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Proprioceptive Neuromuscular Facilitation Protocol for Thumb Osteoarthritis: A Pilot Study

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Abstract

Background: Osteoarthritis (OA) of the thumb carpometacarpal (CMC) joint often presents with joint instability and proprioceptive deficits. Proprioception has been found to play an important role in the rehabilitative process. The purpose of this study was to evaluate the effectiveness of a proprioceptive training program on pain and function in individuals with early-stage thumb Carpometacarpal joint OA. **Methods:** A double-blind experimental trial using a 2-group pretest/posttest design was used in this pilot study. Participants had a diagnosis of grade I and II thumb CMC joint OA in their dominant hand and a pain rating of >4/10 on Visual Analogue Scale. Participants received either standard treatment (control group) or standard treatment plus a proprioceptive training program (experimental group). Outcome measures were lateral pinch strength, pain intensity during activities, and proprioceptive response via joint position sense (JPS) testing. **Results:** Twelve individuals (average age of 66.25 years) participated. Both groups had a statistically significant decrease in pain and increase in lateral pinch strength, all occurring with a large effect size but no statistically significant difference between groups. The experimental group experienced a large effect size for JPS testing, whereas the control group experienced a trivial effect size, and there was a statistically significant difference between groups for JPS testing. **Conclusions:** Individuals who completed the proprioceptive training program in this study had an improvement in proprioceptive functioning. This program shows potential for routine inclusion in hand therapy for thumb CMC joint OA; however, additional high-level studies with larger sample sizes are required.

Keywords: thumb, anatomy, osteoarthritis, arthritis, diagnosis, proprioception, rehabilitation, specialty, cartilage, basic science

Introduction

The thumb carpometacarpal (CMC) joint has been described as the most important functional joint of the first digit.[1] The unique biomechanics of the CMC joint allows opposition to the digits and performance of resistive pinch as needed for daily tasks such as buttoning, twisting caps, writing, and manipulating small objects. The distinctive mechanics of this joint also contributes to the prevalence of thumb CMC joint osteoarthritis (OA). Carpometacarpal joint OA is strongly associated with individuals of advanced age, women, and joint laxity or hypermobility. The effects of thumb Carpometacarpal joint OA include functional limitations, participation restrictions, and, in some cases, debilitating pain.[2,3]

High-level evidence is supportive of conservative management in the early stages of thumb CMC joint OA (stage I or II according to Eaton classification).[4,5] The primary goals of conservative treatment include the delay or prevention of surgery, modulation of pain, and improvement in activity and participation levels with daily activities.[5] Common conservative treatments for thumb CMC joint OA include the use of orthotics, joint protection techniques, exercise, heat modalities, and patient education[6,7]; however,

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these measures are found to have varied degrees of effectiveness.[4,5]

Osteoarthritis of the thumb CMC joint often presents with poor neuromuscular capacity, and proprioceptive deficits. The unique articulation of the thumb CMC joint allows the thumb both a complex and a wide range of movement, which also contributes to joint instability and ultimately poor neuromuscular capacity, joint instability, and proprioceptive deficits. The loss of stability leads to a progression of imbalance and functional deformity.[1] Cadaveric studies of the thumb CMC joint have suggested that ligament innervation may correlate with neuromuscular and proprioceptive changes in CMC joint OA.[8,9] A variety of exercise programs have been described in the literature to address these deficits.[9-11]

Mobargha et al[11] identified the first dorsal interossei (FDI) as an important stabilizer of the thumb CMC joint and the abductor pollicis brevis as a destabilizer. Similarly, Adams et al[10] suggested the beneficial effects of selective strengthening exercises including the opponens pollicis (OP) and FDI muscles, with the OP likely being the predominant muscle for reducing subluxation. Despite these findings, there are no high-level studies that provide specific guidelines for strengthening or proprioceptive techniques for the thumb CMC joint.

Rehabilitation programs for ligament laxity of the CMC joint should be designed to inhibit torque forces that contribute to instability and imbalance, and instead focus on pain-free isometrics, strengthening, neuromuscular reeducation, and joint protection.[11,12] A specific rehabilitation strategy for the thumb CMC joint was developed by Albrecht and referred to as a dynamic thumb stability program. It is a multimodal staged approach that includes, among others, manual release, joint mobilization, specific muscle strengthening, and joint protection.[13]

Proprioception plays an important role in motor planning and therefore should be an integral component in rehabilitation.[14] Proprioceptive sensation is derived from mechanoreceptors in muscle, joint capsule, tendon, ligaments, and skin. A cadaveric study identified the presence of mechanoreceptors in the thumb CMC joint ligaments, inferring that this joint has proprioceptive and neuromuscular functions.[9] Similar to other joints, the proprioceptive structures of the thumb CMC joint provide information about position in space, movement, force, and effort, which are fundamental requirements for motor planning and control as found in simple activities of daily living (ADLs) and more physically demanding tasks.[15] A retrospective review examined a dynamic stability program for thumb CMC joint pain and included proprioceptive/kinesthetic training as 1 step of a 13-step program with the use of textile tape for proprioceptive input to the skin.[12] However, currently there are no studies examining proprioceptive exercises for thumb CMC joint OA.

