and special-themed issues and forums. Thank you for joining us

Assoc. Prof. Kingkaew Pajareya
Editor-In-Chief
The ASEAN Journal of Rehabilitation Medicine

Original Article

Short-Term Efficacy of Peripheral Magnetic Stimulation in Reducing Pain in Knee Osteoarthritis: A Randomized Controlled Trial

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ABSTRACT

Objectives: To investigate the short-term efficacy of repetitive peripheral magnetic stimulation (rPMS) on pain reduction in knee osteoarthritis.

Study design: Randomized controlled trial.

Setting: Ramathibodi Hospital, Mahidol University, Bangkok, Thailand.

Subjects: Knee osteoarthritis patients with Kellgren-Lawrence classification (KL) 2-4 and Visual analog scale (VAS) > 4.

Methods: Participants were allocated into two groups. The rPMS group received 6,000 pulses of magnetic stimulation of the knee joint at a frequency of 20 Hertz for one session, and the sham group received a sham stimulation for one session. All the participants received conventional treatment. The result was measured by VAS and the Thai version of the modified Western Ontario and McMaster Universities Arthritis Index (WOMAC) score.

Results: The KL 2, 3, and 4 grades of the 30 participants, average age 62.83 years (SD 6.38), were 16, 11, and 3, respectively. The median (Q1, Q3) decrement of VAS between baseline and immediately after treatment and between baseline and one week after treatment of the rPMS group were 47 (38, 59) and 21 (9, 46). The median (Q1, Q3) decrement of VAS between baseline and immediately after treatment and between baseline and one week after treatment of the sham group were 41 (29, 50) and 17 (3, 30). The median (Q1, Q3) decrement of modified WOMAC between baseline and one week after treatment of rPMS and sham group were 25 (7, 53) and 2 (1, 15). The study found improvement of VAS and modified WOMAC in both groups, but the change in VAS was not statistically significant while modified WOMAC in the rPMS group showed statistically significant.

Conclusions: rPMS provides no significant additional therapeutic effect in a short-term improvement of pain in primary knee osteoarthritis patients compared with sham treatment.

Keywords: repetitive peripheral magnetic stimulation, knee osteoarthritis, pain

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Introduction

Knee osteoarthritis is one of the most common joint problems in Bangkok, Thailand. The prevalence of knee osteoarthritis is 0.34-0.45.[1] In due course, the causes of knee osteoarthritis are older age, greater weight, female sex, family history of osteoarthritis, strenuous work, and knee trauma. The main symptoms of knee osteoarthritis are pain and swelling in the knee, limited range of motion, and crepitation.[2] These symptoms affect activities of daily living and decrease quality of life.[3]

There are several treatments for knee osteoarthritis, such as non-medication, medication, and surgery. Non-medication treatments include lifestyle modification, exercise, and physical modalities.[2] Subsequently, pulsed electromagnetic field therapy is one of the physical modalities that can decrease pain in knee osteoarthritis[4] and able to slow the increase of osteoarthritis in animals.[5]

A recent study reported on the use of rPMS to reduce pain, a method which produces a more powerful magnetic field than traditional pulsed electromagnetic field therapies.[6] A magnetic field around a coil passes the magnetic field's pulses to the body. It also induces a voltage difference between two points which inducing an ion flow. Axonal depolarization and action potential can stimulate the brain and change the nervous system's connections.[6] However, there is no evidence regarding mechanism by which rPMS can decrease pain.[6,7] It has been hypothesized that the magnetic field stimulates A-beta afferent fibers and inhibits A-delta and C fibers which are pain conductor to the brain, thus decreasing pain. Another possible mechanism is that rPMS may simulate the descending inhibitory pathway.[8]

A review of the literature found that many studies mentioned rPMS and musculoskeletal pains,[8-16] however, no studies of rPMS and knee osteoarthritis were identified. The present study aimed to investigate the short-term effects of repetitive peripheral magnetic stimulation on pain reduction in knee osteoarthritis.

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Methods

Study design

This randomized control trial was approved by the Faculty of Medicine Ethics Committee, Ramathibodi Hospital, Mahidol University, on Aug 9, 2019 (approval number MURA2019/707). The ClinicalTrials.gov number is NCT05484752.

Participants

Study participants were knee osteoarthritis patients at the outpatient clinic, Department of Rehabilitation Medicine at Ramathibodi Hospital, Mahidol University, Bangkok, Thailand, from August 2019 through March 2020. The inclusion criteria were patients with primary knee osteoarthritis who had had knee pain for at least six months, were age 50 years or older, had morning stiffness lasting not more than 30 minutes, and had crepitation, KL classification 2-4, and a VAS pain score of 4 or higher. The exclusion criteria were patients with other musculoskeletal problems associated with the knee joint; a history of physical therapy in the past month; patients with a pacemaker, cochlear implant, or cerebral shunt; patients with a history of knee surgery; patients with a neurological or other severe disease and patients who had previously had a seizure.

The sample size was calculated using the standard deviation (SD) of the pain score of 1.657. The minimal clinically significant difference (MCSD) in VAS pain score was set at 2, the statistical significance level was set at $p < 0.05$, and the power was 80%. The sample size was calculated based on a loss follow-up of 20% and sample size was 15 participants per group.

Randomization

Participants were randomly assigned to either the rPMS or the sham group using a computer-generated block of 6 randomizations. All participants were blinded to whether they received real or sham rPMS.

Materials

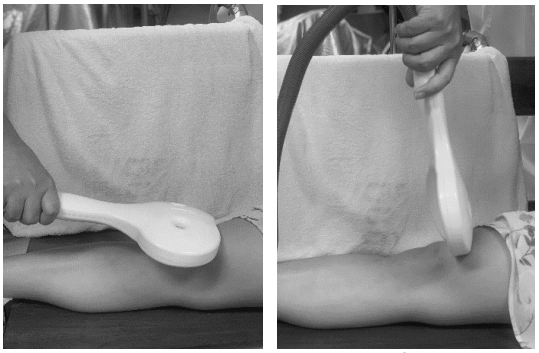
1. Neuro-MS magnetic stimulator form Neurosoft® Ivanovo, Russia
2. 100-mm horizontal Visual Analog Scales (VAS)[17]
3. The Thai version of modified Western Ontario and McMaster University Osteoarthritis Index (WOMAC)[18]
4. Lifestyle modification and self-exercise leaflet produced by the Thai Rheumatism Association Guideline for the Treatment of Osteoarthritis[19]

Intervention

After randomization, participants answered a questionnaire about baseline characteristics, VAS pain score at baseline, and completed the modified WOMAC questionnaire. In the rPMS group, the participants received peripheral magnetic stimulation at the medial and lateral knee joint of 6,000 pulses at a frequency 20 Hertz for one 20-minute session. The stimulation was delivered through a figure-of-eight coil using a Neurosoft® stimulator. The initial intensity was 20% of maximum output which was then increased by increments of 5% until the participants had non-pain sensation at the knee joint. On-time was 10 seconds, and the off-time was 30 seconds. The sham group received a sham magnetic stimulation at the knee joint for one session. The sham magnetic stimulation was performed using the same coil as rPMS, but at a position perpendicular to the knee joint at the medial and lateral sides, using an intensity of 5% of the maximum output. Although there was a sound of stimulation, the participants did not receive actual stimulation. All participants were educated on lifestyle modification and were taught to do strengthening exercises, including isometric quadriceps exercises, isometric knee exercises, and semi-squats. Each patient did each of the exercises with 10 repetitions per set, 2 sets per day. Figure 1 shows the application of rPMS in the rPMS and sham groups.

Outcome measurements

The primary outcome, level of pain, was as measured using VAS with a pain scale of 0-100 where a higher score indicates greater pain. VAS measurements were made at baseline, immediately after treatment, and one week after treatment. The secondary outcome was the modified WOMAC which contains 22 items and covering three dimensions: pain, stiffness, and function. A higher score means poorer health performance. The modified WOMAC was measured at baseline and one week after treatment. Outcomes were also assessed by the same blinded assessor prior to and after the intervention. The flow chart of the study is shown in Figure 2.



a b

Figure 1. Application of the rPMS; a. Intervention group, b. Sham group

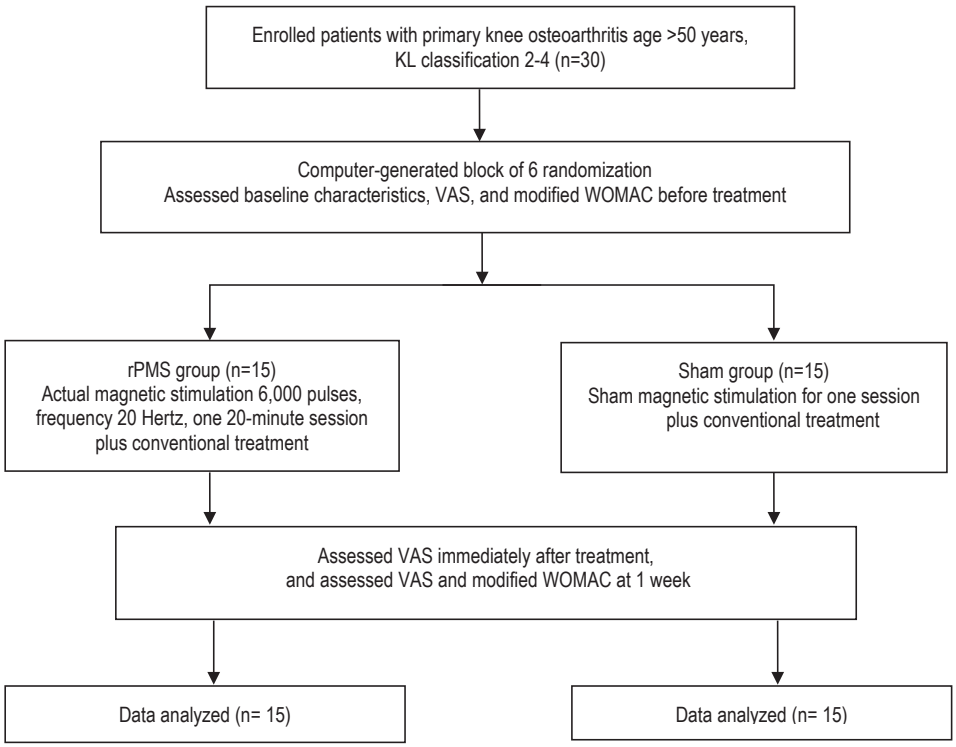


Figure 2. Flow chart of the study

Statistical methods

STATA version 16 was used for all statistical analyses. This study used descriptive statistics to analyze the baseline characteristics of the patients, including age, sex, BMI plus duration and severity of the disease. VAS and modified WOMAC scores were assessed using the Mann-Whitney U test. $P < 0.05$ were considered statistically significant.

Results

The mean (SD) age of the thirty participants was 62.83 (6.38) years, 81% were female, mean (SD) BMI was 26.24 (4.25) kg/cm^2, and the median (Q1, Q3) duration of knee pain was 3 (1,5) years. Most of the participants' severity was in KL 2 and 3. In the rPMS group, there were 8 participants in KL 3 (53.33%), more than the KL 3 in the sham group (20%). Baseline VAS and modified WOMAC were not statistically significantly different between the groups. Baseline demographics and clinical characteristics of patients are shown in Table 1.

The median (Q1, Q3) difference in VAS before and immediately after treatment had decreased in both groups. In the rPMS group, VAS decreased by 47 (38,59) points compared to 41 (29, 50) points in the sham group. The difference in VAS before and one week after treatment also decreased in

Table 1. Baseline demographics and clinical characteristics of patients with knee osteoarthritis

Characteristics	rPMS (n=15)	Sham (n=15)	*p*-value
Age[1], year	63.80 (5.93)	61.86 (6.86)	0.41
BMI[1], kg/m^2	26.57 (4.69)	25.90 (3.89)	0.65
Sex, No. (%)			1.00
Female	13 (86.67)	14 (93.33)	
Duration[2], month (Q1, Q3)	36 (12, 60)	24 (12, 60)	0.41
Severity (KL grading), No (%)			0.19
2	6 (40.00)	10 (66.67)	
3	8 (53.33)	3 (20.00)	
4	1 (6.67)	2 (13.33)	
VAS baseline[2]	60 (48,70)	60 (43,73)	0.88
Modified WOMAC baseline[2]	104 (39,126)	72 (45,102)	0.50
Pain (Q1, Q3)	26 (13, 31)	17 (13, 26)	0.29
Stiffness (Q1, Q3)	6 (0, 12)	7 (4, 13)	0.47
Function (Q1, Q3)	61 (33, 85)	50 (34, 68)	0.53

[1]Mean (SD), [2]Median (Q1, Q3)

rPMS, repetitive peripheral magnetic stimulation; KL, Kellgren-Lawrence classification; VAS, Visual analog scale

Table 2. Effects of repetitive peripheral magnetic stimulation on pain and function in patients with knee osteoarthritis

	rPMS (n=15)	Sham (n=15)	*p*-value
ΔVAS[1]			
- Baseline-immediate after treatment	47 (38,59)	41 (29,50)	0.21[a]
- Baseline-after treatment 1 week	21 (9,46)	17 (3,30)	0.41[a]
ΔModified WOMAC [total][1]	25 (7,53)	2 (1,15)	0.01[a]
ΔModified WOMAC [pain][1]	8 (3,18)	1 (0,3)	0.003[a]
ΔModified WOMAC [stiffness][1]	0 (0,4)	1 (0,2)	0.95[a]
ΔModified WOMAC [function][1]	12 (3,28)	4 (0,9)	0.04[a]

[1]Median (Q1, Q3), [a]Mann-Whitney U test

both groups: 21 (9, 46) points in the rPMS group and 17 (3, 30) in the sham group, although the difference was not statistically significant ($p = 0.21$ and $p = 0.41$, respectively). The effects of rPMS on pain and function in patients with knee osteoarthritis are shown in Table 2. Baseline and follow-up VAS in rPMS and sham groups are shown in Figure 2.

The median (Q1, Q3) decrement in the modified WOMAC scores between baseline and one week after treatment of rPMS and the sham group were 25 (7, 53) and 2 (1, 15), respectively, with a statistically significant difference in both groups ($p = 0.01$). The median (Q1, Q3) difference in modified WOMAC pain subscale at baseline and one week after treatment of rPMS and sham groups were 8 (3,18) and 1 (0, 3) respectively, with a statistical difference in both groups ($p = 0.003$). The median (Q1, Q3) difference in the modified WOMAC stiffness subscale between baseline and one week after treatment of rPMS and the sham group were 0 (0, 4) and 1 (0, 2), respectively, with no statistically significant differences ($p = 0.95$). The median (Q1, Q3) difference in the modified WOMAC function subscale between baseline and one week after treatment of rPMS and the sham group were 12 (3, 28) and 4 (0, 9), respectively, with a statistically significant difference in both groups ($p = 0.04$) as shown in Table 2. All participants reported no side effects or pain after the treatment.

Discussion

In previous studies, Smania[14,15] and Pujol[16] found that repetitive peripheral magnetic stimulation could produce muscle contraction-relaxation and decrease pain. Masse-Alarie[13] also found that 6,000 pulses of rPMS at a frequency of 20 Hz for 20 minutes combined with conservative back exercise could decrease pain scores (VAS) in patients with low back pain. The possible mechanisms might be rPMS, potentially influencing cerebral activation, neuroplasticity,[20] and activation of the descending inhibitory pathway. Consequently, rPMS may trigger massive proprioceptive afferents via two pathways when applied to muscles. The first pathway is the direct activation of sensorimotor nerve fibers and indirect activation of mechanoreceptors in muscle fiber.[20] Moreover, the contraction and relaxation of muscle produced by rPMS might also reduce pain as suggested by the spinal cord gate control theory.[6,7] Many studies[13-15] have reported that multiple sessions of rPMS can decrease pain in patients with chronic diseases such as low back pain or musculoskeletal pain. The current study, however, used only one session of rPMS to examine the short-term efficacy of rPMS in knee osteoarthritis patients. In contrast to other studies, this study found that the VAS score decreased immediately after treatment and at 1-week after treatment in both the rPMS and sham groups, with no statistically significant differences between the groups?

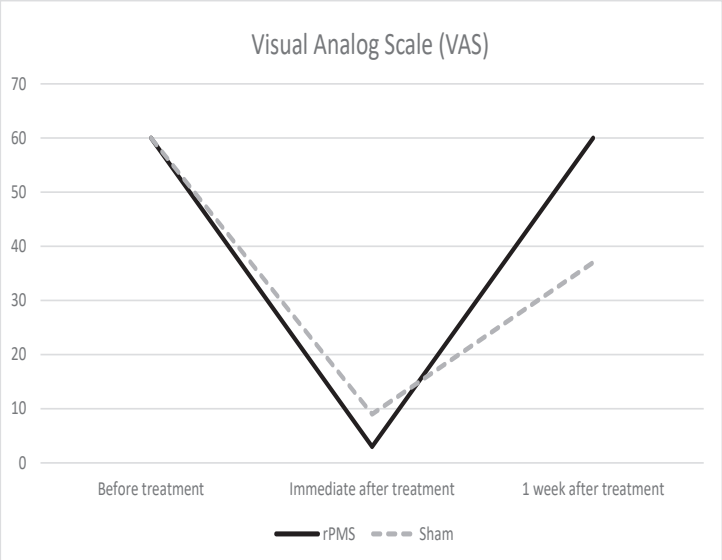


Figure 3. VAS before treatment, immediately after treatment, and 1-week after treatment

One difference between this study and previous studies is that the current study's population was knee osteoarthritis patients, while previous studies evaluated chronic musculoskeletal pain. The primary pathology of pain in knee osteoarthritis is a result of degenerative changes in the knee joint. There have been no definite conclusions regarding the mechanisms by which rPMS could reduce pain in abnormal structural joints. However, the statistically significant decrease in VAS of the rPMS group might result from rPMS producing contraction and relaxation of the muscles around the knee and a decrease in pain as described in the gate control theory.[6,7] Additionally, the patients also received conventional therapies, including strengthening exercises and lifestyle modification, which have shown level 1 evidence of the ability to decrease pain in knee osteoarthritis patients.[19] The VAS of the patients in both groups decreased one week after treatment.

A 2021 study by Lee[21] which used rPMS 20 minutes per day, five times a week for a total of 4 weeks in knee osteoarthritis patients showed a significant decrease in VAS and WOMAC in the rPMS group four weeks post-treatment. That study reported that rPMS might have cumulative effects which were not demonstrated in our study which aimed to study only the effect of single-dose rPMS.

Tubach (2005)[22] found that the change of VAS 19 points was a minimal clinically significant difference. In this study, the decrease in VAS score of rPMS and sham groups immediately occurred after treatment was clinically significant (47 and 41 points, respectively). However, the decrease of VAS one week after treatment was clinically significant only in the rPMS group (21 points). Then the efficacy of rPMS to decrease pain in knee osteoarthritis patients might last longer than the sham group.

This current study found that the decrease in the modified WOMAC before and one week after treatment in the rPMS group was statistically significant when compared to the sham group (25 points vs. 2 points, respectively). This difference was clinically significant. Bellamy (2015)[23] found that a change in modified WOMAC score of ≥ 7 points was the minimal clinically significant difference. A subanalysis in the present study found that the pain and function dimensions of the modified WOMAC in the rPMS group was statistically significantly decreased one week after treatment. When the pain score improved, the function score improved as well which may have also resulted in a reduction of the total modified WOMAC score. A similar result was found with the VAS: there was a clinical significantly decrease in the rPMS group one week after treatment.

The present study found that one session of rPMS can decrease pain in knee osteoarthritis patients for at least one week. Knee osteoarthritis is a chronic disease; however, if the results of treatment last longer, the patient may have a better quality of life.

A limitation of this study is that the results included only short-term effects from one session of rPMS. Future studies should include more than one rPMS session, should investigate an appropriate rPMS protocol including the optimum dose and should observe the long-term effect of rPMS.

Conclusions

Repetitive peripheral magnetic stimulation of 6,000 pulses at a frequency of 20 Hz for 20 minutes for one session provides no significant additional therapeutic effect in short-term improvement of pain in primary knee osteoarthritis patients compared with sham treatment.

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Original Article

Comparison of Post-Needling Soreness among Three Soreness Reduction Methods: Diclofenac Spray with Contract-Relax Stretching, Cold Gel Pack with Self Stretching, and Spray and Stretch Technique in Patients after Upper Trapezius Dry Needling

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ABSTRACT

Objectives: To compare post-needling soreness among three different soreness reduction methods: diclofenac spray with contract-relax stretching, cold gel pack with self-stretching, and spray and stretch technique in patients after upper trapezius dry needling.

Study design: A randomized controlled trial.

Setting: Department of Rehabilitation Medicine, Phetchabun Hospital, Phetchabun Province, Thailand.

Subjects: One hundred and twenty-six participants who had a numeric rating scale (NRS) score of post-needling soreness intensity of 3 or more and who received dry needling as a treatment of myofascial pain syndrome at the upper trapezius.

Methods: Participants were allocated into three groups (42 patients per group) which received different soreness reduction methods: a cold gel pack combined with self-stretching (CP group), a diclofenac spray combined with contract-relax stretching (DCF group), and a spray and stretch technique (SS group). The primary outcome was the post-needling soreness numeric rating scale score. Secondary outcomes were muscle pain NRS and pain-free cervical range of motion (ROM).

Results: No statistically significant difference ($p > 0.05$) among the dependent variables, including post-needling soreness, muscle pain, and pain-free forward neck flexion, was observed among the 3 groups with the exception of pain-free lateral neck flexion which was greater in the DCF and SS group. Pairwise analyses demonstrated that the DCF and SS groups both had significantly greater post-needling soreness reduction immediately after the treatment when compared with the CP group (DCF = -1.9, SS = -1.5, CP = -0.7) and also 24 hours after dry needling (DCF = -2.6, SS = -2.1, CP = -1.3).

Conclusions: DCF spraying with contract-relax stretching can reduce post-dry needling soreness at the upper trapezius muscle at a level comparable to the spray and stretch technique. Both methods were superior to cold gel packs with self-stretching. In addition to the spray and stretch techniques, DCF spraying with contract-relax stretching might be the intervention of choice to effectively reduce post-dry needling soreness at the upper trapezius muscle.

Keywords: post-needling soreness, cold gel pack, spray and stretch technique, diclofenac spray, upper trapezius

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Introduction

The upper trapezius is one of the muscles most commonly affected by myofascial pain syndrome (MPS).[1] MPS at the upper trapezius presents in 93.75% of chronic neck pain patients.[2] Patients mainly present with pain and fatigue at the trapezius region, in some cases also radiating to the neck, occiput, mandible, temporal region, and forehead.[3] Some also report headache, neck pain, dizziness, vertigo, and difficulty in neck and shoulder movement.[4] During physical examination, a trigger point at the upper trapezius muscle is palpated, which potentially reproduces radiating pain to the neck and temporal region.[3] Limitation of the use of the neck and shoulder which affects their job, socialization, and quality of life is usually observed.[5]

One of the most effective and widely used treatments for MPS at the upper trapezius is dry needling, in which a thin solid needle is inserted into a muscle trigger point[5,6] to decrease muscle tightness, increase blood flow and reduce pain. Patients often report immediate relief after dry needling treatment. It has been shown that dry needling has a level of efficacy in alleviating musculoskeletal pain similar to lidocaine injection[7] but without the risk of allergic reactions, muscle infarction,[3] skin depigmentation, tendon atrophy, and serious side effects such as fainting, palpitations, and apnea associated with lidocaine injection.[8] Thus, dry needling is a safer alternative treatment for myofascial pain syndrome.[9]

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Dry needling has, however, been associated with post-needling soreness.[10] Patients may feel continuous dull aching pain only at the dry needling site, which can be distinguished from the tight feeling of muscle pain from pre-existing MPS.[7] In a study by Hong et al., patients who were treated with dry needling reported post-needling soreness which was significantly more severe and had a longer duration than that reported by patients who were treated with lidocaine injection.[7] The duration of the soreness varies from a few hours to 2-3 days.[11] A consequence of this unpleasant adverse effect is that it can make patients feel discomfort and fear, resulting in their eventually refusing to undergo dry needling at subsequent visits or fail to appear for follow-up.[10] Literature reviews have suggested that post-needling soreness is related to hemorrhage caused by tissue damage at the needled site.[1,7] It also stimulates the inflammatory processes, resulting in increased swelling and soreness.[12] Thus it is often necessary to apply an additional technique simultaneously with dry needling to reduce post-needling soreness.

Several techniques are currently used to reduce post-dry needling soreness. Applying cold packs is the oldest and simplest therapy for treating acute soft tissue injuries.[13] It is safe and has a low cost. Physiological effects of cryotherapy include vasoconstricting, decreasing local metabolism and blood flow, reducing nerve excitability, increasing the pain threshold, and reducing muscle contraction, resulting in a reduction in swelling, pain, and inflammation of acutely injured tissues.[14] Although one previous study reported that cryotherapy alone has no significant effect on reducing post-dry needling soreness,[15] applying a cold gel pack for 10 minutes after dry needling is still a conventional method for reducing post-needling soreness. In Phetchabun Hospital, the cold gel pack is followed by five sets of self-stretching for 10 seconds for reducing pain and increasing range of motion.[16] The spray and stretch technique is another safe intervention and has demonstrated a short-term (< 6 hours) effect of post-needling soreness reduction at the latent myofascial trigger points.[11] Vapocoolant spray, abruptly decreases skin temperature and induces transient anesthesia by blocking the spinal stretch reflex and pain sensation. This anesthetic effect allows the physician to passively stretch the affected muscles toward their normal length. Passively stretching the affected muscles also helps to decrease myofascial trigger point sensitivity and the intensity of referred pain.[17]

At present, diclofenac (DCF) spray is increasingly used to treat pain and other symptoms such as inflammation, swelling, and stiffness. Previous evidence has demonstrated that DCF spray can reduce pain and inflammation in the acute phase of injury.[18] Since the mechanism of post-needling soreness is related to tissue inflammation, it is reasonable to hypothesize that DCF spray could be used to reduce post-needling soreness. Using it is considered to be safe if the patient has no history of allergy to DCF. If it is available, it can be used in place of vapocoolant spray which is not available in Phetchabun Hospital. However, there have been no studies demonstrating the efficacy of DCF spray in reducing post-needling soreness. A previous study demonstrated that concentric and eccentric exercises immediately improve post-needling soreness and raise the pain pressure threshold,[19] suggesting the interesting option of combining contract-relax stretching with DCF spray to further increase the efficacy of reduction of post-needling soreness. In our pilot study, DCF spray was applied once in the target region, followed by sets of contract-relax stretching of 10 seconds each, with the protocol repeated five times. Following this treatment, patients reported feeling more comfortable and less sore after dry needling. The present study was conducted to determine whether a combination of DCF spray with contract-relax stretching (the DCF group) has a better effect on post-needling soreness than either the spray and stretch technique (the SS group) or cold gel pack combined with self-stretching (the CP group) in patients who had undergone upper trapezius dry needling.

Methods

This randomized controlled trial was approved by the Institutional Ethic Committee of Phetchabun Hospital (Approval number 06/2565). Patients diagnosed with acute, subacute, or chronic cases of MPS at an upper trapezius muscle based on the Travel and Simon's clinical criteria[3] who visited the Rehabilitation Outpatient Clinic at Phetchabun Hospital between January and September 2022 and were treated by dry needling were invited to join the study.

The sample size was estimated using G*power software version 5.1. Repeated measures and within-between interaction analysis of variance (ANOVA) were used and an effect size of 0.25, power of 0.9, and α value of 0.05 were selected. The estimated necessary sample size was 39 participants plus an estimated 20% loss in follow-up, yielding 42 participants per group, a total of 126 subjects. Simple randomization was used to allocate the participants into one of three groups: 1) the CP group received the cold gel pack combined with self-stretching, 2) the DCF group received the DCF spray combined with contract-relax stretching and 3) the SS group received the spray and stretch technique.

After giving their informed consent, patients were recruited into the study. The inclusion criteria consisted of age between 18-65 years and a soreness intensity score on a numeric rating scale (NRS) of at least 3. Patients with any of the following were excluded from the study: coagulopathy, thrombocytopenia, receiving antiplatelet/anticoagulant, a history of trigger point dry needling/injection in the upper trapezius during the previous seven days, fibromyalgia, cervical disc herniation, cervical stenosis, cervical radiculopathy or radicular pain, cervical myelopathy, a history of neck surgery or trauma during the previous six months, numbness at the upper trapezius region, poor perception or communication, having contraindications for cryotherapy[20,21] or DCF spray.[22] The schematic flow diagram of the study is shown in Figure 1.

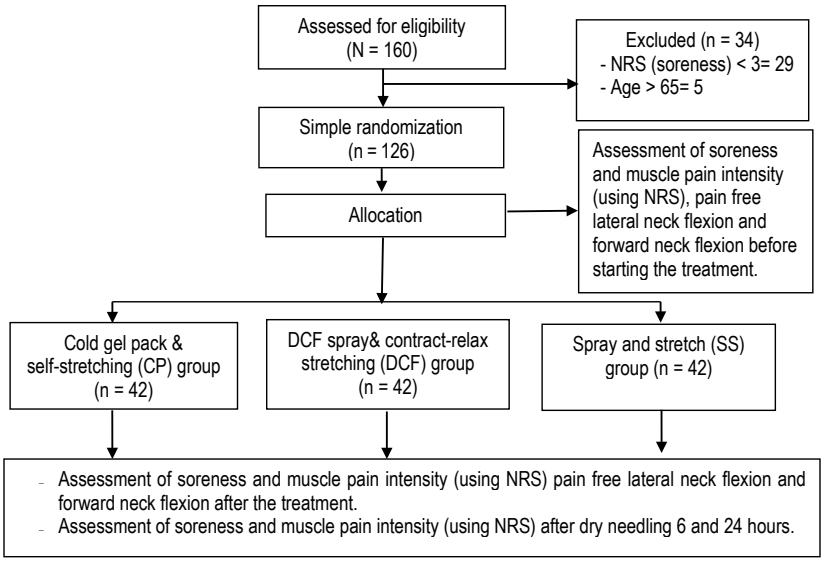


Figure 1. Schematic flow diagram of the study

Procedure

A blinded assessor, a well-trained nurse, interviewed participants regarding their demographic data, including gender, age, BMI, and affected side. The participants were then asked to record their level of post-needling soreness and muscle pain intensity using a numeric rating scale (NRS) where 0 means no pain and 10 means the most severe pain. Next, the participants related the characteristics of the soreness before needling describing it as constant pressure or dull aching as distinguished from a sharp and tight aching experience.[7] The blinded assessor then measured the pain-free active lateral neck flexion and forward neck flexion angles.

Dry needling (fanning technique) using an acupuncture needle at the upper trapezius was performed in all patients by a physiatrist with 11 years of experience. The needle size was selected depending on the trigger point depth and toughness. The number of needles used with each patient depended on the number of palpated active trigger points and patient tolerance. The number of needle insertions in each needling depended on patient responses during needling (e.g., no response, dull sensation, sharp sensation, radiating pain, muscle twitching), level of patient tolerance, and the physiatrist's judgment. Typically, the physiatrist continued needling until muscle responses were observed or until the patient's level of tolerance was reached even if there were no muscle responses, after which needling was stopped. The needling procedure was normally ended within 10 minutes in each case. After the completion of the dry needling, patients who reported a soreness intensity of over 3 were randomly allocated into one of 3 groups by the researcher. Only the researcher had access to the allocation schedule. Due to the nature of the subsequent interventions, patients and treatment providers were not blinded to the treatment allocation.

Subjects in the CP group received a cold gel pack covered with a damp towel[23] for 10 minutes.[24] After that, the patients were advised to perform self-static stretching of the upper trapezius muscle by sitting in the upright position, pulling the chin in and depressing the affected shoulder, then rotating the neck to the opposite side and flexing the neck using the opposite hand to stretch the neck to the point of first feeling tightness[25] and holding in this position for 10 seconds. This protocol was repeated for five times.

Subjects in the DCF group received a spray of 1% diclofenac sodium at the upper trapezius region which was alternated with contract-relax stretching performed by a physiatrist. Patients were sitting in an upright position as in the CP group. The physiatrist instructed the patients to turn their head to one side and bend downwards to stretch the upper trapezius muscle for 10 seconds, then to repeat the exercise turning their head to the opposite side. The physiatrist then asked the patients to contract the upper trapezius muscle exerting approximately 60% resistance and to hold that position for 10 seconds.[26] This protocol was repeated five times.

Subjects in the SS group received vapocoolant spray (Perskindol® cool spray) applied by a physiatrist. Patients were sitting in an upright position as in the CP group. The physiatrist swept the spray parallel to the upper trapezius muscle at a 30º angle from a distance of about 12 inches, moving from shoulder to neck three times. This was alternated with static stretching of the upper trapezius to the end of the range of motion by the physiatrist for 10 seconds.[27] This protocol was repeated five times.

Outcome measures

The primary outcome was subjective soreness intensity measured on a numeric rating scale (NRS) where 0 means no pain and 10 means the most severe pain. The assessor asked the participants to rate the soreness intensity within 2 minutes after the treatment and to use a pain diary to record the intensity at 6 and 24 hours after the dry needling.

The secondary outcomes were subjective muscle pain intensity and pain-free cervical range of motion with lateral

neck flexion and forward neck flexion. Similar to the soreness intensity scoring system, the muscle pain intensity was determined using NRS immediately after the treatments. A pain diary was used to record the muscle pain intensity at 6 and 24 hours after the dry needling. Pain-free lateral neck flexion and forward neck flexion were measured using a standard goniometer immediately after the treatment.

Statistical analysis

SPSS statistical software system version 16.0 (SPSS Inc. Released 2007. SPSS for Windows, Version 16.0, SPSS Inc., Chicago, IL, USA,) was used for all statistical analyses. A 95% confidence interval was employed, and values with a *p*-value < 0.05 were considered statistically significant. The demographic data of the participants in all three groups were analyzed. Baseline quantitative data were described using means and standard deviations and were compared across the groups using one-way ANOVA. Baseline categorical variables were described using frequencies and percentages and compared across the groups using the Chi-square test. Two-way repeated-measures ANOVA was performed to demonstrate the effect of an intervention interacting with a within-subject factor (time of an assessment). The partial eta squared was used as a measure of effect size (d) for each main effect and interaction in the ANOVAs, and post hoc analysis with Bonferroni correction was used in the case of statistically significant ANOVA findings for multiple comparisons between variables.

Results

Subjects' demographic and clinical data

A total of 160 patients were initially screened, of whom 126 were enrolled. The 126 participants were allocated into three groups (Figure 1). All participants were analyzed according to the group they were initially assigned, complying with an intention to treat analysis. Most participants were female (79.4%) with a mean age of 48 years, a mean body mass index (BMI) of 24 kg/m^2, an initial soreness intensity of 4.5, an initial muscle pain intensity of 3.9, and an initial lateral neck flexion of 32 degrees and initial forward neck flexion of 41 degrees. The most frequently affected side was the right (57.1%). Baseline demographic and clinical characteristics as of the beginning of the study are summarized in Table 1. There were statistically significant differences in age (p = 0.039), BMI (p = 0.016), and gender (p = 0.045) among the groups but no statistically significant difference in the outcome parameters across the groups (p > 0.05).

Primary outcomes

Post-needling soreness intensity

Using two-way repeated-measures ANOVA, there was statistically significant group-time interaction for post-needling soreness intensity (F = 2.80, p = 0.020, d = 0.044), indicating a difference in the trend of changes in post-needling soreness over times among the CP, DCF, and SS groups (Table 2). All three interventions statistically significantly reduced post-

Table 1. Comparison of demographic and clinical data of participants between the three groups (n=126)

Demographic and clinical data	Intervention group			*p*-value between groups
	CP (n=42)	DCF (n=42)	SS (n=42)	
Age (years)[1]	50.2 (11.9)	44.4 (11.3)	49.9 (11.8)	0.039[a]
BMI (kg/m^2)[1]	24.2 (3.2)	22.9 (3.3)	24.8 (3.0)	0.016[a]
Gender (male)[2]	6 (14.3)	14 (33.3)	6 (14.3)	0.045[b]
Affected side (right)[2]	24 (57.1)	25 (59.5)	23 (54.8)	0.907[b]
Muscle pain intensity after dry needling(score)[1]	3.9 (1.4)	3.8 (1.8)	4.0 (1.8)	0.927[a]
Post-needling soreness intensity (score)[1]	4.2 (1.5)	4.7 (1.6)	4.7 (2.0)	0.377[a]
Lateral neck flexion after dry needling (degrees)[1]	33.1 (6.5)	32.1 (7.1)	31.6 (6.2)	0.575[a]
Forward neck flexion after dry needling (degrees)[1]	42.9 (4.9)	40.4 (7.9)	41.2 (9.9)	0.346[a]

[1]Mean (SD), [2]number (%); [a]One-way ANOVA, [b]Chi-square

BMI, body mass index; CP, cold gel pack & self-stretching; DCF, diclofenac spray & contract-relax stretching; SS, spray & stretching

Table 2. Primary and secondary outcomes analysis between the three groups with two way repeated-measures ANOVA

Outcomes	Time			Between group			Time x group		
	F (3, 369)	p-value	d	F (2, 123)	p-value	d	F (6, 369)	p-value	d
Primary outcome									
Soreness intensity score	75.94	< 0.001	0.382	0.63	0.532	0.010	2.80	0.020*	0.044
Secondary outcomes									
Muscle pain intensity score	54.12	< 0.001	0.306	0.55	0.577	0.009	1.02	0.403	0.016
Pain-free lateral neck flexion (degrees)	122.49	< 0.001	0.499	0.72	0.491	0.011	18.56	< 0.001	0.232
Pain-free forward neck flexion (degrees)	57.40	< 0.001	0.318	0.24	0.786	0.004	10.23	< 0.001	0.143

CP, cold gel pack & self-stretching; DCF, diclofenac spray & contract-relax stretching; SS, spray & stretch

Between-group analysis used Two-way ANOVA, *statistically significant p < 0.05

needling soreness over time: CP (F = 16.74, $p < 0.001$, d = 0.29), DCF (F = 31.68, $p < 0.001$, d = 0.44), and SS (F = 28.45, $p < 0.001$, d = 0.41). Pairwise analyses demonstrated that the DCF and the SS groups had statistically significantly more post-needling soreness reduction when compared with the CP group immediately after treatment (DCF = -1.9, SS = -1.5, CP = -0.7) as well as at 24 hours after dry needling (DCF = -2.6, SS = -2.1, CP = -1.3).

Regarding effect size, i.e., the post-needling soreness reduction between groups, the DCF group showed the highest magnitude of soreness reduction (d = 0.44), followed by the SS group (d = 0.41) and the CP group (d = 0.29). The highest magnitude of soreness reduction was observed 24 hours after dry needling in all 3 groups. However, there were no statistically significant between-group differences at any of the time points ($p > 0.05$). Data on post-needling soreness is presented in Table 3 and Figure 2 (A).

Secondary outcomes

Muscle pain intensity and reduction of muscle pain intensity

Using two-way repeated-measures ANOVA, there was no statistically significant group-time interaction for muscle pain intensity, indicating that there was no difference in the trend of changes in muscle pain intensity over time among the CP, DCF, and SS groups (Table 2). When the muscle pain intensity among the three groups was compared, there was no statistically significant between-group differences at any of the time points ($p > 0.05$). However, all 3 groups had a statistically significant reduction in post-needling muscle pain intensity over time, including CP (F = 18.28, $p < 0.001$, d = 0.38), DCF (F = 20.36, $p < 0.001$, d=0.33), and SS (F=17.63, $p < 0.001$, d = 0.31). Additionally, the magnitude of within-group post-needling muscle pain intensity reduction was not different among the three groups (d < 0.38) (Table 4 and Figure 2 (B).

Table 3. Comparison of differences in soreness intensity within groups and between-groups

Outcomes	Intervention group mean (SD)			Within group differences (95% CI)			Between group differences (95% CI)	*p*-value between groups
	CP	DCF	SS	CP	DCF	SS		
Soreness intensity score								
Immediately after dry needling	4.2 (1.5)	4.7 (1.6)	4.7 (2.0)	-	-	-	-0.5 (-1.4, 0.5) p=0.240[1] -0.5 (-1.4, 0.4) *p*=0.216[2] -0.0 (-0.9, 0.9) *p*=0.949[3]	F (2, 123) =0.983 *p*=0.377 d=0.016
Immediately after the programs	3.5 (1.7)	2.8 (1.9)	3.2 (2.0)	-0.7 (-1.1, -0.2) *p*<0.001[a]	-1.9 (-2.4, -1.5) *p*<0.001[a]	-1.5 (-1.8, -1.2) *p*<0.001[a]	0.7 (-0.3, 1.7) *p*=0.072[1] 0.3 (-0.6, 1.3) *p*=0.397[2] -0.4 (-1.4, 0.6) *p*=0.335 3	F (0.12, 123) =1.653 *p*=0.196 d=0.026
6 hours after dry needling	4.0 (1.3) 2.9 (1.6)	3.8 (1.9) 2.1 (1.9)	4.3 (1.9) 2.6 (2.0)	-0.2 (-0.4, 0.3) *p*=0.330[b]	-0.9 (-1.3, -0.3) *p*<0.001[b]	-0.4 (-1.0, 0.1) *p*=0.096[b]	0.2 (-0.8, 1.1) *p*=0.709[1] 0.3 (-1.2, 0.6) *p*=0.456[2] -0.5 (-1.4, 0.5) *p*=0.264[3]	F (2, 123) =0.653 *p*=0.522 d=0.011
24 hours after dry needling				-1.3 (-1.9, -0.8) *p*<0.001c	-2.6 (-3.1, -2.0) *p*<0.001[c]	-2.1 (-2.7, -1.6) *p*<0.001[c]	0.9 (-0.2, 1.7) *p*=0.060[1] 0.93 (-0.7, 1.3) *p*=0.478[2] -0.5 (-1.5, 0.5) *p*=0.238[3]	F (2, 123) =1.835 *p*=0.164 d=0.09
		p-value within group		F=16.74, *p*<0.001, d=0.29	F=31.68, *p*<0.001, d=0.44	F=28.45, *p*<0.001, d=0.41		

[a]Immediately after the programs - immediately after dry needling, [b]6 hours after dry needling - immediately after dry needling, [c]After dry needling 24 hours - immediately after dry needling

[1]CP-DCF, [2]CP-SS, [3]DCF-SS

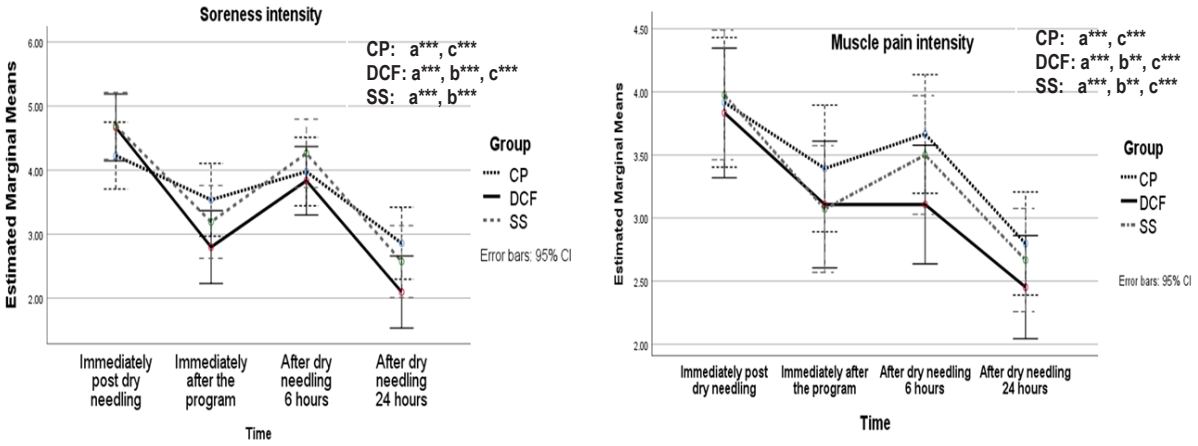


Figure 2. Post-needling soreness (A) and muscle pain intensity (B) in three groups, CP, DCF, and SS, in different times periods; immediately after dry needling; immediately after the programs, after dry needling 6 and 24 hours
a, Immediately after the programs – Immediately after dry needling; b, After dry needling 6 hours – Immediately after dry needling; c, After dry needling 24 hours – Immediately after dry needling, **significance level $p < 0.01$, *** $p < 0.001$

Table 4. Comparison of within group and between-group differences in muscle pain intensity

Outcomes	Intervention group Mean (SD)			Within group differences (95% CI)			Between group differences (95% CI)	*p*-value between groups
	CP	DCF	SS	CP	DCF	SS		
Muscle pain intensity score[1]								
Immediately after dry needling	3.9 (1.4)	3.8 (1.8)	4.0 (1.8)	-	-	-	0.1(-0.8, 1.0) p=0.821 1 -0.1(-1.0, 0.8) p=0.871 2 -0.2(-1.0, 0.8) p=0.698 3	F (2, 123) =0.076 p=0.927 d=0.001
Immediately after the programs	3.4 (1.4)	3.1 (1.7)	3.1 (1.8)	-0.5 (-0.8, -0.2) *p*<0.001[a]	-0.7 (-1.0, -0.4) *p*<0.001[a]	-0.9 (-1.4, -0.4) *p*<0.001[a]	0.3(-0.6, 1.2) *p*=0.427 1 0.3(-0.6, 1.2) *p*=0.372 2 0.0 (-0.9, 0.5) *p*=0.921 3	F (2, 123) =0.482 *p*=0.618 d=0.008
6 hours after dry needling	3.7 (1.5)	3.1 (1.4)	3.5 (1.7)	-0.2 (-0.7, 0.2) *p*=0.843[b]	-0.7 (-1.3, -1.9) *p*=0.003**[b]	-0.5 (-0.9, -0.1) *p*=0.005**[b]	0.6(-0.3, 1.4) *p*=0 .098 1 0.2(-0.7, 0.9) *p*=0.621 2 -0.4 (-1.3, 0.4) *p*=0.245 3	F (2, 123) =1.462 *p*=0.236 d=0.023
24 hours after dry needling	2.8 (1.2)	2.5 (1.3)	2.7 (1.5)	-1.1 (-1.6, 0.6) *p*<0.001[c]	-1.3 (-1.9, -0.8) *p*<0.001 c	-1.3 (-1.8, -0.8) *p*<0.001[c]	0.3(-0.4, 1.1) *p*=0.239 1 0.1(-0.6, 0.8) *p*=0.655 2 -0.2(-0.9, 0.5) *p*=0.464 3	F (2, 123) =0.712 *p*=0.492 d=0.011
	p-value within group			F=18.28, *p*<0.001, d=0.38	F=20.36, *p*<0.001, d=0.33	F=17.63, *p*<0.001, d=0.31		

[a]Immediately after the programs - immediately after dry needling, [b]After dry needling 6 hours - immediately after dry needling, [c]After dry needling 24 hours - immediately after dry needling
[1]CP-DCF, [2]CP-SS, [3]DCF-SS **significance level $p < 0.01$

In the between-group comparisons using one-way ANOVA, there were no statistically significant differences in muscle pain intensity between groups ($p > 0.05$) at the beginning of the study, immediately after the treatments, or after 6 and 24 hours of dry needling. Regarding the reduction of muscle pain intensity, there were no statistically significant differences

Table 5. Comparison of cervical range of motion within groups and between-groups

Outcomes	Intervention group Mean (SD)			Within group differences (95% CI)			Between group differences (95% CI)	p-value between groups
	CP	DCF	SS	CP	DCF	SS		
Pain-free lateral neck flexion (degrees)								
Immediately after dry needling	33.1 (6.5)	32.1 (7.1)	31.6 (6.2)	-	-	-	1.0(-2.5, 4.5) p=0.510[1] 1.5(-1.9, 4.5) p=0.300[2] 0.5(-2.9, 4.0) p=0.704[3]	F (2, 123) = 0.555 p=0.575 d=0.009
Immediately after the programs	34.0 (6.6)	38.1 (5.5)	37.3 (5.9)	0.9 (0.4, 1.4) p<0.001	6.0 (4.1, 7.7) p<0.001	5.7 (4.4, 6.9) p<0.001	-4.1(-7.2, -0.9) p=0.002**[1] -3.3(-6.4, -0.1) p=0.015*[2] 0.8(-2.4, 3.9) p=0.538[3]	F (2, 123) =5.340 p=0.006** d=0.080
	p-value within groups			F=13.65, p<0.001, d=0.25	F=44.54, p<0.001, d=0.52	F=74.99, p<0.001 d=0.65		
Pain-free forward neck flexion (degrees)								
Immediately after dry needling	42.9 (4.9)	40.4 (7.9)	41.2 (9.9)	-	-	-	2.5(-1.7, 6.6) p=0.156[1] 1.7 (-2.5, 5.9) p=0.327[2] 0.8 (-4.9, 3.4) p=0.658[3]	F (2, 123) =1.069 p=0.346 d=0.017
Immediately after the programs	43.2 (5.0)	43.4 (7.2)	43.6 (8.4)	0.3 (-0.7, -0.0) p=0.042	3.0 (1.0, 4.1) p<0.001	2.4 (1.4, 3.6) p<0.001	-0.2(-3.9, 3.5) p=0.877[1] -0.4 (-4.2, 3.3) p=0.768[2] -0.2(-3.9, 3.5) p=0.889[3]	F (2, 123) =0.044 p=0.957 d=0.001
	p-value within groups			F=4.42, p=0.042*, d=0.10	F=35.23, p<0.001, d=0.46	F=19.90, p<0.001, d=0.37		

[1]CP-DCF, [2]CP-SS, [3]DCF-SS *statistical significance level p < 0.05, **p < 0.01

between groups (p > 0.05) throughout the study period. Muscle pain intensity and the reduction of muscle pain intensity are presented in Table 4.

Pain-free cervical range of motion

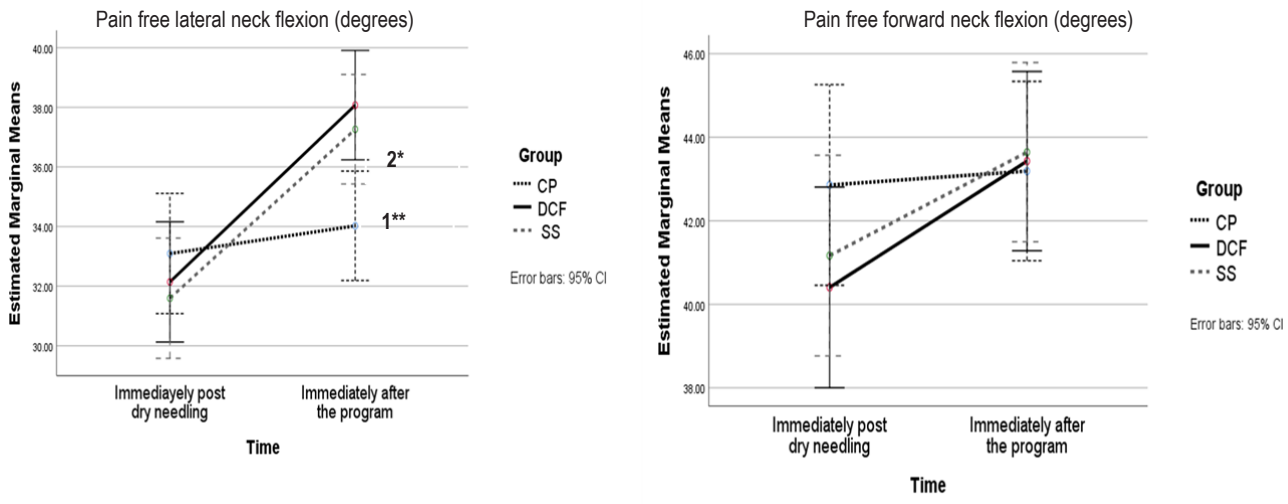
Using two-way repeated-measures ANOVA, there were statistically significant differences in group-time interaction for pain-free lateral neck flexion (F = 18.56, p < 0.001, d = 0.232) and pain-free forward neck flexion (F = 10.23, p < 0.001, d = 0.143), indicating that there was a difference in the trend of the change in pain-free cervical range of motion over time among the CP, DCF, and SS groups (Table 2). In addition, pairwise analyses demonstrated that the DCF and SS groups had a significantly greater increase in pain-free lateral neck flexion cervical range of motion both in increased pain-free lateral neck flexion (DCF = 6.0, SS = 5.7, CP = 0.9) and forward neck flexion (DCF = 3.0, SS = 2.4, CP = 0.3) immediately after the treatment programs.

Regarding the comparative findings for cervical range of motion (ROM) outcomes among three groups, there were statistically significant differences between groups immediately after the treatment programs (F = 5.340 p = 0.006, d = 0.080), but not in pain-free forward neck flexion (p > 0.05). The DCF and SS group had statistically significantly greater increased pain-free lateral neck flexion than the CP group (CP-DCF = -4.1 (95% CI -7.2, -0.9), p = 0.002) (CP-SS = -3.3(95% CI -6.4, -0.1), p = 0.015) but there was no statistically significant difference between the DCF and SS groups (p > 0.05). A large within-group effect size (d > 0.5) was observed in the DCF and SS groups. Data on pain-free cervical range of motion is presented in Table 5 and Figure 3.

Discussion

Baseline characteristics

Although there were statistically significant differences in age, BMI, and gender among the groups, previous evidence



(A) (B)

Figure 3. Pain-free lateral neck flexion (A) and pain-free forward neck flexion (B) in three groups, CP,

DCF and SS in different times periods: immediately after dry needling, immediately after the programs, 6 and 24 hours after dry needling, [1]CP-DCF, [2]CP-SS, *statistically significant $p < 0.05$, **$p < 0.01$

has demonstrated that age, gender, and BMI do not affect post-needling soreness.[28] Therefore, the differences in baseline characteristics were not considered a confounding factor in comparing the baseline post-needling soreness among groups and the data could be analyzed without adjusting for the differences in baseline characteristics.

Post-needling soreness intensity

There was no statistically significant difference in post-needling soreness intensity among the three groups. However, there were statistically significant differences in the reduction of post-needling soreness intensity among the groups. The results show that the DCF and SS groups had significantly greater post-needling soreness reduction over time, particularly at 24 hours post-intervention, compared to the CP group. These differences might be the result of differences in the effect of the different pathophysiologic mechanisms of each of the three intervention techniques.

The mechanism of DCF which has been shown to decrease pain and inflammation after tissue injury,[29] potentially could also reduce post-needling soreness. Another recent study found that applying proprioceptive neuromuscular facilitation (PNF) stretching can effectively reduce pain in patients with chronic low back pain.[30] When combined with contract-relax stretching, one of the PNF techniques with DCF spray produces greater post-needling soreness reduction. The mechanism of pain reduction of contract-relax stretching was presented via gate control theory, in which Golgi tendon organs (GTOs) are activated to reduce injury. PNF stretching decreases nociception or pain by producing an inhibition caused by an activation of the GTOs.[31]

In the SS group, vapocoolant spray provided transient anesthesia by inducing skin cooling from evaporation, thus suppressing pain receptor sensitivity and decreasing pain perception. Cold sensations transmitted via A-delta cold-specific nerve fibers also induce central gating of pain sensation transmitted via C fibers,[32] effectively reducing post-needling soreness. Additionally, stretching exercises can reduce pain by generating a biomechanical and sensory signal, resulting in an analgesic effect explained by the gate control theory.[33] A previous study has shown that the combination of acupuncture and stretching improves cervical movement and reduces trigger point pain in the short-term,[34] and a recent study reported that a single application of the spray and stretch technique had an immediate effect on reducing post-needling soreness after deep dry needling in a latent myofascial trigger points (MTrP) in an upper trapezius muscle.[11]

In the CP group, a cold gel pack increased the pain threshold and decreased the pain sensation by reducing nerve conduction velocity.[15] Stretching exercises have also been shown to reduce pain sensation via biomechanical and neurophysiological mechanisms.[33] Previous evidence has demonstrated that self-stretching can increase the pain pressure threshold immediately after exercise.[35] Therefore, a combination of a cold gel pack and self-stretching could be expected to produce greater soreness reduction, contrary to the results of a previous study which reported that a cold gel pack alone had no significant effect on reducing post-dry needling soreness.[15]

Compared to the SS group, vapocoolant spray caused a greater reduction in skin temperature than ice massage.[36] That is, the cold gel pack in the CP group had less effect on pain reduction than the vapocoolant spray in the SS group. Compared to the DCF group, DCF spray has a rapid onset of absorption, leading to a measurable plasma level of 1 ng/ml in as little as 30 minutes.[37] In contrast, cold gel packs have very short-term and only small continuous effects after removal.[32] Regarding the stretching technique, contract-relax stretching used in the DCF group was more effective in decreasing pain in upper trapezius myofascial trigger points than the self-static stretching technique[16] used in the CP group. That is, post-needling soreness in the DCF group was reduce better than in the CP group.

A literature review found the spray and stretch technique has a short-term (< 6 hours) effect on reducing post-needling soreness.[11] DCF spray was recommended to be used at 4 hour intervals but not more than 4 times a day.[38] A cold gel pack was recommended to be applied for 10 minutes once an hour for the first 72 hours after injury.[39] The upshot is that 6 hours after the dry needling timepoint, there was no significant difference in soreness intensity among the three groups.

Muscle pain intensity

This study showed that muscle pain intensity was not different between the three groups which may be due to the same factors as post-needling soreness and the fact that all groups had a statistically significant reduction in muscle pain intensity. In the DCF group, DCF spray was effective in musculoskeletal pain, and contract-relax stretching was also effective for pain reduction in MPS,[16] indicating that this method can be used in treating MPS in addition to the spray and stretch technique[15] to effectively increase the pain threshold and decrease pain intensity associated with an upper trapezius trigger point among patients.[40] This effect is similar to cold therapy in that it delays nerve conduction and raises the pain threshold. This modality enables muscles to decrease their contractility and to reduce tension in the trigger point.[15] Stretching exercises are also essential to any pain management regime.[15] These three soreness reduction methods can be used as an additional method following dry needling for treating myofascial pain trigger points.

Pain-free cervical range of motion

This study showed that the DCF group and the SS group both had greater improvement in pain-free lateral neck flexion than the CP group immediately after treatment.

A previous study demonstrated that DCF sprays effectively improve ROM after tissue injury.[29] PNF stretching has been shown to improve hip range of motion in patients with chronic low back pain.[30] Another study suggested that a combination of four theoretical mechanisms of PNF, including autogenic inhibition, reciprocal inhibition, stress relaxation, and the gate control theory, are responsible for improving the range of motion.[31] Combining these two methods produces more increase in pain-free cervical ROM.

As in the SS group, the spray and stretch technique abruptly decreases skin temperature at the target area, resulting in temporary anesthesia by blocking the spinal stretch reflex and pain sensation. The physician can then passively stretch the contracted muscles toward their normal length,[16] increasing cervical ROM. Similarly, another study showed an increase in cervical lateral flexion range after spray and stretch treatment on upper trapezius myofascial trigger points.[41]

In the CP group, it had minimal effect on increasing pain-free cervical ROM although cold gel packs can increase the pain threshold.[15] Self-stretching might also effectively increase cervical ROM.[36] However, since patients performed static stretching themselves, the effectiveness of each individual might need to be further investigated.

In comparing the DCF group and the CP group, although there was no statistically significant reduction of post-needling soreness intensity, contract-relax stretching was more effective in decreasing pain than the self-static stretching technique.[16] Contract-relax stretching in the DCF group might have produced more effective stretching, leading to a more significant increase in cervical ROM. Similarly, when comparing the SS group to the CP group, the vapocoolant spray in the SS group caused a more significant reduction in skin temperature than ice massage.[36] Moreover, stretching by a physiatrist in the SS group might have been more effective than the self-stretching in the CP group. The effectiveness of vapocoolant spray combined with stretching by a physiatrist might produce a more significant increase in cervical ROM than applying a cold gel pack and self-stretching. Cervical ROM in both the DCF and SS groups improved more than in the CP group.

Comparison of the DCF group and the SS group found no significant difference in the improvement of the pain-free cervical range of motion in either lateral neck flexion or forward neck flexion. This may be due to the similar effect on post-needling soreness of the methods used with the DCF and SS groups and that in both groups the stretching techniques were performed by a physiatrist.

Clinical application

Regarding the minimal clinically significant change in patient pain severity, a 2.0 NRS score,[42] there was no clinically significant difference between the three groups in post-needling soreness or muscle pain intensity. However, there was a clinically significant difference in post-needling soreness in the DCF and SS groups after 24 hours after dry needling compared to baseline. The minimum clinically significant difference in cervical ROM is forward neck flexion of more than 2 degrees and lateral neck flexion of more than 3 degrees.[43] Thus, there was a clinically significant difference in pain-free lateral neck flexion in the DCF group and the SS group but not in the CP group. There was also a clinically significant difference in pain-free lateral neck flexion and forward neck flexion in the DCF and SS groups immediately after treatment when compared to baseline. Thus, all three methods are recommended for post-needling soreness reduction. In patients with high soreness intensity and greater cervical ROM restriction, however, the DCF and SS methods would be more suitable choices.

Cold gel packs with self-stretching is recommended for patients who do not have contraindications for cryotherapy and who do not have a high BMI as cold gel packs cannot change the temperature of tissue that is deeper than 2 cm from the skin.[44] In addition, it takes at least 10 minutes for a cold gel pack to induce an analgesic effect. A cold gel pack should be applied in combination with effective self-stretching. Although the cost of the cold gel pack is similar to the DCF spray and Perskindol cool spray, it can be reused many times,

making it potentially more cost-effective. Use of a cold gel pack with self-stretching is recommended as a primary soreness reduction method for patients with low to moderate soreness intensity who have no limitations on neck range of motion.

DCF spray combined with contract-relax stretching is recommended for patients who do not have contraindications, have moderate to severe soreness intensity, and have restriction of cervical ROM. This method requires only two minutes to provide an effective analgesic effect and is preferable to the spray and stretch technique as it is more comfortable, requires a lower dosage of spray, and is readily available at most hospitals, including the Phetchabun Hospital.

The spray and stretch technique is recommended for use with patients who do not have contraindications for cryotherapy, have moderate to severe soreness intensity, and have a restriction of cervical ROM. However, this method is unsuitable for patients with sensitive or fragile skin or low-thickness skin folds, e.g., elderly or low BMI patients, because the cooling sensation of the vapocoolant spray may be painful.[32] Additionally, a higher dosage of the vapocoolant spray is needed than of the DCF spray. There is also a potential limitation on use of vapocoolant spray alone at home as to be effective the spraying should be done at least 12 inches away from the upper trapezius region.

Study limitations

This study has some limitations. First, the dry needling and pain reduction treatments were only performed at the upper trapezius muscle. Although this muscle is a common site for developing myofascial pain syndrome, additional muscles can be involved which have not been evaluated. Second, as there was no placebo group, we cannot exclude the placebo effect occurring in all three groups. Third, in this study, a cold gel pack was applied for 10 minutes.[24] However, Otte, et al. found that there was a direct relationship between adipose thickness and adequate cooling time, i.e., greater skin fold thickness requires a longer duration cold pack application.[45] For example, in obese patients, longer duration of application of cold gel packs, e.g., more than 10 minutes is needed. Fourth, the outcomes recorded at 6 and 24 hours after dry needling were subjective outcomes and lacked objective confirmation, e.g., determination of cervical range of motion or pain pressure threshold. Finally, outcomes were recorded only once after the first 6 hours. A further study with more frequent recording of outcomes to investigate each method's effective frequency and duration is needed.

Conclusions

DCF spraying with contract-relax stretching reduces post-dry needling soreness at the upper trapezius muscle which is comparable to the spray and stretch technique. Both methods are more effective than cold gel packs with self-stretching. In addition to the spray and stretch technique, DCF spraying with contract-relax stretching might help further reduce post-dry needling soreness at the upper trapezius muscle, especially in patients with high post-needling soreness.

Disclosure

The author certifies that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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Original Article

Efficacy of High-Intensity Laser Therapy in Patellofemoral Pain Syndrome: A Double-Blinded Randomized Controlled Trial

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ABSTRACT

Objectives: To conduct a double-blinded randomized controlled trial study of the efficacy of high-intensity laser in patellofemoral pain syndrome patients in Ramathibodi Hospital, Thailand.

Study design: A double-blinded randomized controlled trial.

Setting: Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand.

Subjects: A total of 18 patients with patellofemoral pain syndrome for at least three months were studied.

Methods: Subjects were randomly allocated into two groups. The treatment group received high-intensity laser therapy (frequency 20 Hz, energy 1,530 mJ/cm^2, total energy 3,000 joules per session (6 sessions, 2-3 sessions per week) at an average power of 10.5 W). The control group received sham laser therapy (6 sessions, 2-3 sessions per week). In both groups, the patients were advised to exercise and to make lifestyle modifications. Pain (assessed by the VAS pain scale), functional ability of the lower extremity (assessed by the Thai version of the Kujala scoring questionnaire), and quality of life (assessed by Short Form-36 health survey version 2.0, SF-36V2) were collected before and at 3, 6, and 12 weeks after treatment.

Results: At baseline, demographic data as well as pain, function, and quality of life were similar between the groups. The differences in VAS decrement from baseline in the treatment and control groups after 3 weeks were 44.0 (28.0) and 34.0 (24.8), after 6 weeks were 44.0 (28.0) and 38.0 (37.3), and after 12 weeks were 47.0 (35.0) and 35.0 (41.3), respectively. There was statistically significant improvement in pain (VAS score), functional ability (Kujala score), and quality of life (SF-36V2) within both groups compared to before treatment ($p < 0.05$), but there was no statistically significant difference in those values between the treatment and control groups at 3, 6, and 12 weeks.

Conclusions: The efficacy of high-intensity laser therapy (HILT) combined with effective exercise was not significantly different from exercise alone in improving pain, function, or QOL.

Keywords: high-intensity laser therapy, patellofemoral pain syndrome, anterior knee pain, RCT

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Introduction

Patellofemoral pain syndrome is one of the most common types of knee pain. The primary symptom is usually anterior knee pain, which will increase while ascending or descending the stairs, bending the knee, jumping, or sitting in a knee-bending position for an extended time.[1] Many factors can contribute to lower extremity abnormalities, including increased Q-angle, patellar malposition, muscle imbalance, thigh muscle tension, and overactivity. These factors cause increasing forces under the patellofemoral joint.[2] Patellofemoral pain syndrome is common in teenagers and early young adults and is more common in women. The prevalence of patellofemoral pain syndrome in normal general populations is 22.7 percent and 28.9 percent in teenagers.[3] The pain is worse with knee joint movement, and hence it causes limitations in activities of daily living.[4]

The treatment goals of patellofemoral pain syndrome are to reduce pain, increase muscle strength, increase flexibility, and correct the patellar movement tract.[5] Muscle strengthening is one of the conventional physical therapies, especially for the quadriceps. Many studies have shown that strengthening the hip abductor and quadriceps muscles decreases pain and can increase knee function better than training only the quadriceps muscles, which would has the effect of decreasing force mainly in the patellofemoral joint.[6-8] Other physical modalities include Kinesio-tape around the patella area, electrical stimulation, and orthosis.[9] At this time, there are no significant differences in pain improvement between each treatment. No significant differences in pain improvement between the different treatments have been reported.[5,9]

The effectiveness of pain relief has been tested by reducing or inhibiting inflammatory mediators as well as by increasing neuroenzyme inhibition and inducing or increasing production of endorphins, opioids, and blood supplies.[10-12] Laser therapy has become popular in treating musculoskeletal problems because it is non-painful and requires less time.[10,13] A review of the literature found that many studies using lasers for

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treating chronic lower back pain, frozen shoulder, osteoarthritis, and rheumatoid arthritis have reported significant pain decreases. Additional studies are presently being conducted with high-intensity lasers, which have a higher intensity but a shorter duration than lower-intensity lasers.[13] Results of studies using high-intensity lasers with osteoarthritis patients have shown that the high-intensity laser is more efficient in decreasing pain than a lower intensity laser. Photothermal and photochemical effects of lasers include increased blood supply and cell metabolism in deep tissue.[14,15]

Nouri et al., 2019 investigated the efficacy of high-intensity lasers (300 J/session for five consecutive sessions) with exercise versus sham laser treatment plus exercise. Pain reduction was measured by VAS, WOMAC, and Kujala scores in 44 patients. The patients in the high-intensity laser group experienced a significantly greater decrease in pain than the sham group at the third week.[16] The 2019 Nouri study is a single-blind randomized control trial that advised patients to train only the quadriceps muscles. In contrast, another study showed that training the abductor as well as the and quadriceps muscles was more effective in decreasing pain.[6-8] There have been few studies of using high-intensity lasers for patello-femoral pain syndrome. Additional research is needed to evaluate the efficacy of high-intensity lasers combined with muscle training in patients suffering from patellofemoral pain syndrome.

Method

Study Design

This double-blinded, randomized controlled trial was approved by the Office of the Committee for Research of the Faculty of Medicine Ramathibodi Hospital Mahidol University (approval number: 2019/903). The Thai Clinical Trials Registry number is TCTR20220418007.

Participants

Study participants were adults aged 20-50 years with anterior knee pain for at least three months and who engaged in two or more physical activities that induced knee pain: standing with the knee bent, ascending or descending the stairs, kneeling, jumping, or sitting in a knee-bending position for an extended time, or contracting the quadriceps muscle. Additionally, anterior knee pain was discovered using the patellar grind test[17] as well as by a pain score of 3 or higher on the VAS scale. Exclusion criteria were a history of knee surgery, recent knee trauma or infection, any signs of knee osteoarthritis (OA), use of corticosteroids or anti-inflammatory drugs in the past 6 months, severe neurological or cardiovascular disorders, and contraindications for laser therapy and a desire not to participate in the study. All participants provided written informed consent.

Sample size

The sample size was determined based on our pilot study of 8 participants, which had a mean difference and standard deviation of VAS of 1.0 and 0.46, respectively. For an alpha level of 0.05, a power of 80% and an estimated dropout rate of 20%, the sample size of this study was calculated to be 18 participants (9 participants per group).

Randomization

The researcher performed block randomization using computer-generated randomization for a block of four. A letter in a concealed envelope indicated to which group the patient belonged; the letter was delivered to the physiotherapist who provided the treatment to the patient. The patients and the assessor were blinded to the treatment allocation.

Intervention

The treatment group was treated with high-intensity laser therapy using a Hilterapia®, HIRO TT® (pulsed, high-power Nd: YAG laser, λ 1064 nm, peak power (max): 3 kW, average power (max): 10.5 W) (ASA S.r.l., Vicenza, Italy). We applied the laser using a global approach method and 5 points surrounding the anterior knee in 30-degree of flexion.[18] The control group received a sham laser treatment using the same technique but with the laser cable switched so the laser energy did not go into the joint (Figure 1). All patients received six treatments (2-3 sessions per week). In addition to the laser treatment, both groups participated the same muscle-strengthening program.

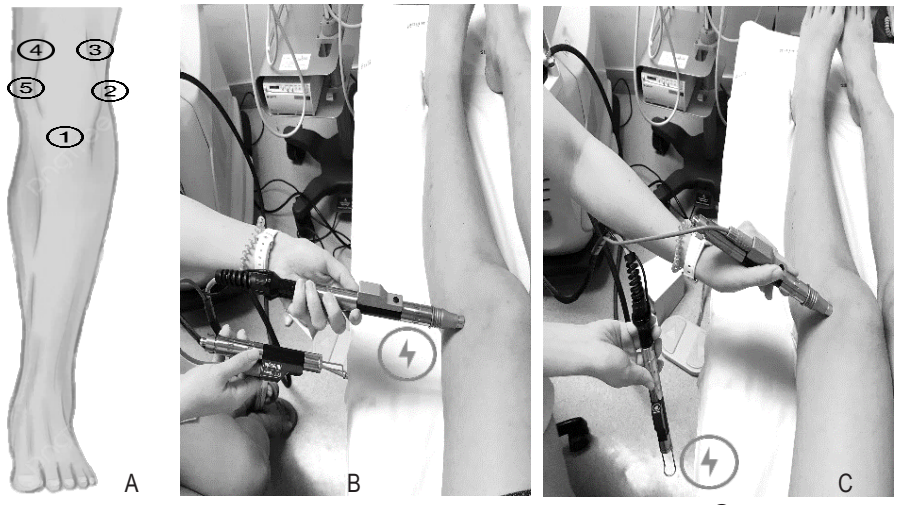

Figure 1. Treatment area around the anterior knee (A), methods of laser application in the treatment group (B) and in the control group (C).

The program included isometric quadriceps strengthening, quadriceps straight leg raise, semi-squat exercise, and hip abductor muscle strengthening for ten repetitions with 10-second holds three times a day and hamstring muscle stretching also with 10-second holds twice daily. In addition, the therapist advised on lifestyle modifications as a form of conservative treatment.[19] Followed-up assessments of patients were conducted at 3, 6, and 12 weeks following treatment after which the physiatrist and the physiotherapist contacted the patients regularly throughout the study to ensure they were continuing to follow the exercise routine and were receiving the prescribed laser therapy.

Outcome measurements

Primary outcome measurement

Pain

A visual analog scale (VAS) was used for pain assessment. The VAS is a 100-mm line on which where 0 indicates "no pain," and 100 indicates "worst pain." Patients were asked to indicate their current pain level by placing a mark at the appropriate spot on the line.

Secondary Outcome Measurement

Functional ability of the lower extremity and quality of life

The Thai version of the Kujala scoring questionnaire, a 13-item questionnaire for assessing patient-reported anterior knee pain, was used to assess lower extremity functional ability,[20] as well as symptom severities and physical limitations. This questionnaire is commonly used for measuring patello-femoral pain. Scoring ranges from 0-100, where 100 indicates no symptoms or disability and 0 indicates severe symptoms and/or disability. The Short Form-36 Health Assessment version 2.0 (Thai version), a 36-item patient-reported survey measuring physical and mental health, was used to evaluate quality of life,[21] with higher values indicating a higher quality of life. The Thai versions of both instruments have been validated and have shown excellent test-retest reliability.

Statistical analysis

All statistical tests were performed using SPSS Version 18.0 (IBM Corp, Armonk, NY, USA). Because the data was non-normally distributed, it was evaluated using the non-parametric Shapiro-Wilk W-Test. The Mann-Whitney U test was used to compare differences between groups, and the Wilcoxon matched-pair signed ranks test was used to compare differences within groups. An intention-to-treat analysis was also carried out. The results are expressed as mean (SD) for parametric data and median ± interquartile range (IQR) for non-parametric data. P values < 0.05 were considered statistically significant.

Results

In this study, 18 patients were recruited and divided into two groups of nine patients each. There were no dropouts during the study (Figure 2). At baseline, demographic data showed no statistically significant differences ($p > 0.05$).

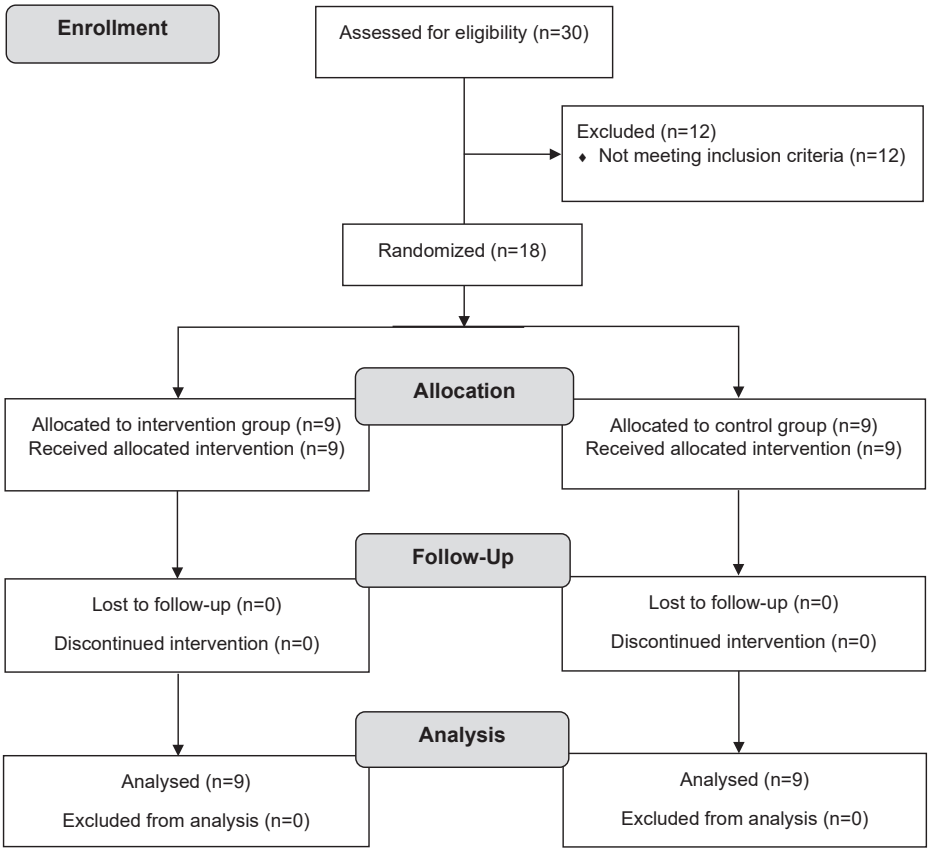

Figure 2. Flowchart of the trial

In the treatment group and control group, the mean ages (SD) were 36.4 (7.5) and 34.3 (8.84) years, the mean BMIs (SD) were 22.2 (3.4) and 25.8 (6.2) kg/m^2, and the mean length of duration of pain were 26.4 (23.8) and 10.7 (10.1) months, respectively. Additional demographic data is provided in Table 1.

Before treatment, the median VAS (IQR) was 60.0 (21.0) and 58.0 (27.5), the median Kujala scores (IQR) were 73.0 (15.5) and 75.0 (16.0), and the median SF-36V2 scores (IQR) were 599.6 (121.0) and 578.8 (151.9) in the treatment and control groups, respectively (Table 2).

At three weeks after treatment, the median VAS (IQR) scores were 16.0 (17.5) and 24.0 (36.5); at six weeks, the scores were 16.0 (18.0) and 17.0 (41.5), and at 12 weeks they were 6.00 (16.0) and 23.0 (32.0) for the treatment and control groups, respectively.

At 3, 6, and 12 weeks there was a statistically significant decrease in VAS compared to before treatment in both groups (Table 2). The differences in VAS decrement between the treatment and control groups at baseline and at three weeks were 44.0 (28.0) and 34.0 (24.8), respectively. At six weeks the differences were 44.0 (28.0), 38.0 (37.3), and at 12 weeks they were 47.0 (35.0) and 35.0 (41.3), respectively. The differences in VAS between the treatment and control groups after 3, 6, and 12 weeks of treatment were not statistically significant, just as with the Kujala scores and the SF-36V2 (Table 3). Similarly, there were no statistically significant differences in VAS scores, Kujala scores, or SF-36V2 within groups or between groups at three weeks after treatment compared to 6 and 12 weeks.

Discussion

In this study, the pretreatment situation of the group that received the high-intensity laser and the group that received the sham laser, both of which included muscle training exercises to decrease pain, improve functional ability, and improve quality of life, were compared following both long-term and short-term treatment. It is noteworthy that the improvement in both groups was much greater in the first three weeks and slightly better, but then improved only slightly between three weeks and six weeks and between six weeks and twelve weeks, similar to a study by Nouri et al.[15] Comparison of the treatment results between the two groups in this study, however, showed no significant difference, unlike a study by Nouri et al.[15] which found statistically significant VAS improvement in

Table 1. Baseline demographic data

	Treatment group (N=9)	Control group (N=9)	*p*-value
Gender, female,1 male[1]	7; 2	6; 3	0.599
Age (year)[2]	36.4 (7.5)	34.3 (8.8)	0.624
Body mass index (kg/m^2)[2]	22.2 (3.4)	25.8 (6.2)	0.200
Duration of pain (month)[2]	26.4 (23.8)	10.7 (10.1)	0.161
Q-angle (degree)[2]	13.6 (3.4)	13.8 (2.4)	0.653
Ober's angle (degree)[2]	4.2 (1.8)	6.6 (3.8)	0.127
Arch of foot, low, normal, high[1]	0, 7, 2	2, 6, 1	0.300
Patellar tilt angle (degrees)[2]	8.8 (7.6)	10.6 (6.3)	0.345
VAS pretreatment[2]	60.0 (21.0)	58.0 (27.5)	0.930
Kujala score pretreatment[2]	73.0 (15.5)	75.0 (16.0)	0.479
SF-36V2 pretreatment[2]	599.6 (121.0)	578.8 (151.9)	0.536

[1]Number, [2]mean (SD)

Q-angle, Quadriceps angle; VAS, visual analog scale; SF-36V2, short-form survey version 2.0

Table 2. Parameters before treatment and at 3, 6, and 12 weeks after treatment: median (interquartile range)

		Treatment group	Control group	*p*-value
VAS	Pretreatment	60.0 (21.0)	58.0 (27.5)	0.930
	3 Weeks	16.0 (17.5)	24.0 (36.5)	0.508
	6 Weeks	16.0 (18.0)	17.0 (41.5)	0.724
	12 Weeks	6.00 (16.0)	23.0 (32.0)	0.351
Kujala score	Pretreatment	73.0 (15.5)	75.0 (16.0)	0.479
	3 Weeks	93.0 (6.0)	89.0 (15.5)	0.132
	6 Weeks	95.0 (11.5)	90.0 (13.0)	0.307
	12 Weeks	94.0 (16.5)	91.0 (14.5)	0.424
SF-36V2	Pretreatment	599.6 (121.0)	578.8 (151.9)	0.536
	3 Weeks	682.5 (76.9)	676.7 (116.8)	0.354
	6 Weeks	697.92 (71.9)	732.9 (109.9)	0.691
	12 Weeks	706.3 (115.4)	707.50 (96.3)	0.596

VAS, visual analog scale; SF-36V2, short-form survey version 2.0

Table 3. Changes in VAS and Kujala score and SF-36V2 among groups: median (interquartile range)

	Weeks	Treatment group	Control group	*p*-value
Δ VAS	3	44.0 (28.0)	34.0 (25.8)	0.627
	6	43.0 (42.0)	38.0 (37.3)	0.596
	12	47.0 (35.0)	35.0 (41.3)	0.791
Δ Kujala score	3	19.0 (11.5)	10.9 (20.5)	0.122
	6	21.0 (16.0)	12.0 (17.5)	0.111
	12	44.0 (28.0)	34.0 (25.8)	0.233
Δ SF-36V2	3	104.1 (55.4)	91.65 (163.3)	1.00
	6	116.3 (113.3)	130.4 (170.5)	0.627
	12	100.0 (71.3)	95.0 (173.1)	0.627

VAS, visual analog scale; SF-36V2, short-form survey version 2.0

the active laser group over the sham laser group. Training of hip abductor and quadriceps muscles in our study was more effective than quadriceps muscle training alone in reducing pain in patellofemoral pain syndrome [6,7] as it decreased force in the patellofemoral joint, as well as improving functional ability because of increased coordination of lower extremity muscles, results in concordance with studies by Sharif et al.,[6] Alammari et al.[7] and Ferber et al.[8] The reduction of pain and other symptoms additionally combined to result in a better quality of life.[22] In the control group in the present study that had only been advised to exercise but received no laser therapy, the average VAS score decreased by 34.0, a clinically significant reduction. This could be one reason why the results in both level of improvement in the two groups showed no statistically significant difference.

High-intensity lasers have photothermal, photochemical, and photomechanical effects that help reduce inflammation and pain while promoting tissue repair.[23] They are typically used with patients who have inflammation and arthritis of joints, tendons, ligaments, and muscles. In patellofemoral joint pain, there are many potential causative factors. The most common factor is a muscle imbalance in the knee joint area. That imbalance affects patellar movement and results in more force around the patellofemoral joint during flexion and extension of the knee.[24] That is why high-intensity laser treatment of patellofemoral pain syndrome may not be effective in patients with muscle imbalance. Between groups comparisons in the present study showed no significant difference in pain relief between the sham group and the laser treatment group. Researchers found which suggests that higher laser energy may not help reduce pain in patients with patellofemoral pain syndrome.

This study's population consisted of more women than men, similar to the Smith et al. study.[3] However, in the present study there were few patients with anatomical abnormalities: only two patients had flat feet, and no patients had iliotibial band syndrome or an unusual Q-angle making it more likely that strengthening exercises alone may be sufficient to relieve pain. However, this study did not was not able to answer the question of the efficacy of high-intensity lasers in patellofemoral pain syndrome treatment.

Limitations

One limitation is that this study did not collect data on patient activity level, which could be one of the factors influencing treatment outcomes. Moreover, the sample size, calculated based on a small pilot study, might have been insufficient to accurately estimate the outcome's standard deviation.

Conclusions

This study found that the efficacy of high-intensity laser treatment combined with effective exercise is not significantly different from exercise alone in terms of pain reduction, function improvement, and increase in QOL.

Conflict of interests

The authors declare no conflict of interest.

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Original Article

The Use of Plastic Ankle-Foot Orthosis Prescribed for Patients with Foot Drop: The Application and Related Factors

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ABSTRACT

Objectives: To study the use patterns and factors related to the use of thermoplastic ankle-foot orthoses (AFO) by patients with foot drop to provide information and to help develop more efficient methods for making decisions regarding the prescription of AFOs.

Study design: Cross-sectional study.

Setting: Department of Rehabilitation Medicine, Maharat Nakhon Ratchasima Hospital.

Subjects: Patients with foot drop who had received thermoplastic AFOs between January 2021 and March 2022.

Methods: Demographics and clinical data were collected from the medical records of the patients. Frequency, duration, and other data related to AFO use were collected via phone interviews with the patients after the AFO had been prescribed for at least 3 months. Use of the AFO was defined as continuous use at least one day a week. Factors associated with compliance with recommended AFO use was analyzed using multivariable analysis.

Results: This study included 117 patients (77 men) with a mean age of 52 years. Of those patients, 59.8% reported continuous use of the AFO with a 95% confidence interval (CI) of 50.8-68.8. Patients who were unable to do ankle dorsiflexion, who wore clogs and who practiced walking with a physical therapist were more likely to use an AFO with adjusted prevalence ratios (95% CI) of 1.49 (1.04-2.14), 1.75 (1.05-2.93), and 1.45 (1.06-1.98), respectively..

Conclusions: Sixty percent of foot drop patients continued using an AFO after 3 months. Half of those patients used the AFO every day. Being unable to do ankle dorsiflexion, wearing clogs, and practicing walking with a physical therapist were all associated with good compliance with AFO use.

Keywords: foot orthoses, patient compliance, cross-sectional studies, stroke

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Introduction

Foot drop is presented as a reduction in dorsiflexion during heel strike and the swing phase of walking, resulting in poor foot clearance, increasing the risks of trips and falls.[1] Foot drop is a frequently occurring problem in stroke, spinal cord injury, and peripheral nerve injury. An ankle-foot orthosis (AFO) is commonly used to treat foot drop. The AFO limits the range of motion at the ankle, aids foot clearance,[2] assists walking by maintaining the ankle and foot alignment, prevents ankle-foot deformities, and increases speed and gait pattern while walking.[3-5]

Regarding the Prosthetic and Orthotic clinic's records from Maharat Nakhon Ratchasima Hospital, Thermoplastic AFO is commonly prescribed. The two common non-articulated thermoplastic AFOs are the posterior leaf spring and the solid ankle type. Each type of AFO prescription depends on the patient's status and preferences. There are differences in the use of AFOs for each disease. In stroke, spinal cord injury, and common peroneal neuropathy, the use of AFO in these patients was 61.3%,[6] 33.3%,[7], and 13.6%[8] respectively. Previous studies showed that many AFO users had discontinued their AFO usage.[7,8] The common reasons for discontinuation were difficulty walking and difficulty wearing.[9] Disadvantages of AFO consisted of weight and appearance of the orthoses[6,10] and pressure points, which are an insufficient adaptation to the foot and shoe shape, causing discomfort.[9] Refusal to wear an AFO leads to wasted healthcare resources.

Approximately 150 AFOs are prescribed in Maharat Nakhon Ratchasima Hospital each year, primarily thermoplastic AFOs. However, their use has not been followed up. There are few studies investigating the use of AFO in each disease group.[6-8] This study aimed to investigate the use of AFO in patients with foot drops, identify related factors to know the information, and develop the most efficient way to decide on an AFO prescription.

Method

Study design

This cross-sectional study was conducted at the Department of Rehabilitation Medicine, Maharat Nakhon Ratchasima Hospital.

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Participants

All patients who qualified for thermoplastic AFO from the Prosthetic and Orthotic Clinic from January 2021 to March 2022 had their data collected from the Hospital database. In addition, the author reviewed the electronic medical records of each patient. Inclusion criteria were as follows: ambulatory patients with unilateral or bilateral foot drop assessed by a Physiatrist and prescribed thermoplastic AFO at least three months ago, and age of 18 years or older. Patients with foot deformity and Charcot's foot were excluded. After the inclusion-exclusion screening, telephone informed consent to participate was obtained from all participants. Patients with cognitive impairment or an inability to communicate verbally were asked for information from their full-time caregivers. From previous studies of AFO use in stroke patients,[6] common peroneal neuropathy patients[8] and spinal cord injury patients[7] averaged 50.4%. According to this formula = $Z2\alpha/^2$ $P(1-P)/d^2$, the significance level was set to 0.05, and the estimation error of P was 0.1 indicating a minimum of 97 subjects were needed.

Procedure

Data were collected using case record forms from medical records and questionnaire forms from telephone interviews by the research author. In addition, patients' clinical manifestations and demographic characteristics were collected from medical records, composed of patients' age, gender, telephone number, diagnosis, underlying diseases, type of AFO, involved side of foot drop, and time since foot drop to a prescription of AFO.

The participants were interviewed to complete an AFO use questionnaire. The items in the questionnaire consisted of education level, the frequency and duration of using AFO, current ability to do ankle dorsiflexion, gait aid use, practice walking with a physical therapist after receiving an AFO, participation in decision-making before applying AFO, ability to independently don and doff AFO, walk with personal support and footwear use. We categorized footwear as sandals, trainers, or clogs (figure 1). Causes of discontinuing AFO were asked in patients not using AFO, and the benefits of AFO were asked in current users. The patients' feedback regarding facilitating AFO usage was also recorded. The newly designed questionnaire was tested for understandability with 10-foot drop patients, including AFO users and nonusers. Ethics approval was obtained from the Maharat Nakhon Ratchasima Institutional Review Board (049/2022).

Statistical methods

The data were analyzed using Stata version 11. Descriptive statistics were used to summarize patient characteristics, including frequency and percentage, mean, standard deviation, and median (IQR). AFO using rate was calculated as a percentage and 95%CI.

Patients were categorized as patients using and not using AFO. Patients using AFO were defined as continuously using AFO at least once a week by referring to Dajpratham et al. study.[6] The time since foot drop to a prescription of AFO was defined as two months because the recovery potential of neurapraxia after nerve injury is two months.[11] Univariate analysis was performed to evaluate the differences between patients using and not using AFO. The chi-square test was used to compare qualitative variables, including age more than 60 years, presence of co-morbid illnesses, diagnosis, type of AFO, involved side of foot drop, ability to do ankle dorsiflexion, use of gait aids, footwear using, practice walking with a physical therapist after prescribing an AFO, participation in decision-making before receiving AFO, ability to independently don and doff AFO, walk with personal support. Multivariable logistic regression analysis was then performed to determine which factors were significantly associated with patients using and not using AFO. Adjusted prevalence ratio and 95% CIs were estimated. A $p < 0.05$ was considered statistically significant.

Results

Thermoplastic AFOs were prescribed for 145-foot drop patients between January 2021 and March 2022. Of those, 25 patients cannot be contacted, two died, and one denied participating. The remaining 117 patients (77 men and 40 women, mean age 52 years) were included. Among these remaining patients, the causes of foot drop were stroke (40.2%), cauda equina syndrome (CES) or radiculopathy (27.4%), common peroneal neuropathy (13.7%), sciatic neuropathy (10.3%), traumatic brain injury (TBI) (3.4%), spastic spinal cord injury (SCI) (2.5%) and polyneuropathy (2.5%). 92.3% had unilateral, and 7.7% had bilateral foot drop (Table 1).

Three months or more after being prescribed thermoplastic AFO, 70 (59.8%) patients were using AFO (95% CI 50.8-68.8). Only 35 (29.9%) patients were using AFO every day. There were 13 from 32 cauda equina syndrome or radiculopathy patients (40.6%), 11 from 47 stroke patients (23.4%), 5 from 12 sciatic neuropathy patients (41.6%), 4 from 16 common peroneal neuropathy patients (25%), and

Figure 1. sandals trainers clogs

Table 1. Clinical characteristics of the patients (N=117)

Characteristics	Number (%)
Age (year)[1]	51.9 (15.4)
Male	77 (65.8)
Patients using AFO	70 (59.8)
Education	
High school or lower	88 (75.2)
Higher than high school	29 (24.8)
Diagnosis	
Stroke	47 (40.2)
TBI	4 (3.4)
Spastic SCI	3 (2.5)
Common peroneal neuropathy	16 (13.7)
Sciatic nerve neuropathy	12 (10.3)
CES or radiculopathy	32 (27.4)
Polyneuropathy	3 (2.5)
Involved side of foot drop	
Unilateral	108 (92.3)

[1]Mean (SD)
AFO, ankle-foot orthosis; TBI, traumatic brain injury; SCI, spinal cord injury; CES, cauda equina syndrome

Table 2. The proportion of the subjects and their frequency and duration of daily thermoplastic ankle-foot orthosis use after receiving a prescribed orthosis (N=117)

Frequency of use per week	Duration of use per day			Total No. (%)
	< 1 hour No. (%)	1-3 Hours No. (%)	> 3 Hours No. (%)	
Not at all				47 (40.2)
1-2 days	10 (8.5)	7 (6.0)	3 (2.6)	20 (17.1)
3-4 days	1 (0.9)	10 (8.5)	4 (3.4)	15 (12.8)
5-7 days	6 (5.1)	7 (6.0)	22 (18.8)	35 (29.9)

2 from 4 traumatic brain injury patients (50%). 47 (40.2%) patients had discontinued the use of the prescribed thermoplastic AFO (Table 2). We categorized the duration of use per day and frequency per week by referring to Dajpratham et al. study.[6] The benefits of wearing thermoplastic AFOs were reported by 70 patients using AFO. 42 (60%) patients reported improved foot clearance, 22 (31%) had better and more confidence in walking, and 6 (9%) reported other benefits. Causes of discontinuation were reported by 47 patients not

Table 3. General characteristic and patient variables comparing patients using and not using ankle-foot orthosis (AFO)

Variables	Patients using AFO (No. = 70) No. (%)	Patients not using AFO (No.= 47) No. (%)	*p*-value
Age (year)			
< 60	44 (62.9)	32 (68.1)	0.069
Presence of co-morbid illnesses	34 (48.6)	21 (44.7)	0.709
Diagnosis			0.483
Stroke	30 (42.7)	17 (36.2)	
TBI	3 (4.3)	1 (2.1)	
Spastic SCI	2 (2.9)	1 (2.1)	
Common peroneal neuropathy	9 (12.9)	7 (14.9)	
Sciatic neuropathy	6 (8.6)	6 (12.8)	
CES or radiculopathy	20 (28.6)	12 (25.5)	
Polyneuropathy	0 (0.0)	3 (6.4)	
Involved side of foot drop			0.481
Unilateral	66 (94.3)	42 (89.4)	
Ability to do ankle dorsiflexion	22 (31.4)	23 (48.9)	0.081
Time since foot drop to a prescription of AFO (months)			0.019
≥ 2 months	51 (72.9)	24 (51.1)	
Type of AFO			0.222
Solid ankle AFO	17 (24.3)	9 (19.1)	
Posterior leaf spring	53 (75.7)	36 (76.6)	
Articulated AFO	0 (0.0)	2 (4.3)	
Footwear			0.279
Unapplied	36 (51.4)	30 (63.8)	
Sandals	24 (34.3)	12(25.5)	
Trainers	2 (2.9)	3 (6.4)	
Clogs	8 (11.4)	2 (4.3)	
Participate in decision-making before receiving AFO	57 (81.4)	35 (74.5)	0.491
Practice walking with a physical therapist after receiving an AFO	44 (62.9)	20 (42.6)	0.038
Ability to independently don and doff	52 (74.3)	33 (70.2)	0.675
Use of gait aids of an assistive device	50 (71.4)	28 (59.6)	0.231
Walk with person support	10 (14.3)	4 (8.5)	0.399

AFO, ankle-foot orthosis; TBI, traumatic brain injury; SCI, spinal cord injury; CES, cauda equina syndrome

Table 4. Multivariate analysis of factors associated with patients using AFO

Factors	Prevalence ratio (95% CI)	APR (95% CI)	*p*-value
Unable to do ankle dorsiflexion	1.36 (0.97, 19.2)	1.49 (1.04, 2.14)	0.030
Onset to prescription ≥ 2 months	1.50 (1.04, 2.17)	1.40 (0.99, 1.97)	
Footwear			
Unapplied	1	1	0.057
Sandals	1.22 (0.89,1.68)	1.20 (0.90,1.61)	0.220
Trainers	0.73 (0.24, 2.20)	0.77 (0.23, 2.55)	0.665
Clogs	1.47 (1.00, 2.15)	1.75 (1.05, 2.93)	0.033
Practice walking with a physical therapist after receiving an AFO	1.40 (1.02, 1.93)	1.45 (1.06, 1.98)	0.019
Participation in decision-making before receiving AFO	1.19 (0.79, 1.80)	1.04 (0.72, 1.50)	0.839
Use of gait aids of an assistive device	1.11 (0.94, 1.33)	1.15 (0.96, 1.36)	0.122
Unable to independently don and doff	0.92 (0.65, 1.31)	0.72 (0.51, 1.02)	0.064
Walk with person support	1.23 (0.85, 1.78)	1.04 (0.69, 1.57)	0.838

AFO, ankle-foot orthosis

using AFO. 18 (38.3%) patients reported natural recovery, 17 (36.1%) patients reported difficulty walking, and 5 (10.6%) patients reported pressure sensations. The median duration of AFO use in patients who reported natural recovery was two months (IQR1,4). We found that recovery groups were 6 from 47 stroke patients (13%), 4 from 12 sciatic neuropathy patients (33%), 4 from 16 common peroneal neuropathy patients (25%), 3 from 32 CES or radiculopathy patients (9%) and 1 from 3 polyneuropathy patients (33%).

Univariate analysis revealed two statistically significant factors associated with AFO application. The two factors were the patient experiencing foot drop for more than two months (p = 0.019) and the patient practicing walking with a physical therapist after being prescribed an AFO (p = 0.038) (table 3). Other factors suspected to affect the use of AFO were analyzed in multivariable logistic regression analysis (table 4). These three factors, including patients unable to do ankle dorsiflexion, wearing clogs, and practicing walking with a physical therapist after applying an AFO, were shown. These factors were likely to increase the rate of using AFO with adjusted prevalence ratios (95%CI) of 1.49 (1.04, 2.14), 1.75 (1.05, 2.93), and 1.45 (1.06, 1.98), respectively.

Patient suggestions to increase the usage of AFO were that the material should be more durable from 7 patients' quotes. Moreover, 4 patients recommended that the AFO should be easy to don and doff. Finally, 4 patients suggested that the shape of the AFO should be improved. However, 81 patients had no suggestions.

Discussion

In this study, the percentage of AFO users after applying AFO for at least three months was 59.8%. Only 29.9% used their AFO almost every day. The patients using AFO reported that it helped increase foot clearance and made them walk more confidently, which was aligned with the previous studies.[12,13] Our findings also explained by the previous report that AFO can increase toe clearance significantly.[14]

Out of the 47 stroke patients in our study, it was found that 63.8% reported continuous use of AFO, which corresponds to Dajpratham et al. study,[6] which found 61.3% of chronic stroke patients continue using AFO after one year. Our study found that 23.4% of stroke patients use AFO every day, while Nakipoglu et al.[9] reported 59.4% of stroke patients used their lower extremity orthosis every day because Nakipoglu et al.[9] recruited stroke patients after discharge from inpatient rehabilitation who received practice walking with AFO. These results are consistent with the current study's findings that practicing walking with a physical therapist increased AFO usage. From our study, 40.6% of cauda equina syndrome or radiculopathy patients used AFO every day, whereas no spinal cord injury patients used AFO every day. This result differed from Koyuncu et al.'s study[7], which showed that 33.3% of spinal cord injury patients used AFO every day. While this study had only three spinal cord injury patients, those were too low to interpret.

AFOs are usually utilized with shoes.[15] Farmani et al. study[16] reported that wearing rocker shoes can lead to much more improved functional mobility and decreased energy expenditure than ankle-foot orthosis. However, finding a suitable shoe to use with AFO is difficult. The best-recommended shoes for AFO are the full-stretch or extra-depth shoes.[17] Clogs have a broad toe box and are flexible. Generally, clogs have a toe-only rocker bottom, and they can be easily purchased in the market and are suitable for Thailand's weather. Our study found that wearing clogs increased the rate of using AFO by about 80% when compared to AFO only. This high percentage is a crucial finding of this study because the likelihood of a patient following a prescription is nearly doubled for such a small cost.

Patients who practice walking with a physical therapist after applying an AFO could increase the rate of using AFO by about 40% compared to untrained people because the practice can help the patients get used to walking with AFO, which allows them to use AFO continuously. For example, Nakipoglu et al.[9]

reported that 59.4% of patients who practiced walking with a physical therapist while admitted to inpatient rehabilitation used AFO every day. Therefore, after being prescribed AFO, patients should practice walking with a physical therapist and have a follow-up to increase the AFO use rate.

Patients were unable to do ankle dorsiflexion use AFO 49% more than patients who were able to do the movement. Because these patients cannot control their ankles and feet, they use AFO more. Although patients could do ankle dorsiflexion, they could not do the full range of motion, so they still needed to use AFO. The previous study by Bruijn et al.[8] found that after follow-up with peroneal neuropathy patients, 40.9% of the patients who stopped using AFO stopped because they had an improvement in active dorsiflexion. This improvement came from the natural recovery of the peroneal nerve. Our study reported causes of discontinuation by patients not using AFO. 18 (38.3%) patients reported natural recovery, which includes 33% of sciatic neuropathy, 33.3% of polyneuropathy, and 25% of common peroneal neuropathy. Patients who recovered naturally were found to use AFO at a median of 2 months (IQR1,4). In this study, about sixty percent of foot drop patients still need to use AFO, and the benefit of using AFO they mostly reported AFO improved foot clearance and better walking. This finding corresponds to Aprile et al.,[18] which found patients still had 68% of patients walked with difficulty.

Some limitations of our study should be mentioned. Because it was cross-sectional, the time between AFO prescription and interview was not constant between each patient, which may affect the rate of using AFO. There was recall bias in asking about practicing walking with a physical therapist and participation in decision-making before applying an AFO. Due to the phone interview, we could not assess spasticity and the ability of ankle dorsiflexion in patients, which might affect the use of AFO. Prescribing AFO should be based on indication and necessity. Physiatrists should always check out AFO, advise for suitable shoes, and practice walking with a physical therapist. Finally, patient follow-up after applying AFO for benefits and cost-effectiveness is recommended.

Conclusions

This study showed that 59.8% of foot drop patients continued using AFO. Half of these patients use AFO every day. In addition, the patients who were unable to do ankle dorsiflexion, wear clogs, and practice walking with a physical therapist after receiving an AFO was associated with AFO use.

Disclosure

The author declares no conflict of interest.

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Original Article

The Value of Ultrasound Performed by a Physiatrist in the Detection of Supraspinatus Tendon Tears Diagnosed Using Magnetic Resonance Imaging

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ABSTRACT

Objectives: To assess the sensitivity and specificity of shoulder ultrasound (US) performed by a physiatrist for detecting supraspinatus tendon tears using magnetic resonance imaging (MRI) as a reference standard.

Study design: Diagnostic research with retrospective data collection.

Setting: The rehabilitation medicine outpatient clinic, Maharat Nakhon Ratchasima Hospital, Nakhon Ratchasima Province, Thailand.

Subjects: Patients over 18 years old with shoulder pain clinically suspected of having a rotator cuff tear who underwent shoulder US and MRI.

Methods: The US was performed by a physiatrist who had completed a 1-month clinical observational course of the musculoskeletal US training program. The MRIs were accomplished by two general radiologists. A physiatrist, who was not an ultrasonographer, reviewed all patients' data from the hospital records. A cross-table comparison was conducted between US assessment and MRIs of the supraspinatus tendon. Sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios were calculated. A total of 65 patients were included in the study.

Results: The US performed by a physiatrist showed a sensitivity of 84.4% and specificity of 100% in detecting all-type supraspinatus tendon tears. The sensitivity and specificity in detecting full-thickness tears were 88.5% and 82.9%, respectively, and 55.3% and 89.7%, respectively, in detecting partial-thickness tears.

Conclusions: Shoulder US by a trained physiatrist showed high sensitivity and specificity for detecting supraspinatus tears diagnosed by MRI. Trained clinicians who are new to musculoskeletal ultrasound could use this method in the clinical-based evaluation of supraspinatus tendon tears for initial diagnosis and management.

Keywords: supraspinatus tendon tear, ultrasound, magnetic resonance imaging, physiatrist

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Introduction

Shoulder pain is a common problem in the outpatient department. It has been found in 16-34% of the general population,[1] with rotator cuff tear as the most common cause of shoulder pain. The supraspinatus tendon is the structure most frequently involved and the first tendon to be injured.[2] Magnetic Resonance Imaging (MRI) of the shoulder is now the imaging gold standard for this condition due to its high sensitivity and accuracy. The Cochrane Database of Systematic Reviews reported that the sensitivity and specificity of MRI for diagnosing rotator cuff tears were 98% and 79%, respectively.[3] However, MRI has the disadvantages of high cost, requiring a long time to perform, and being contraindicated in patients with a pacemaker or who suffer from claustrophobia.

Ultrasound (US) has been used in the diagnosis of rotator cuff tears for years. It has the advantages of low cost, a relatively short duration process and greater accessibility. However, it has the limitation of being operator-dependent, although current evidence shows that US has high sensitivity (91%) and specificity (85%) when performed by a radiologist or sports orthopedist.[3-5]

For the past ten years, physiatrists in Thailand have been using US as a diagnostic tool for screening musculoskeletal disorders, followed by initial management and further investigation. Maharat Nakhon Ratchasima Hospital is a tertiary referral hospital that has a sports clinic in the orthopedic surgery department; however, no musculoskeletal US service by a radiologist is currently available at the hospital. MRI shoulder is the only imaging done for a suspected rotator cuff tear; however, the procedure has a waiting time of at least three months. Due to the high cost of MRI, it is usually performed only in selected cases where surgery is required. In the rehabilitation clinic, there are many patients with shoulder pain but without a specific diagnosis because of the limitations of investigations. US could help address this issue. Therefore, one physiatrist in the clinic participated in a 1-month clinical observational course of musculoskeletal US in 2014.

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Musculoskeletal US service in our hospital begins with a shoulder US examination to detect shoulder pathologies. The most common disorder is a rotator cuff tear. However, no information is currently available concerning the sensitivity and specificity of the US that have been performed. The aims of this study were to retrospectively compare ultrasonographic findings with MRI findings and to evaluate the accuracy of US conducted by a trained physiatrist after completing one month of training on diagnosing supraspinatus tendon tears.

Methods

This retrospective study was performed at a rehabilitation medicine outpatient clinic of a tertiary care hospital in Nakhon Ratchasima which receives 5-10 shoulder-pain cases per month. Patients with shoulder pain seen by the clinic between January 1, 2016 and December 31, 2021 were identified. Patients with a history of shoulder surgery, and no data of shoulder US or shoulder MRI were excluded from the study.

Data was collected on a total of 65 patients over age 18 with shoulder pain who were suspected of having a supraspinatus tear and who had undergone shoulder US as well as an MRI within 3 months of the US. The US was performed by a physiatrist (R.S.) who had completed a 1-month clinical observational course of the musculoskeletal US training program prior to performing US.

A physiatrist (P.C.), who did not perform US, reviewed all patient data including gender, age, side of shoulder pain, history of shoulder surgery, shoulder ultrasound reports from the Electronic Medical Record (EMR) program, and shoulder MRI reports from the picture archiving and communication system (PACS) program.

Ultrasonography

A physiatrist (R.S.), who has completed the 1-month clinical observation course of the musculoskeletal US examination training program at National Taiwan University Hospital, performed all shoulder US using a Hitachi Arietta V60 5-10 MHz linear array ultrasound transducer (38 mm). The supraspinatus tendon US examinations were performed with both patient and sonographer seated on backless stools facing each other. The patient positioned the arm in extension and internally rotated with the elbow in flexion and their hand placed on their buttock. Imaging was completed in both the long axis (sagittal plane) and the short axis (transverse plane).

Long axis: The transducer was placed parallel to the longitudinal line of the supraspinatus tendon at the greater tubercle of the humerus. A hyperechoic fibrillation pattern is seen on the humerus cortex, similar to a bird's beak.

Short axis: The transducer was rotated 90 degrees from the long axis position with the transducer perpendicular to the longitudinal line of the tendon. The image appears as a hyperechoic fibrillation pattern resembling a rainbow.[6]

Diagnosis of the supraspinatus tendon abnormality was recorded as either no tear, partial-thickness tear, or full-thickness tear. A full-thickness tear was defined as a well-defined hypoechoic or anechoic defect that disrupts the hyperechoic tendon fibers and extends from the articular to bursal surfaces of the tendon. A partial-thickness tear showed a well-defined hypoechoic or anechoic abnormality that disrupts the tendon fibers, which may be at the bursa surface, articular surface, and/or within the tendon (Figure 1). Other pathologies, e.g., tendinopathy and tendinosis, appeared as calcification and inhomogeneity of the tendon.[7-9]

Magnetic resonance imaging

MRI of the shoulder was performed following the protocol using a 1.5 Tesla magnet with a field of view of 15 cm without Gadolinium and using a T2-weighted images sequence in the axial, coronal oblique, and sagittal planes as follows:

1. Axial: T2-weighted fat-suppressed, 3D T2, T2 GRE, and proton density-weighted 3 mm thick slices with a 1 mm gap (20 slides)
2. Coronal oblique: T2-weighted fat-suppressed, proton density-weighted 3 mm thick slices with an 0.8 mm gap (20 slides)
3. Sagittal: T2-weighted fat-suppressed, proton density-weighted 3 mm-slice thickness with a 1 mm gap (20 slides)

The patients were in a supine position with the affected arm at their side in partial external rotation. The criterion for a full-thickness supraspinatus tear was a focal discontinuity in the tendon extending from the articular to the bursal side, seen as a fluid signal intensity on T2-weighted images. A partial-thickness tear was defined as an incomplete tear involving the articular side, bursal side or within the tendon appearing as high signal intensity on T2-weighted images (Figure 1).

Statistical analysis

The sample size was calculated based on a pilot study of 20 patients with shoulder pain who had undergone shoulder US and MRI. The overall prevalence of supraspinatus tears in our hospital was 0.9. The sensitivity and specificity were 0.83 and 1. We assumed a sampling error of approximately 5% and the precision of estimation was 0.1. The calculated required sample size was 60 patients.

A cross-table was constructed to compare the US assessment with the MRI of the supraspinatus tendon. We calculated the sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios. All statistical analyses were performed using STATA version 13 for Windows.

Results

Of the patients with shoulder pain, 260 shoulders received a shoulder US examination but only 67 shoulders also received a confirmatory MRI examination within 3 months of the US. The patients had a mean age of 56.9 years (SD 9.7) and there were 37 males (55.3%). The right side was affected in 35 of the cases (53.8%), 28 cases (43.1%) on the left side

Table 1. Comparison between MRI and ultrasonographic findings in the diagnosis of supraspinatus tendon tears

MRI finding	Ultrasonographic finding			Total[1]
	No tear	Partial-thickness tear	Full-thickness tear	
No tear	3	0	0	3 (4.5)
Partial-thickness tear	10	21	7	38 (56.7)
Full-thickness tear	0	3	23	26 (38.8)
Total	13	24	30	67

[1]Number (%)

and 2 cases (3.1%) on bilateral sides.

MRI examination detected supraspinatus tears in 64 shoulders, of which 26 (38.8%) had full-thickness tears and 38 shoulders (56.7%) had partial-thickness tears, while US detected supraspinatus tears in only 54 shoulders (Table 1). US showed a sensitivity of 84.4% and a specificity of 100% in detecting supraspinatus tendon tears, including partial-thickness and full-thickness tears. The positive predictive values and negative predictive values were 100% and 23.1%, respectively. The calculated the negative likelihood ratio was 0.16 but the positive likelihood ratio could not be calculated because there were no shoulders where US detected a supraspinatus tear with no tear detected by MRI (Table 2).

We further analyzed the sensitivity and specificity of US for detecting full-thickness and partial-thickness supraspinatus tears. The sensitivity and specificity of detecting full-thickness tears were 88.5% and 82.9%, respectively (Table 3). Of the full-thickness supraspinatus tears, 23 of 26 were identified correctly with US and 3 shoulders were misdiagnosed as partial-thickness tears. Two of the three false negative cases had subdeltoid bursitis.

The sensitivity and specificity of US for detecting partial-thickness tears were 55.3% and 89.7%, respectively (Table 3). US correctly identified 21 of 38 partial-thickness supraspinatus tears while ten shoulders were incorrectly underestimated as having no tears, and 7 shoulders were overestimated as full-thickness tears. Among the underestimated group, most of the partial-thickness tears were intrasubstance tears (n=2) or articular side tears (n=6), while 50% (n=5) were cases of tendinopathy or tendinosis.

Discussion

In this study, we assessed the sensitivity and specificity of clinic-based US by a physiatrist in detecting supraspinatus tears, using MRI as a reference. We found that US has high sensitivity and specificity at 84.4% and 100%, respectively, but slightly lower sensitivity compared to previous studies. For example, Cole et al., Kurz et al., and Guo et al. found that US had a sensitivity of 87- 97% and a specificity of 80-100% for detecting all-type supraspinatus tears.[10-12] The Cochrane Database of Systematic Review published by Lenza et al., which included 13 studies, reported that US has high sensitivity (91%) and specificity (85%) for detecting rotator cuff tears.[3] However, surgery was used as a reference in these studies which resulted in selection bias because only patients with severe pathology or a full-thickness supraspinatus tear underwent the surgery. The actual accuracy might be a bit higher. We believe that MRI, which has a high sensitivity (98%)[3] and specificity (86%)[13] can help eliminate this bias, but it is not a perfect reference test that may affect the estimate of accuracy.

The specificity of US for detecting supraspinatus tears in our study was 100% which may have been a result of the small sample size. There were only three shoulders with no supraspinatus tears and no shoulders where US detected a supraspinatus tear but no tear was detected by MRI (false positive), hence we could not calculate the positive predictive value (PPV), one of the limitations of our study.

Table 2. Sensitivity, specificity, likelihood ratio and predictive value, and 95% CI of ultrasound in detecting supraspinatus tendon tears

MRI finding	All types of tears
Sensitivity[1]	84.4 (73.1-92.2)
Specificity[1]	100 (29.2-100)
Positive likelihood ratio[2]	-
Negative likelihood ratio[2]	0.16 (0.09 -0.28)
Positive predictive value[1]	100 (93.4-100)
Negative predictive value[1]	23.1 (5.0-53.8)

[1]% (95% confident interval), [2]ratio (95% confident interval)

Table 3. Sensitivity, specificity, likelihood ratio, predictive value and 95% CI of ultrasound in detecting partial-thickness and full-thickness supraspinatus tendon tears

	Partial-thickness tear	Full-thickness tear
Sensitivity[1]	55.3 (38.3-71.4)	88.5 (69.8-97.6)
Specificity[1]	89.7 (72.6-97.8)	82.9 (67.9-92.8)
Positive likelihood ratio[2]	5.34 (1.76-16.2)	5.18 (2.6-10.3)
Negative likelihood ratio[2]	0.49 (0.34-0.73)	0.14 (0.048-0.41)
Positive predictive value[1]	87.5 (67.6-97.3)	76.7 (57.7- 90.1)
Negative predictive value[1]	60.5 (44.4- 75)	91.9 (78.1-98.3)

[1]% (95% confident interval), [2]ratio (95% confident interval)

We also analyzed the sensitivity and specificity of US for detecting each type of supraspinatus tear. We found high sensitivity (88.5%) and high specificity (82.9%) in detecting full-thickness tears but low sensitivity (55.3%) and high specificity (89.7%) in detecting partial-thickness tears. Our results are similar to those reported in previous studies. In a systematic review by Farooqi et al., ultrasound showed a sensitivity of 88% and specificity of 93% for detecting a full-thickness tear of the rotator cuff, and a sensitivity of 65% and specificity of 86% for detecting a partial-thickness tear.[5]

In 10 of 38 shoulders (26%), US missed a supraspinatus tear which was identified by MRI as a partial-thickness tear. The location of the lesion was an important factor in the misinterpretation. Intrasubstance tears and articular side tears are difficult to detect, especially in small lesions.[14,15] For the underestimated group in this study, we consulted the radiologist to get further information regarding the tear's location. There were 2 shoulders with intrasubstance tears and 6 shoulders with articular side tears (Figure 2). Waldt et al. found that the ability to detect small partial-thickness supraspinatus tears by US was limited due to it being difficult to distinguish them from tendinopathy or tendinosis.[16] Tendinopathy was seen as hypoechoic as well. Moreover, a calcified tendon causes an error in interpretation because the calcified stone reflects ultrasound waves, allowing less energy to pass through the area behind it, like an acoustic shadow obscuring the lesion. Our study found 5 shoulders with tendinopathy or calcification in the underestimated group.

Another reason that US had low sensitivity in detecting partial-thickness supraspinatus tears was the overestimation of tears using ultrasound with some partial-thickness tears being identified as full-thickness tears. There were 7 of 38 shoulders (18%) with this error type. Teefy et al. reported that extensive partial-thickness tears involving greater than 50% of the cuff resemble full-thickness tears because the structures of the rotator cuff are deformed.[17]

The sensitivity of US for detecting full-thickness supraspinatus tears was higher than that for partial-thickness tears. We missed only 3 of 26 shoulders (11%) with full-thickness tears that ultrasound revealed to be partial-thickness tears. Rutten et al. conclude that the misinterpretation may be caused by granulation or that bursal synovial tissue may fill in a full-thickness tear, thereby impeding sonographic visualization.[18]

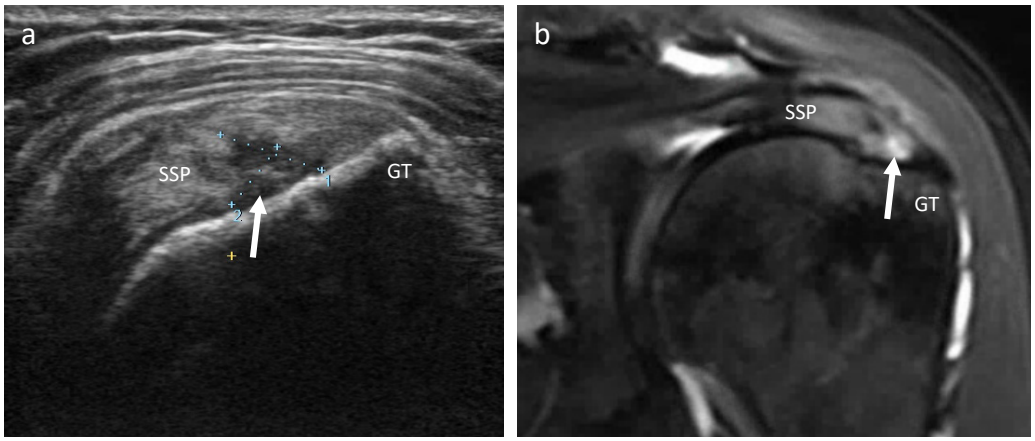

Figure 1. Partial-thickness supraspinatus tear. (a) Ultrasound (long axis) showed an articular side tear (arrow) of the supraspinatus tendon (SSP). (b) The oblique coronal T2-weighted fat-suppressed MRI showed the same configuration of the partial-thickness tear (arrow) of the supraspinatus tendon (SSP). Abbreviations: GT = greater tuberosity

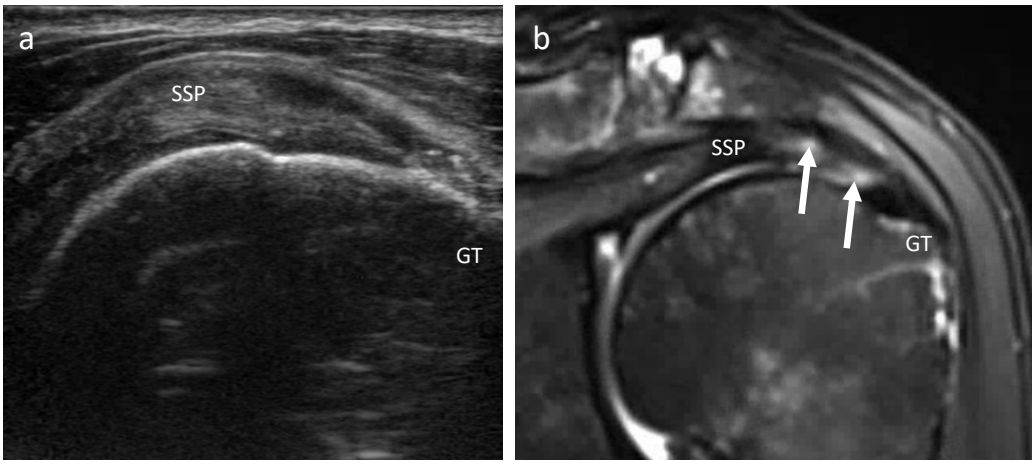

Figure 2. Ultrasonographic imaging underestimated partial-thickness supraspinatus tears. (a) Ultrasound (long axis) showed no tear of the supraspinatus tendon (SSP). (b) The oblique coronal T2-weighted fat-suppressed MRI showed an articular side tear (arrows) of the supraspinatus tendon (SSP). Abbreviations: GT = greater tuberosity

The critical weakness of US is that it is operator-dependent. That is, the result depends on the expertise of the sonographer. Yazigi et al. studied the accuracy of US using MRI as a reference standard and discovered that it has a low sensitivity (36%) but a high specificity (91.7%) for detecting all types of supraspinatus tears.[19] In the Yazigi study, the US operators were general radiologists, not musculoskeletal radiologists, so the sensitivity of ultrasound was low. In our study, the sensitivity was higher which could be the result of clinically relevant evaluation of the US operator.

One factor that may potentially have affected the sensitivity and specificity of US for detecting supraspinatus tears was that the US was performed by a physiatrist, not a musculoskeletal radiologist. However, the results showed good sensitivity, sufficient for screening supraspinatus tears in patients with shoulder pain. In the opinion of the authors, clinic-based US performed by a physiatrist has several advantages including real-time assessment, patients being more comfortable, being more cost-effective, requiring less time, and being more accessible, making it suitable for tertiary care hospitals. Additionally, US performed by a physiatrist can aid in the initial diagnosis and initial planning of treatment, especially in conservative treatment patients. In cases where severe pathology is found, the patient can then be referred to a specialist. MRI may also be performed to determine the exact location and size of the injury, aiding the planning of surgery.

There were some limitations of this study. First, the US findings were only compared with MRI but not with surgical findings, the gold standard, because most patients did not undergo surgery. Second, the US diagnosis, which is operator-dependent, was performed by only one physiatrist, so the results are specific to that examiner and cannot be generalized to other physiatrists. However, the results did show the accuracy of US done by a physiatrist after 1 month-training in musculoskeletal US, information which should be useful to physiatrists who are new to musculoskeletal US. Third, as it was a retrospective study, there was potential for a selection and information bias. We did not define the type of partial-thickness tears as articular, bursal, and intra-tendinous in both US and MRI. Additionally, the physiatrist who performed the ultrasound knew the patient's history and the results of clinical examination. Although those factors might have inflated the diagnostic accuracy of ultrasound, the US was performed in a real situation involving the clinical practice of a physiatrist. Lastly, the sample size was relatively small. A positive likelihood ratio of US for detecting all-type supraspinatus tears could not be calculated because there were no false positive cases. Future studies are needed which include a larger number of patients with shoulder pain and need to be conducted as prospective studies.

Conclusions

Shoulder US by a trained physiatrist showed high sensitivity and specificity for detecting supraspinatus tears diagnosed by MRI. Trained clinicians who are new to musculoskeletal ultrasound could use it in clinical-based evaluation of supraspinatus tendon tears for initial diagnosis and management.

Disclosure

The authors declare no conflicts of interest.

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Original Article

The Multiple Mini-Interview for Physical and Rehabilitation Medicine Residency Admissions: Reliability and Acceptability

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ABSTRACT

Objectives: To evaluate the reliability and acceptability of using the multiple mini-interview (MMI) for Physical and Rehabilitation Medicine in the residency admission selection process.

Study design: A retrospective cross-sectional study.

Setting: Department of Rehabilitation Medicine, Maharat Nakhon Ratchasima Hospital, Nakhon Ratchasima, Thailand.

Subjects: Candidates for the Physical and Rehabilitation Medicine residency program in November 2022 and interviewers who evaluated the candidates using the MMI.

Methods: The MMI consisted of 6 ten-minute structured interview scenarios mapped with the expected competencies of the candidates. Some parts of the traditional interview were included, e.g., the candidates presenting themselves in station 1 where two interviewers, faculty members and residents, evaluated the candidates independently without discussion among themselves. Interviewers used scoring forms to evaluate the overall performance of the candidates in each MMI using a rating scale of 1 to 10 with an open section for comments. Reliability within each of the MMI stations was determined by intraclass correlation coefficients (ICC). The candidates and interviewers completed an anonymous survey questionnaire regarding the MMI. Candidates' responses to the open-ended questions were recorded.

Results: A total of 12 interviewers and seven candidates participated in the MMI process on the day of the interviews. The overall satisfaction of the candidates and interviewers with the 70-minute MMI was positive. Both candidates and interviewers thought the MMI was fair, decreased bias, and could efficiently evaluate the candidates' performance and strengths. Most of the interviewers (83%) had score differences of at most 3 points for each candidate, which indicates the ability to discriminate between the candidates was quite low. The ICCs of the six MMI stations were 0.34, 0.29, 0.64, 0.95, 0.88, and 0.77. The ICC for MMI scores across all stations was 0.7.

Conclusions: The MMI is a reliable Physical and Rehabilitation Medicine residency admission method. The ICC of 4 of the 6 stations was acceptable. The MMI's high acceptability among both candidates and interviewers, especially in terms of fairness and decreased bias, allowed efficient evaluation of the candidate's performance and strengths.

Keywords: interview, physical and rehabilitation medicine, internship and residency, medical education

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Introduction

The selection of medical school and residency training candidates involves evaluation of cognitive and non-cognitive attributes. Cognitive abilities are evaluated by means of either a written examination or previous academic performance, e.g., grade point average (GPA) and National license examination scores (NL). Traditional interviews, conducted face-to-face with either one or a panel of interviewers using structured questions, is a standard selection process method. The objective is to evaluate interpersonal and behavioral attributes of the candidates. However, there have been questions regarding interviewer bias, reliability, and validity.[1] Multiple mini-interviews (MMI) were introduced by Eva et al. in 2004.[2] Using a "multiple sample-based" approach with an OSCE-style exercise, MMI is intended to assess non-cognitive attributes such as communication skills, critical thinking, and ethical decision-making. The MMI has been used in undergraduate and postgraduate admissions around the world.[3-10] Postgraduate applicant pools generally have fewer and more homogeneous candidates than undergraduate pools.[3]

A 2019 review of the MMI by Ali, S et al. reported that the MMI has high internal consistency and item-total correlation for each station, ranging from 0.53 to 0.96.[11] A total of 5 to 12 stations were studied and showed good G coefficients.[11] A previous study in a cardiology residency program with ten stations showed a relative G coefficient between 0.56 and 0.73.4 The duration of the station interviews has been studied, with 5-to-8-minute working times reflecting adequate reliability.[11] A study of resident selection for the Physical and Rehabilitation Medicine program in Canada which involved four 15-minute stations was published in 2011.[5] The intraclass correlation coefficients (ICC) ranged from 0.1 to 0.69, and the ICC between stations ranged from -0.45 to 0.47. There was sufficient inter-rater reliability in three out of four MMI stations, while the

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overall MMI had moderate reliability.[5] In Thailand, many medical schools currently use the MMI as a selection method, but published research is limited.[12]

The Department of Rehabilitation Medicine, Maharat Nakhon Ratchasima Hospital has been a training center for the Physical and Rehabilitation Medicine residency program since 2018, accepting two new residents per year. Responding to the growing demand for physiatrists in the public health service, the number of candidates has increased. The yearly residency program's acceptance rate in Thailand has decreased from 69% in 2019 to 51% for the 2023 training year. The selection process for candidates is intended to measure the expected competencies that result in successful residency graduates and satisfied, capable physiatrists working in government hospitals.

The traditional interview has been used since residency training was begun in 2018 and consists of a 30-60-minute interview with each candidate conducted by a panel of 4-6 interviewers. Scores from the interviews are combined with information from the candidates regarding their experience during their internship period and the hospitals that give them a position after graduating from the training. The traditional interview method was adequate when there were only a small number of candidates and thus a low level of competition. Because of the advantages of the MMI, our department's committee decided to use the MMI instead of the traditional interview process for residency admission in 2022 with the MMI interview portion counting for 65% percent of the candidate's total score. Evaluating the reliability and acceptability of this first experience with the MMI presents a challenge to both the hospital committee and to other stakeholders. This study aimed to evaluate the reliability and acceptability of the multiple mini-interview (MMI) for Physical and Rehabilitation Medicine residency admission.

Methods

Setting

Department of Rehabilitation Medicine, Maharat Nakhon Ratchasima Hospital, Nakhon Ratchasima, Thailand.

Study design

A retrospective cross-sectional study was performed. The present study was approved by the Ethics Committee of Maharat Nakhon Ratchasima Hospital (No.140/2022).

Participants

An anonymous questionnaire survey was conducted with seven candidates and twelve interviewers after completion of the interviews.

The multiple mini-interview (MMI)

The seven competencies expected of the candidates identified by a Department of Rehabilitation Medicine committee included: 1) knowledge and skills in patient care, 2) interpersonal skills and teamwork, 3) communication skills, 4) reasoning, problem-solving, and management skills, 5) responsibility and professionalism, 6) continuous professional development, and 7) committed to the career (Table 1), competencies which correlate with the outcomes when graduating from the residency program.

The MMI consisted of 6 ten-minute structured interview scenarios. The different scenarios were developed by the committee and correspond to the expected competencies of the candidates. In addition to the MMI, an abbreviated version of the traditional interview process was included in station 1.

The two interviewers in each station included eight faculty members (six physiatrists, one nurse, and one occupational therapist) and four residents. Each member of a station evaluated the candidates independently. The interviewers had been trained in the MMI scoring system and were blinded to information about the candidates. Candidates were identified by number only rather than by name. The interviewers were instructed not to discuss the candidates with each other through either verbal or non-verbal communication both during and after the evaluation of each candidate. A staff member collected the scoring forms for each candidate after each rotation after which the interviewers were not allowed to edit their scoring of previous candidates. A scoring data spreadsheet which included appropriate evaluation formulas had been designed before the interviews by an expert with experience in evaluating medical students.

The scoring forms evaluated overall performance on communication skills, the strength of the discussion or performance, and the candidate's suitability for the medical profession.[6] The rating scale of 1 to 10 included descriptive terms, e.g., unsuitable, less suitable, satisfactory, above average, and

Table 1. The MMI blueprint showing the expected competencies of candidates in each station

Station number	Knowledge and skills	Interpersonal skills and teamwork	Communication skills	Reasoning, problem-solving, and management	Responsibility and professionalism	Continuous professional development	Committed to the career
1		⊙			⊙	⊙	⊙
2			⊙	⊙	⊙		
3	⊙		⊙	⊙	⊙		
4	⊙		⊙	⊙		⊙	
5	⊙		⊙		⊙	⊙	
6		⊙	⊙	⊙			

MMI, multiple mini-interview

outstanding. The form also included a space for comments. No candidate's name or other information regarding the candidate was recorded on the scoring forms. Because this was the first use of the MMI at this hospital, station 1, which was an abbreviated form of the traditional interview, had a maximum score of 15, while the other five stations each had a maximum score of 10, giving a total possible MMI score of 65.

Each station was located in a separate room each of which had been checked to ensure there was no sound interference among the stations. The scenarios of each station were posted at the entrance to the room. The candidates had 2 minutes to read the scenario followed by 8 minutes of response time at each station. The candidates were randomly assigned a number, which was their only identification during the interview. The initial station for each candidate was also randomly assigned, after which they rotated through the remaining stations in numerical order. Station 7 was a rest station. The candidates were informed of the MMI orientation before the interview process started. To help the candidates keep track of the time remaining, an audible signal was given at each station after 2, 9, and 10 minutes.

Outcome measurements

The scores from all interviewers for each candidate were evaluated to assess the reliability of the MMI. The opinions of the candidates and interviewers regarding the acceptability of the MMI were obtained by means of an anonymous questionnaire. The questionnaire included closed-ended questions regarding the usefulness of the MMI, the level of stress involved, the efficiency of the MMI in evaluating a candidate's performance and the candidate's preferences regarding the MMI and a traditional interview. Responses were marked as "strongly agree," "agree," "disagree," and "strongly disagree." Overall satisfaction was scored on a rating scale of 1 to 10, with 10 indicating greatest overall satisfaction. In addition, candidates were asked to respond to two open-ended questions about the interview experience and the strengths and limitations of the MMI. The candidates were also asked to vote for the stations that they "liked the most, "did it best," and which were "the most appropriate for the selection process."

Statistical methods

The demographic data of candidates and interviewers and the MMI scores are shown as percentage, mean, standard deviation (SD), minimum, maximum, and relative standard deviation (RSD).[6] A wide variance in scores (RSD) of each interviewer indicates that they were able to discriminate between the candidates in their station.

The reliability of the 6 MMI station scores was determined by intraclass correlation coefficients (ICC). A two-way mixed-effects model was used. The reliability within the same competency was similarly investigated. The ICC across the 6 MMI stations was calculated to determine overall reliability. Values of less than 0.5, 0.5-0.75, 0.75-0.9, and greater than 0.9 indicate poor, moderate, good, and excellent reliability, respectively.[13]

The candidates' and interviewers' opinions regarding the MMI were evaluated using numbers and percentages. Quotes from the open-ended questions were also recorded. Finally, MMI scores and previous academic performance were compared.

Results

Eight candidates applied for the residency program for the training year 2023, but only 7 candidates appeared for the interview. Demographic data of the candidates are shown in Table 2. Four were male. The mean age was 27.57 years (range 27-31, SD 0.61). Five candidates graduated from medical school in the Collaborative Project to Increase Production of Rural Doctor (CPIRD). The mean grade point average score (GPA) was 3.11 (2.58-3.71, SD 0.42). The mean total MMI score was 49.7 (44.38-53.5, SD 3.48) out of a possible 65 points.

The ICC within stations (Table 3) ranged from 0.29 for the conflict resolution station to 0.95 for the searching on the Internet and presenting in English station. From the guidelines of reporting ICC,13 there were two stations with very good reliability, two stations with good reliability, one with moderate reliability, and two with poor reliability. The ICC within competencies is shown in Table 4. Moderate reliability was found for most competencies with the exception of interpersonal skills and teamwork which had good reliability. The ICC for MMI scores across all stations was 0.7.

Table 5 summarizes the MMI scores from each interviewer. From the total score of 10 in each station, the interviewers scored each candidate between 3 and 10 points, with a score difference among the interviewers of between 1 and 5. Ten of the twelve interviewers (83%) had an MMI score difference of at least 3 points. The scores by five interviewers had a relative standard deviation (RSD) below ten: 1-A, 1-B, 2-A, 3-B, and 6-B.

Table 2. Demographic data of the candidates (N=7)

Category	Value
Age (years)[1]	27.57 (0.61)
Gender[2]: male	4 (57.14)
Time since graduation from medical schoo[l2]	
< 3 years	5 (71.43)
> 3 years	2 (28.57)
Undergraduate medical school	
CPIRD	5 (71.43)
Non-CPIRD	2 (28.57)
GPA[1]	3.11 (0.42)
NL1[1]	64.42 (4.62)
NL2[1]	61.14 (4.66)
Mean total MMI score[1]	49.7 (3.48)

CPIRD, Collaborative Project to Increase Production of Rural Doctor; GPA, Grade Point Average score; NL, National License Examination score; MMI, Multiple mini-interview
[1]Mean (SD), [2]Number (%)

Table 3. ICC within stations

Station	Details	Assessors	ICC	95%CI
1	Traditional interview	One staff, one resident	0.34	-2.83, 0.89
2	Conflict resolution	One staff, one resident	0.29	-3.15, 0.88
3	Telling bad news	One staff, one nurse	0.64	-1.07, 0.95
4	Searching on the Internet and presenting in English	One staff, one resident	0.95	0.72, 0.99
5	Physical examination and writing medical records	One staff, one resident	0.88	0.27, 0.97
6	Team building with wooden blocks	One staff, one OT	0.77	-0.35, 0.96

ICC, Intraclass correlation coefficient; 95%CI, 95% Confidence interval

Table 4. ICC between stations with the same competencies

Station	Competencies	ICC	95%CI
3,4,5	Knowledge and skills	0.61	-0.10, 0.92
1,6	Interpersonal skills and teamwork	0.75	0.21, 0.95
2,3,4,5,6	Communication skills	0.62	-0.02, 0.92
2,3,4,6	Reasoning, problem-solving, and management	0.64	0.01, 0.93
1,2,3,5	Responsibility and professionalism	0.59	-0.13, 0.92
1,4,5	Continuous professional development	0.73	0.23, 0.95

ICC, intraclass correlation coefficient; 95%CI, 95% confidence interval

Table 5. MMI scores for each station and interviewer

Station	Minimum score	Maximum score	Score difference	Score mean	SD	RSD
1-A	8	10	2	9.07	0.68	7.50
1-B	7	9	2	8.57	0.73	8.52
2-A	7	9	2	8.29	0.7	8.44
2-B	6	9	3	7.5	1.1	14.67
3-A	6	9	3	7.43	1.18	15.88
3-B	7	8	1	7.43	0.49	6.59
4-A	7	10	3	8.14	1.12	13.76
4-B	6	9	3	7.14	1.36	19.05
5-A	5	9	4	7	1.31	18.71
5-B	5	8	3	7	0.93	13.29
6-A	3	8	5	5.86	1.55	26.45
6-B	6	8	2	7.14	0.64	8.96

SD, Standard deviation; RSD, Relative standard deviation

The correlation between past academic performance and the MMI scores were investigated. GPA was categorized into three groups (2.5-2.99, 3.0-3.49, and 3.5-4.00). National license examination scores parts 1 & 2 and grades in Rehabilitation Medicine subjects were divided into 2 groups. The dividing lines were 60 points and B+ (3.5), respectively. Years since graduation (3 years and more than three years) and medical schools (CPIRD and non-CPIRD) were also studied. MMI scores between these variable groups showed no statistically significant difference.

Overall satisfaction with the MMI on a scale of 1 to 10 showed a range of 5 to 9 from the candidates and 7 to 10 from the interviewers. More than 70 percent of the candidates gave a score of 7 or more.

The acceptability survey was completed by 100% of the candidates (Figure 1). Six of 7 candidates stated they had sufficient time to prepare for each scenario. All candidates agreed that they were able to display their strengths effectively. They also mentioned that the MMI is fair, decreases bias, and is more appropriate than the traditional interview for residency admission. Five candidates preferred the MMI to the traditional interview, although most candidates felt that the MMI was more stressful than the traditional interview.

All 12 interviewers completed the acceptability questionnaire. Their mean age was 38.75 years (28-60, SD 9.67). Ten were female. About half of the interviewers (58%) had previous interview experience. All the interviewers agreed that the candidates had sufficient time to prepare for each scenario and that they were able to exhibit their strengths efficiently (Figure 2). All answered that the MMI is fair. Ten interviewers (84%) agreed that the MMI is more stressful for the candidates than the traditional interview although most of the interviewers (84%) preferred the MMI to the traditional interview. Regarding the interview process, all agreed that the scoring system was appropriate. Eleven of the 12 interviewers reported that they had received sufficient training prior to the

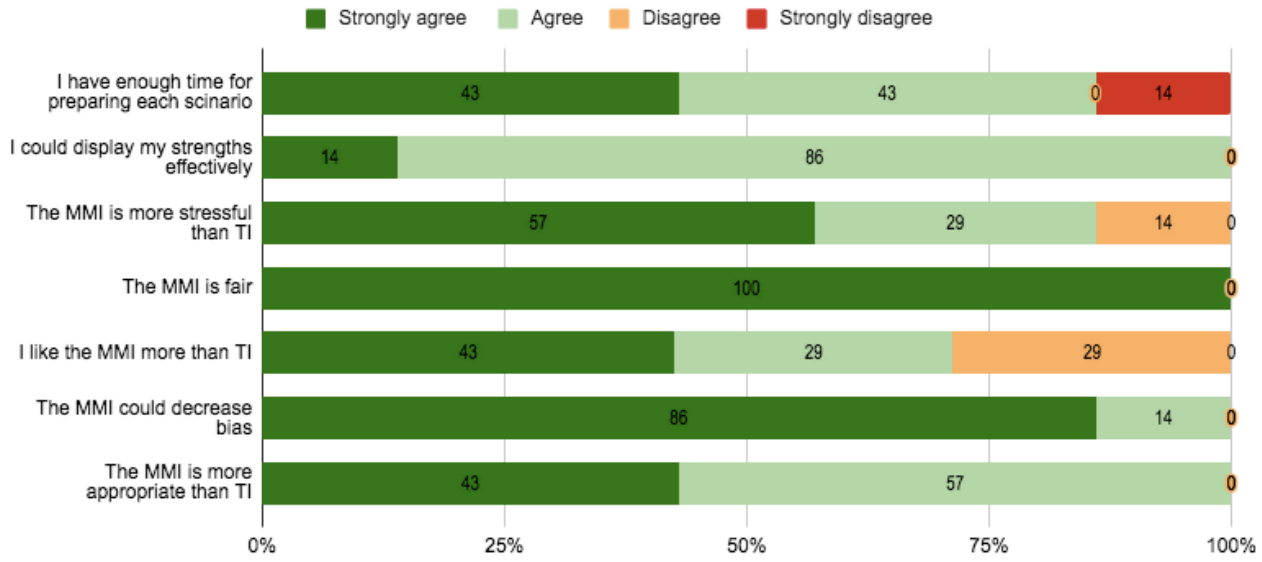

Figure 1. Acceptability of the MMI by candidates (percentage of different ratings of agreement)

MMI, multiple mini-interview; TI, traditional interview

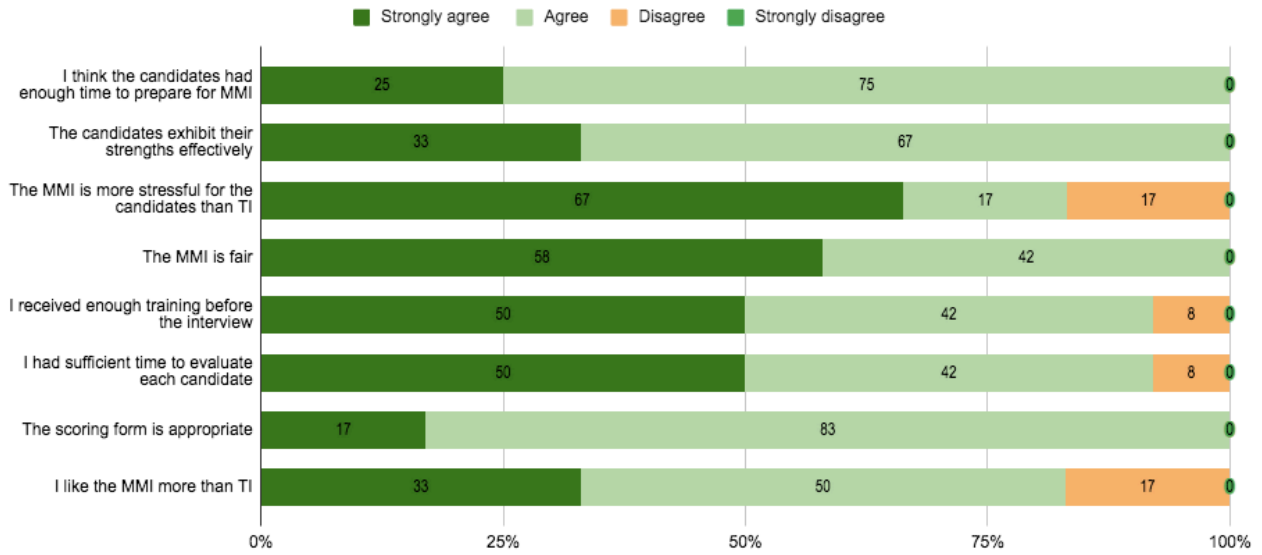

Figure 2. Acceptability of the MMI by the interviewers (percentage of different ratings of agreement)

MMI, multiple mini-interview; TI, traditional interview

interview and that they had sufficient time to evaluate each candidate.

Answers to the open-ended questions about the candidates' feelings toward the interview experience showed they were excited and optimistic about the new method, especially its fairness, decreased bias, and the multiple performances evaluated. Examples of their own quotes include: "I am so excited" (candidate number 1, 2 and 5, male 27 years old); "The interviews are appropriate and comprehensive" (candidate number 7, female, 26 years old) and "It was fun. I performed something I have never done before" (candidate number 5, male, 27 years old). However, the feeling of stress and being under pressure were also mentioned, e.g., "The multiple stations made me feel pressured" (candidate number 4, female, 27 years old)" and "Before the interview, I felt stressed because it was new and I have had no experience with MMI. However, in the actual station, I was not so much stressed as excited" (candidate number 3, female, 27 years old), and "If the performance at the first station is not done well, it may create discouragement for the following stations" (candidate number 4, female, 27 years old).

The interviewers' opinions were similar to those of the candidates. One suggested combining the MMI and the traditional interview. Examples of the interviewers' comments include: "Under stressful conditions, the candidates may not exhibit their true strength," "The scoring form should add a description section to evaluate the candidates more clearly," and "I could not see the candidates' performance in other stations."

The candidates were asked to vote for the station they liked the most, the one where they did their best, and the one most appropriate for the selection process. Five candidates liked station 1 the most, and the other two liked stations 2 and 6. Most chose station 3 and thought they did their best in station 1. As to the most appropriate station for selecting residents, 5 candidates chose station 1, the other 2 chose stations 2 and 5.

Discussion

This is the first study in Thailand to evaluate the reliability and acceptability of the multiple mini-interview (MMI) for residency admission. The MMI is a multiple-station interview process that can evaluate multiple competencies of the candidates. It is a reliable method for identifying individuals for Physical and Rehabilitation Medicine residency admission with an acceptable ICC in 4 of the 6 stations and an 0.7 overall reliability. High overall satisfaction and positive feedback from the candidates and interviewers was reported in this study. Although preparing the scenarios, formulating simulated patients, and analyzing evaluation forms requires time and resources, the time required on the interview day was significantly less than that for traditional interviews. The traditional interview process takes approximately 3.5 hours, but the MMI required only 70 minutes for interviewing seven candidates. The upshot is that the MMI process is feasible and can be applied successfully.

As shown in Table 3, four of six stations had an ICC of 0.64 to 0.95. This MMI had at an acceptable level of reliability, consistent with previous studies.[5,6,7] The scenarios of these four stations included performance that was easily evaluated. The scenarios of searching on the Internet and presenting in English had the highest ICC of 0.95. The stations of performing a physical examination and of writing a medical record and team building with wooden blocks both also had good reliability with ICC of 0.88 and 0.77, respectively. The station 3 telling bad news, had an ICC of 0.64, indicating moderate reliability.

The stations that had low reliability were stations 1 (ICC 0.34) and 2 (ICC 0.29). The composition of these two stations should be discussed. For station 1, the scenario was similar to the traditional interview but shorter, reduced from around 30 minutes to 8 minutes. During those 8 minutes, the candidates were asked to present their work experience, responsibility, professional development, readiness for residency training, and their intention to be a physiatrist in a government facility. The ICC in this station was 0.34, indicating the reliability within this station was low. The two interviewers in this station each scored candidates in different directions. The range of scores from interviewers in this station was 2 points, with RSDs of 7.5 and 8.52. The ability to discriminate between the candidates was poor as well. Station 1, on the other hand, was the most liked, did it best, and was considered the most appropriate for residency selection in the opinion of the candidates, although it had some limitations in terms of reliability and in the ability to discriminate among candidates.

Station 2 also had low reliability. The scenario was the candidate communicating with a senior research co-worker in a conflict situation. The candidate was the principal researcher, and the research had been accepted for presentation at an international conference. The senior co-worker and the candidate both wanted to attend, but the hospital could provide a grant for only one person. The candidates were asked to talk with a senior co-worker about getting the grant. This station used a senior resident as the co-worker who interacted with the candidates. This resident was also the interviewer that evaluated the candidates. Some unintended bias might have occurred, especially in cases where there was emotional involvement. Other factors that resulted in this station having a low reliability may be related to the scoring form and to the degree difficulty in evaluating the performance of the candidate. The scoring form for overall performance used a rating scale which does not include a description of the expected performance. It may be difficult to judge the performance of individual interviewers because of differences in personal preferences.

The ICC between the stations that evaluated the same competencies is shown in Table 4. Most of the competencies had an ICC of 0.59 to 0.73. Interpersonal skills and teamwork were the only competencies that had good reliability with an ICC of 0.75. This result may be due to the fact that only two stations evaluated these competencies, whereas other competencies were evaluated by at least three stations. The MMI scenarios were mapped with the expected competencies. The good reliability between the same competencies was not surprising as reliability depends on the objectives of the scenarios. A previous study by Abri RA et al. used two scenarios to evaluate medical knowledge and five scenarios to measure behavioral knowledge. That study found the reliability scores between the 2 types of knowledge were independent.[7]

The MMI score differences reported by the interviewers are shown in Table 5. Only 2 of 12 interviewers had a score difference of more than 3 points. Only one interviewer gave an RSD of more than 20, 6 interviewers gave an RSD between 10 to 20, and 5 interviewers gave an RSD below 10. The wide variance in scores (RSD) among the interviewers indicates that they were able to discriminate between the candidates in the station. Most of the interviewers' MMI station scores in the present study were lower than in a previous study, in which most of the interviewers gave an RSD of more than 20.[6] The small numbers of candidates may be the main reason for this difference: there were only 7 candidates in this study whereas a previous study included 187 candidates.[6] In the present study, interviewers who were not directly involved in training, e.g., a nurse (3-B) and an occupational therapist (6-B), gave narrow scores of 1 and 2 with low RSD which may be another factor affecting the variance. The last factor involves the details of the scenarios that were mentioned earlier. Both interviewers in station 1 (1-A and 1-B) and one interviewer in station 2 (2-A) gave a score difference of 2.

Scenarios that are clear, valid, and involve performance that can easily be observed should be considered for future MMI.

The overall level of satisfaction and acceptance of the MMI as evidenced by the candidates' and interviewers' opinions were high, especially in terms of fairness, decreased bias, and the capacity to evaluate the candidates' performance and strengths efficiently which is consistent with previous studies.[7-9] Limitations of the MMI were creation of stress and provoking anxiety, findings consistent with the previous studies of Boysen-Osborn M et al.[8] and Sklar M et al.[10] Being new to and not familiar with the MMI may have led to some degree of stress for both candidates and interviewers.

Sklar M et al. described how MMI resulted in a loss of interaction between candidates and interviewers, e.g., getting to know each other and learning more about the residency program. In the traditional interview, candidates were given the opportunity to discuss their educational background, extracurricular activities, and desire to be a doctor in that specialty.[10] A study by Boysen-Osborn M et al. found that candidates felt the MMI neglected the "getting to know you" aspect. Some mentioned that the MMI was "one-sided," and candidates could not discover if the program would really suit them. Many candidates thought the traditional interview should be added to the MMI.[8] Because all candidates already had had at least one week of elective in our department, they had all been afforded the opportunity to get to know the training program and the staff members. That experience should have provided the "getting to know you" aspect. Combining the traditional interview and the MMI was suggested by one interviewer in the present study.

Previous academic performance such as GPA and NL scores have commonly been part of interviewers' considerations in resident selection. The present study, however, found that differences in previous academic performance did not affect the total MMI scores. This is not surprising as the MMI is intended to evaluate non-cognitive attributes, while previous academic performance is mainly evaluated by written examinations which measure cognitive attributes. The traditional interview and the MMI both aim to assess non-cognitive attributes which are correlated but which do not reliably lead to the same rank order,[10] i.e., these two interview methods evaluate different characteristics.

This study showed the relatively high level of reliability, acceptability, and feasibility of the MMI. This first-time experience, however, leaves room for improvement. Suggestions for enhancing the MMI include: 1) using appropriate scenarios that facilitate rapid evaluation of the candidates and which can be mapped with the expected competencies, 2) ensuring that the time used in each station appropriates with the scenarios, 3) using a scoring form that provides expected performance details as rubric scores, 4) adequately training interviewers, e.g., conducting a simulated MMI interview before the actual interview, especially in the case of new interviewers, 5) including stress-reducing techniques during the MMI, and 6) considering combining traditional interviews and the MMI.

There were some limitations of this study. First, this study had a small number of participants. Second, the study was conducted at only one small training center. The acceptability of the MMI may be different elsewhere. Finally, this was the first experience of the training center with the MMI, so the scenarios and the process of the interviews leave many areas for improvement.

Conclusions

The MMI is a reliable evaluation method for Physical and Rehabilitation Medicine residency admission. An ICC of 4 of the 6 stations is considered acceptable. The MMI has a high acceptability among candidates and interviewers, especially in the areas of fairness, decreased bias and ability to evaluate the candidate's performance and strengths efficiently.

Disclosure

The authors have no conflict of interest.

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Original Article

Evertor Muscle Function as a Predictor of Recurrence of Deformity Following Treatment of Pediatric Idiopathic Clubfoot, A Cohort Study

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ABSTRACT

Objectives: This study aimed to evaluate the relationship between evertor muscle function and the recurrence of deformity following treatment of pediatric idiopathic clubfoot.

Study design: A cohort study.

Setting: Maharat Nakhon Ratchasima hospital, Nakhon Ratchasima province, Thailand.

Subjects: Sixty-two children with idiopathic clubfoot.

Methods: Children with idiopathic clubfoot who were treated and followed up at Maharat Nakhon Ratchasima hospital, Thailand for a minimum of 2 years were enrolled. After the initial success of serial manipulation and plaster casting, parents were advised regarding the child's foot evertor muscle training and Achilles and tibialis posterior tendon stretching exercises without using the Denis Browne bar. Demographic data included age at onset, gender, Dimeglio score, number of casts required for initial correction, the need for Achilles tenotomy, and evertor muscle grading before and after training. All children were evaluated regularly for signs of recurrence. Univariate analysis was used to analyze the relative risk of recurrence with good and poor evertor muscle function.

Results: Sixty-two children with clubfoot, 42 males (67.7%) and 20 females (32.3%) were enrolled. Twenty-six (41.9%) children had bilateral deformities. Recurrence of deformities after treatment was documented in 22 children (35.5%). Severe deformity at presentation according to the Dimeglio score was a significant predictor of recurrence (p 0.012). After adjusting for relative risk base on the Dimeglio score, the recurrence was significantly higher in the poor evertor muscle function group with an adjusted RR of 9.59 (95%CI 3.43 - 26.80).

Conclusions: Evertor muscle function is associated with the recurrence rate of pediatric idiopathic clubfoot.

Keywords: recurrent clubfoot, evertor muscle function, evertor muscle grading

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Introduction

Clubfoot is a complex three-dimensional deformity. It is almost universally agreed that the initial treatment should be non-operative with serial manipulation and plaster casting according to the Ponseti method[1] with or without Achilles tenotomy, followed by the use of a brace to maintain the correction. Success rates for the initial treatment of idiopathic clubfoot were reported to be more than 90%.[2-4] Previous studies have identified clinical and demographic risks for recurrence, which has often been attributed to poor compliance with the recommendations for regular use of a foot abduction brace after the correction has been achieved.[5-8] Consistent use of the brace, however, cannot be the only factor determining recurrence. Muscle imbalance is recognized as a cause of joint deformity in pediatric orthopedics, and subtle imbalance around the ankle joint is an etiological factor in both idiopathic and non-idiopathic clubfoot deformity.

Only a few studies have addressed the specific issue of evertor muscle function as a contributing factor to recurrence in children with idiopathic and non-idiopathic clubfoot. Moreover, none of those studies specify whether the evertor muscle had been trained after the initial correction of clubfoot deformity. Rather, the studies mentioned only static immobilization using a foot abduction brace. In a study by Gelfer et al.,[9] all cases complied fully in using the foot abduction brace 23 hrs a day for three months and then 12-14 hrs a day during sleep and nap times after that. At the mean age of follow-up, 3.2 years (range 2.1-6.3 years), Gelfer reported that after the initial deformity had been corrected, there was no change in evertor muscle activity over time. Eamsobhana et al.,[10] who also prescribed wearing the foot abduction brace 23 hrs a day for the first 3 months and during sleep and nap time 8-10 hrs a day for another 4 years, reported no change in evertor muscle activity grading at six months after initial complete correction. However, muscle development during the infancy stage is crucial and can be encouraged through various activities, e.g., hand grip strengthening while the parent's finger touches the baby's palm. If the parent does this often, the finger will become difficult to pull out of the baby's grasp. It was also proposed that the evertor muscle could be strengthened by touching stimulation along the lateral dorsal surface of the toes

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to the foot's lateral border. Because no quantitative method of measurement is currently available which could provide helpful information on the foot muscles involved in this infant age group, the principle author of this study proposed a qualitative method which involves categorizing responses into five grades (Figure 1). In Infants, the function is measured as the observed response after manual stimulation over the lateral border of the foot which is then compared to a standard set of pictures. In older children, the muscle function is tested by asking the children to evert the foot as much as possible and noting the degree of eversion.

This study aimed to assess the improvement of the evertor muscle after training without the foot abduction brace protocol as well as the relationship between evertor muscle function and recurrence rate in children with idiopathic clubfoot.

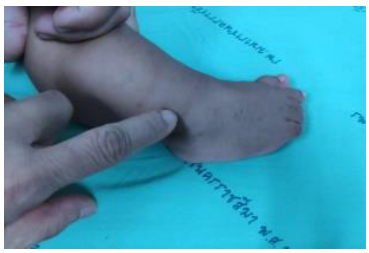
Methods

Children with idiopathic clubfoot, aged less than six months, who were treated at Maharat Nakhon Ratchasima hospital, Thailand, from January 2006 to December 2014 and who were followed up for at least two years were enrolled in this study. Children who had received previous treatment from other hospitals, previous surgery to the foot, or who were lost follow-up were excluded. In children with bilateral deformities, only one side was randomly selected. The Maharat Nakhon Ratchasima Hospital Institutional Review Board gave ethical approval for the study. The sample size was calculated using OpenEpi, Version 3, open-source calculator—SSCohort with a 95% confidence interval and 80% power. Using the Eamsobhana study as a reference, the ratio of good evertor to poor evertor was 1.8, the recurrence with a good evertor was 3.9%, the recurrence with a poor evertor was 57, so the necessary sample size was calculated to be 19 good evertor cases and 11 poor evertor cases, a total of 30 cases.

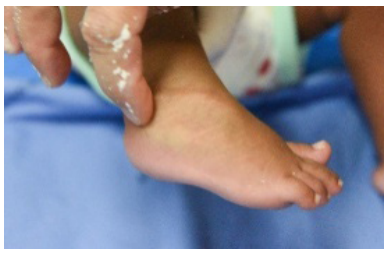
Sixty-two feet (42 males,20 females) were enrolled in this study. Baseline demographic data, including the age at onset, sex, severity (Dimeglio score), and evertor muscle function, were recorded.

The initial treatment consisted of serial manipulation and casting according to the Korat technique.[11] The Korat technique of manipulation and casting was developed at Maharat Nakhon Ratchasima hospital in the Nakhon Ratchasima (Korat) province of Thailand. The technique involves simultaneous pushing and pulling in supination, combining principles of both Kite's and Ponseti's manipulation methods. The cast was changed weekly to correct the clubfoot deformity until the normal foot form was achieved. The dorsal surface of all toes were exposed while casting. In addition, the parents were encouraged to repeat touching stimulation of the dorsal surface of the lateral toes to strengthen the toes extensor and to do the isometric evertor muscle exercise. The number of casts used was recorded. In cases of a very tight heel cord or inability to achieve passive dorsiflexion of the calcaneus through zero degrees even when holding the knee at 90 degrees of flexion, early percutaneous needle Achilles tenotomy was performed. After correction was achieved and with the patient's foot in a good position, evertor muscle function was evaluated using specific grading as described above.

After that, the parents were encouraged to follow an exercise program[11] aimed at continued stretching of the Achilles tendon and tibialis posterior muscles and strengthening the peroneus muscles. Parents were instructed to repeat the program as often as possible, for a daily minimum of 200 stretches (5 seconds for each stretching) and 200 strengthening stimulations (1-2 seconds for each strengthening stimulation), which

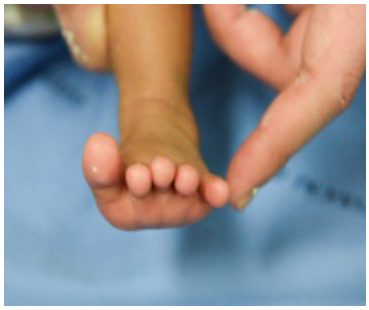


Grade 0: No muscle contraction seen.

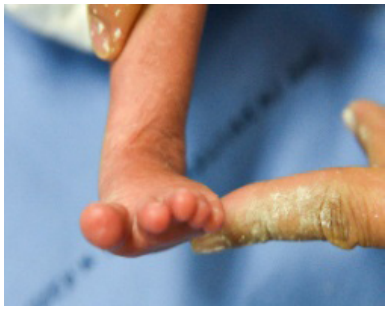


Grade I: Prominence of the peroneus tendon under the skin seen only while stimulating

Grade II: Some foot eversion, but unable to reach perpendicular to the leg axis



Grade III: Eversion perpendicular to the leg axis



Grade IV: Eversion beyond perpendicular to the leg axis

Figure 1. Visual grading of evertor muscle function

could be divided into 2-4 sessions. No Denis Browne bars were used. All children were assessed regularly for signs of recurrence, defined as deterioration of the deformity component (cavus, forefoot adductus, heel varus, and equinus).

If a child had a recurrence of the deformity, the evertor muscle function was evaluated after the presentation. In non-recurrence cases, the evertor muscle function was evaluated at 2 years. Evertor muscle grades III and IV were classified as good evertor muscle function.

A single pediatric orthopedist documented all data.

Statistical analysis

STATA Statistics version 12 was used to analyze the data. Descriptive statistics are expressed as median, IQR (for skewed data), and percentage (for grouped data). Univariate analysis was used to assess the relative risk of recurrence between groups. Statistically significant difference for all between groups tests was defined as $p < 0.05$. The adjusted RR and the 95% confidence interval (CI) were used to analyze the association between evertor muscle functions and the recurrence.

Results

The demographic data and clinical characteristics after treatment of the good evertor muscle function group and the poor evertor muscle function group are shown in Table 1. There was no significant difference in the age of onset, sex, severity (Dimeglio score), number of casts, and percentage of early tenotomy between groups.

At baseline, all the clubfoot children had poor evertor muscle function. After serial manipulation and casting, 57 children had poor evertor muscle function, and only 5 children had good evertor muscle function. After training, 41 children developed good evertor muscle function, while 21 children still had poor evertor muscle function. The improvement of evertor muscle function during treatment is shown in Graph 1.

Recurrence was documented in 22 children (35.48%), and 19 had poor evertor muscle function. The incidence of recurrent idiopathic clubfoot in the good evertor muscle function group was 7.32%, and in the poor evertor muscle function group was 90.48% (Graph 2).

After adjusting for relative risk (Dimeglio score), children with poor evertor muscle function had a risk of recurrence of 9.59 times that of the good evertor muscle function group Table 2.

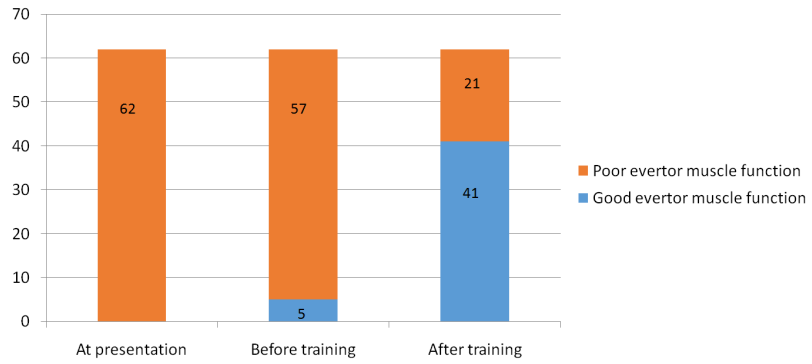
Discussion

The recurrence rate after treatment of idiopathic clubfoot ranges from 14% to 41%.[12] Some previous studies have identified clinical and demographic risks for recurrence in idiopathic clubfoot, with only lack of brace compliance being associated with poor outcomes.

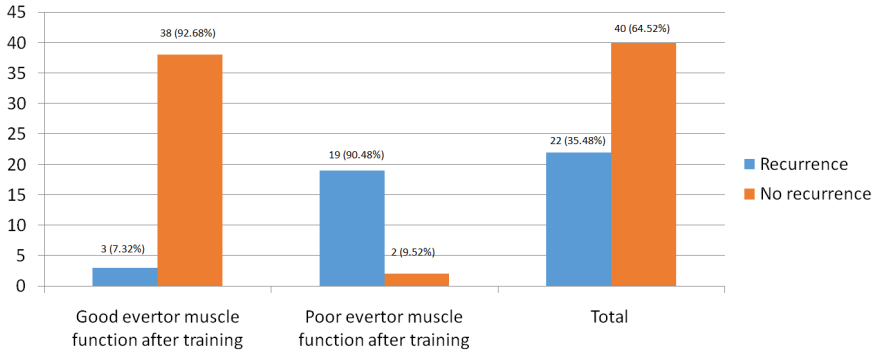
Table 1. Baseline demographic and clinical characteristics of clubfoot children comparing good and poor evertor muscle after training

	Good evertor muscle after training (N=41)	Poor evertor muscle after training (N=21)	*p*-value
Age of onset (days)[1]	17 [10-35]	16 [8-29]	0.33[a]
Sex female[2]	12 (29.27)	8 (38.09)	0.48[b]
Severity (Dimeglio score)[2]			
Mild	10 (24.39)	1 (4.76)	0.07[c]
Moderate	18 (43.90)	8 (38.10)	
Severe	13 (31.71)	12 (57.14)	
Numbers of casts[1]	3 [3-4]	3 [3-4]	0.90[a]
Early tenotomy[2]	24 (58.54)	12 (57.14)	0.64[b]

[1]Median [IQR], [2]number (%), [a]Mann-Whitney U test, [b]Chi-square test, [c]Fisher exact test



Graph 1. Proportion of patients with poor and good evertor muscle functions at initial presentation, before beginning training and after training



Graph 2. Proportion of patients with recurrence and no recurrence of deformity comparing good evertor muscle function after training and poor evertor muscle function after training plus both groups combined

Table 2. Relative risk of recurrence of deformity with good and with poor evertor muscle function

Factor	% Recurrence Crude	RR (95% CI)	Adjusted RR* (95% CI)
Good evertor muscle Function	7.32	1	1
Poor evertor muscle Function	90.48	12.37 (4.12-37.08)	9.59 (3.43-26.80)

*Adjusted for severity (Dimeglio score)

Edmonds and Frick[13] reviewed 187 clubfoot patients and found nine infants with clinical evidence of anterior and lateral compartment dysfunction. Of these nine infants, four (44%) had a recurrence despite a well-documented bracing regime.

Feldbrin et al.[14] performed electrophysiological studies on 52 children with 74 clubfeet and found isolated peroneal nerve damage in 27% of patients. An abnormal electrophysiological condition was a predictive factor for poor outcomes both in patients who were treated conservatively and those who were treated surgically, indicating that neurological abnormality might be one of the causes of recurrence.

Gelfer[9] studied 67 children (116 feet) with idiopathic and non-idiopathic clubfoot, and found that only poor evertor muscle function activity was associated with recurrence in both groups. That study also reported there was no change in evertor muscle activity over time once the initial deformity had been corrected. The cause of the recurrence may be neurological abnormality and may be due in all cases to prolonged immobilization with a foot abduction brace without evertor muscle strengthening exercise.

The present study showed an association between poor evertor muscle function and the recurrence of idiopathic clubfoot, similar to previous studies by Gelfer (2014),[9] Eamsobhana (2017),[10] and Little (2019)[15] which reported that only poor or absent evertor muscle function was found to be significantly associated with recurrence. However, the risk of recurrence in patients with poor evertor muscle activity was reported to be high (57% and 67.9%) in studies by Eamsobhana[10] and Little,[15] respectively.

The present study found the risk of recurrence of idiopathic clubfoot in children with poor evertor muscle function was 9.59 times higher than in those with good evertor muscle function after adjusting for relative risk as measured by the Dimeglio severity score. Nineteen of 21 cases (90.5%) with poor evertor muscle activity had recurrence after treatment, while only 3 of 41 cases (7.3%) with good evertor muscle had a recurrent deformity. The differences in the recurrence rate of poor evertor muscle in other studies may be due to differences in patients' idiopathic clubfoot severity level and the treatment protocol.

Because a foot abduction brace (FAB) was applied in all cases, this study supports that the evertor muscle function can be improved with appropriate muscle training. Little[15] reported that good evertor muscle activity was strongly predictive of no recurrence (negative predictive value=1) which invites further investigation as it is possible that in patients with good evertor muscle, a long period of FAB use may be unnecessary.

Evertor muscle training combined with the Achilles tendon and tibialis posterior tendon stretching exercises is an option for promoting the elimination of idiopathic clubfoot after correcting deformities by serial casting. The goal is to maintain normal foot form, prevent the recurrence of clubfoot deformities and optimize foot function. Another critical point is that the poor evertor muscle function in cases which are not getting better after training should be investigated further to identify the causes. Moreover, for the recurrent cases, early repeat serial casting either with or without Achilles tenotomy followed by prolonged use of a suitable orthotic device and a surgical plan for improving foot muscle balance such as tibialis anterior tendon transfer[16] are needed.

A limitation of this study is that adherence to the minimum of 200 stretching and 200 strengthening exercise repetitions a day of the exercise programs carried out by parents to optimize evertor muscle strength varied depending on the parents' diligence. Amazingly, some parents did the exercise program for their children up to 1,000 stretching and 1,000 strengthening repetitions a day. Further studies that closely monitor adherence

to exercise programs and that include design additional appropriate exercise programs are needed.

Another limitation is that ankle dorsiflexion and calf muscle function were not measured pre- and post-training. That information could have helped evaluate the success of Achilles tendon stretching and improvement of muscle balance.

Conclusion

Poor evertor muscle function is associated with higher rates of recurrence of deformity in pediatric idiopathic clubfoot. To minimize recurrence, the importance of exercises for the improvement of the evertor muscle should be emphasized to parents to help promote good outcomes following clubfoot treatment.

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Case Report

Riche-Cannieu Anastomosis Presenting in a Patient with Suspected Carpal Tunnel Syndrome: A Case Report

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ABSTRACT

Objectives: To present an anatomical variant detected from the non-clinical correlation of electrophysiologic findings in a patient suspected of carpal tunnel syndrome (CTS).

Study design: A case report.

Setting: Rehabilitation Unit of Nakhon Pathom Hospital, Nakhon Pathom, Thailand.

Subjects: A 77-year-old man with a history of numbness in both hands for six months who underwent electrodiagnostic evaluation of CTS.

Methods: The patient's medical record was reviewed, and a nerve conduction study (NCS) was conducted.

Results: The nerve conduction study was conducted to rule out other forms of peripheral neuropathy. Despite the thenar muscles' bulk and strength being preserved, it was not possible to record the left median compound muscle action potential (CMAP). Further ulnar nerve stimulation at the wrist and elbow, recorded at the left abductor pollicis brevis (APB) muscle, revealed a normal CMAP response. Based on these results, Riche-Cannieu anastomosis in the left hand was suspected.

Conclusions: In the absence of other supportive evidence, Riche-Cannieu anastomosis should be excluded if the median CMAP response from the APB muscle cannot be obtained due to, e.g. motor weakness and muscle atrophy at the thenar eminence. Stimulation of the ulnar nerve while recording at the APB muscle can help avoid misdiagnosis

Keywords: carpal tunnel syndrome, electrodiagnosis, median-ulnar nerve communications, Riche-Cannieu anastomosis, ulnar-median anastomosis

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Introduction

Four major classifications of anomalous interconnections exist between the median and ulnar nerves. Interconnections manifesting in the forearm include Martin–Gruber and Marinacci, while those found in the hand are known as Riche–Cannieu and Berrettini.

Riche–Cannieu anastomosis (RCA) is an anatomic variant in which the deep branch of ulnar nerve fibers crossover to the recurrent branch of median nerve fibers in the hand, hence the ulnar nerve innervates muscles of the thenar eminence. RCA has been described in cadaveric dissections with a frequency range of 3.12-77%.[1] Roy et al.[2] conducted a meta-analysis of nerve communications in the upper limbs, analyzing 501 cases in 6 studies, and found the prevalence of RCA to be 55.5%.

Clinical presentation of RCA can take three forms. Whether these communications are sensory, motor, or mixed is still being investigated. All hand muscles can be innervated by the ulnar nerve (all ulnar hand), motor innervation can be dominantly provided by the ulnar nerve, or some of the median innervated muscles can be innervated by the ulnar nerve.[3-6] Of these three types of RCA, pure motor anastomosis between the deep branch of the ulnar and the recurrent branch of the median is the most common, while the all ulnar hand is rare.[1,3] The nerve conduction in studies of RCA varies depending on which types of anastomosis each individual has. In general, an absence of median motor response despite preserved bulk of the thenar muscles should raise the examiner's suspicion of possible RCA.

The presence of an anatomic variant may interfere with the interpretation of electrodiagnostic studies in diagnosing neuropathy. Normal subjects without median motor nerve response may be interpreted as severe median neuropathy at the wrist regardless of the average strength of the thenar muscles. The patient in the present case presented with RCA which was suspected of being carpal tunnel syndrome. If RCA is not recognized, nerve conduction study (NCS) results can be misdiagnosed as severe carpal tunnel syndrome (CTS) with no distal median motor nerve response preservation.

Case presentation

A 77-year-old man with a history of numbness in both hands for six months was sent for underwent an electrodiagnostic evaluation. The patient experienced paresthesia in both palms and all fingers. The symptoms were more prominent in the left hand than the right hand. His numbness symptoms were unrelated to weakness of the hands or upper limbs. He

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denied a history of neck, shoulder, or arm pain. During the diagnostic interview, the patient also reported intermittent numbness in both feet for one month. He had no significant back pain or radiated pain along either leg. His underlying condition was atrial fibrillation. The laboratory results were normal for fasting blood sugar.

Physical examination found the patient had no muscle atrophy with thenar eminences preserved in both hands. There was a slight decrease in abductor pollicis brevis (APB) muscle strength in the left hand (Medical Research Council grade 4/5), while the right hand was intact (5/5). Light touch sensation was decreased in the palmar surface of both hands, including all fingers and the plantar surface of both feet. The patient had a typical gait pattern. Spulring's test and the straight leg raise test (SLRT) were normal. Deep tendon reflex responses of the upper and lower limbs were 2+ with the plantar reflex causing a downward response to the Babinski test.

Nerve conduction studies (NCS) were performed using a Natus Synergy EDx machine (Natus Neurology Incorporated, Middleton, Wisconsin, USA) with controlled skin temperature of not below 32 °C. Motor nerve conduction studies were conducted by recording compound muscle action potential (CMAP) responses from the abductor pollicis brevis (APB) and adductor digiti minimi (ADM) muscles following stimulation of median and ulnar nerves at 8 cm. In addition, antidromic sensory nerve action potential (SNAP) of the median and ulnar nerves was obtained from the third and fifth fingers at 14 cm using ring electrodes. NCS of lower limb muscles was examined to rule out other possible peripheral neuropathy. The results were normal.

NCS of the right hand was consistent with a moderate degree of median neuropathy at the wrist. There were delayed response latencies with normal amplitudes in median SNAP and CMAP with normal ulnar SNAP and CMAP responses. However, when the median nerve was stimulated at the left wrist, no sensory response was obtained from the third finger, and no motor response was obtained from the APB muscle. Normal ulnar sensory and motor responses were obtained from left ulnar nerve stimulation. These findings would normally be interpreted as a severe degree of left median neuropathy at the wrist; however, the preserved motor strength in left thenar muscles suggested the possibility of an anomalous innervation.

Further studies were conducted, recording from the left third fingers and the left APB muscle while stimulating the ulnar nerve at the wrist and the elbow. Stimulation of the left ulnar nerve at the wrist resulted in a standard-looking shape of sensory nerve response being obtained from the third finger. There was normalization of the left ulnar-APB CMAP response. (Figs. 1 and 2).

Discussion

The prevalence of RCA in a normal population varies among studies. However, a recent meta-analysis reported RCA in 55.5% of individuals in the studied populations (95% CI, 30.6%-79.1%).[2] Caetano et al.[7] identified RCA in 100% of 80 dissected hands and suggested that RCA should be considered a normal anatomical neural connection, not an anatomical variation. Because of the high prevalence of RCA, recognizing its pattern in patients with normal NCS findings is crucial for an accurate diagnosis.

In this study, the RCA was confirmed by an absence of median motor response at the APB muscle when stimulated at the median nerve, but with normalization of the motor response when stimulating an ulnar nerve. In typical RCA, a

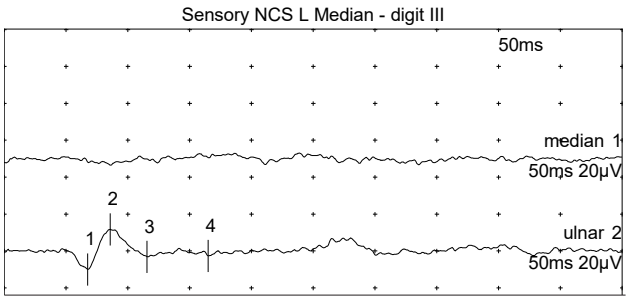

Figure 1. Sensory NCS stimulated from the left median and left ulnar nerves at the wrist, recorded from the left third finger

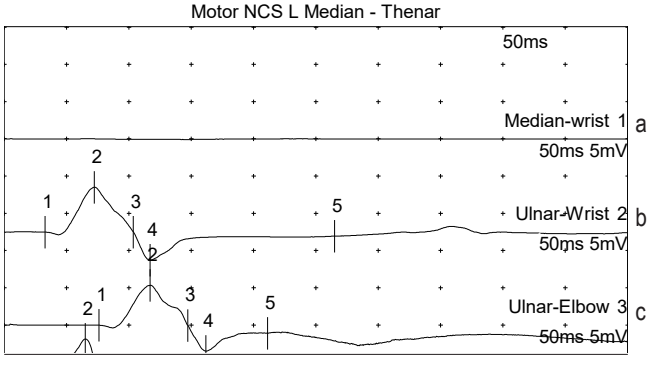

Figure 2. Motor NCS stimulated at median at left wrist recorded from APB muscle (a), stimulated at left ulnar at wrist (b) and elbow (c) recorded from APB muscle

Table 1. Nerve conduction study findings on the left hand

Nerve	Recording site	Stimulation site	Latency (msec)	Amplitude	Conduction velocity (m/s)
Sensory					
Median	3rd finger	Wrist	No response	No response	
Ulnar	3rd finger	Wrist	8.59	15.0 μV	
Motor					
Median	APB	Wrist	No response	No response	
Ulnar	APB	Wrist	3.28	6.0 mV	
Ulnar	APB	Elbow	7.6	5.4 mV	57.8

pathognomonic initial negative deflection waveform occurs when the APB muscle is stimulated by the ulnar nerve at the wrist.[1,8] In the present case, however, a positive rather than a negative deflection was observed. This finding could have resulted from volume conduction to other intrinsic hand muscles, apart from the APB muscle, that were innervated by the ulnar nerve which is the reason the all-ulnar hand type of RCA was suspected.

The absence of median sensory response recorded from the third finger when stimulating the median nerve at the wrist suggested the possibility of either co-existent CTS or the less common sensory-motor involvement in all ulnar-type RCA. To resolve this question, an antidromic sensory response stimulated by the ulnar nerve while recording at the third finger was performed which resulted in an ordinary-looking shape of the sensory nerve response with relatively prolonged distal latency. This finding further supported the probability of sensory fiber anastomosis between ulnar to median digital nerves, helping to confirm the presence of all ulnar-type RCA. The relatively prolonged sensory distal latency found in this case was similar to the results in a previous study by Kim et al.[3] in which the authors proposed that anomalous thin cutaneous nerves can lead to small amplitude and delayed latency sensory nerve action potential. In the present study, the slight positive deflection observed in the sensory response could have resulted from the aberrant ulnar to the median sensory anastomosis of RCA found in this patient. Additionally, the anastomosed ulnar to median fibers in this patient traveled longer distances to the third finger than the usual pathway of median innervation. For that reason, a lesion in the left ulnar nerve was not suspected because of the normal ulnar sensory and motor responses.

In addition to the NCS findings, needle EMG should be performed to confirm a patient's APB muscle denervation. In suspected CTS patients with RCA, typical results of needle EMG findings should be expected despite the absence of median motor response stimulated at the median nerve because the ulnar nerve, rather than the median nerve, innervates the thenar muscles.

In summary, the relatively high prevalence of RCA anastomosis is generally under-appreciated. Thorough knowledge of clinical correlation remains an essential tool for electrodiagnostic physicians. RCA should be excluded if no CMAP response is obtained from the APB with median stimulation in the absence of other supportive evidence, e.g., motor weakness and muscle atrophy. Stimulation of the ulnar nerve with recording at the APB muscle can help avoid misdiagnosis.

Disclosure

The author has nothing to disclose regarding this study.

Acknowledgment

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