Purpose of the Study

The purpose of this study was to evaluate the effectiveness of a proprioceptive training program on pinch strength, pain with activity, and joint position sense (JPS) for individuals with symptoms of early-stage thumb CMC joint OA.

Materials and Methods

Design

A double-blind experimental trial using a 2-group pretest/posttest design was used in this pilot study.

Participants

Participants were recruited from Tecan Hand Center located in Malaga, Spain, where they were seeking hand therapy treatment for symptoms related to thumb CMC joint OA. Individuals were assigned to either the experimental or the proprioceptive training group based on the order in which they attended skilled therapy. Participation in the study was voluntary. Inclusion criteria were a diagnosis of grade I or II thumb CMC joint OA according to the Eaton Classification Stage in their dominant hand, a minimum pain rating of 4/10 on the Visual Analogue Scale (VAS) during ADLs at initial evaluation, the ability to read and understand the patient information sheets and exercises, and the ability to sign a consent form. Individuals were excluded if they had a neurological disorder affecting the upper limb; received other conservative treatments in the last 6 months for thumb CMC joint OA, fractures, tenosynovitis, or other significant injuries to the thumb, hand, or wrist; or had a diagnosis of Dupuytren disease. Participants were assessed at baseline and at a 3-month follow-up.

Study Procedure and Interventions

All data collection occurred at the same location and by the same hand therapist. This assessor was blinded to the participants' group allocation. Upon agreement to participate in the study, baseline data were collected and entered into an Excel database, and the participant was randomly assigned to either the experimental or the control group. Both groups received identical conservative treatments, including a short opponens orthosis for night-time wear, self passive traction of the thumb CMC joint, self-massage to the thumb muscles, active resistance of the FDI muscle, and instruction for functional incorporation of the thumb for ADLs. The exercise routine was performed on a home program basis 2 times per day (3 sets of 8-10 repetitions) and seen twice a week in the clinic to monitor and provide feedback for proper performance of the exercise routine.

In addition to the conservative treatment discussed above, the experimental group received a proprioceptive

Figure 1. In phase 1 of the proprioceptive training program, the therapist passively moves the thumb interphalangeal and metacarpophalangeal joint into flexion or extension, and the participant is asked to identify the direction of motion to improve ability to detect movement sense.

Figure 2. Phase 2, step 1 in which the patient is moving his or her finger along the ball to different points marked by the rubber bands. The position of the elastic band can be moved to stimulate specific receptors with different movements.

training program. This program was based on a previously described proprioception program[16-18] and is divided into 3 phases. Each phase is performed for 2 consecutive weeks and are as follows: phase 1, threshold to detection of passive motion[18]; phase 2, reproduction of passive and active joint position[16]; and phase 3, active movement extent discrimination assessment.[17]

Phase 1. With vision occluded, the therapist passively moves the patient's thumb metacarpophalangeal (MCP) or interphalangeal joint (Figure 1) in the direction of either flexion or extension. The patient must then identify the direction in which the thumb was moved. The main objective is to improve the patient's ability to detect movement sense.

Phase 2. This phase comprises 2 stages: passive angle repositioning (PAR) and active angle repositioning (AAR).[16] In PAR, the patient's thumb is passively moved by the therapist to a target position, and the patient must identify where the thumb was moved to. The steps for AAR are as follows (with vision and then vision occluded):

1. The patient will move their thumb to different points marked by the rubber bands as directed by the therapist (Figure 2).
2. The same instruction and format as (1); however, the patient will now move his or her thumb on the ball to touch the different points marked by the elastic band. The position of the elastic band can be moved to stimulate specific receptors with different movements. There are several variations to this exercise to increase complexity or resistance. (Figure 3).
3. The patient will now move the thumb, first with open eyes and then with eyes closed to draw or "simulate" drawing numbers, figures, and so on. This task can be performed on a table or on a wall based on the objective of the task.
4. This step introduces proprioception with some resistance. The patient will squeeze the sponge and stop at the color as directed by the therapist. Resistance can be increased using a firmer material.
5. Using a marble or the other small ball, the patient will move his or her index finger to the red or blue line. This stimulates the first dorsal interosseous muscle. The size of the ball can also be changed according to hand size or the objective of the exercise (Figure 4).
6. Using a dynamometer, the patient should perform active resistive movement to the number chosen by the therapist. The use of the dynamometer allows the patient to have graded resistance during the movement while receiving immediate feedback. This exercise is customizable by altering the thumb motion to allow a focus on specific thumb muscles (Figure 5).

Phase 3. The patient is introduced to a variety of devices used in everyday tasks that incorporate different strengths, textures, and weight of the objects. This introduces dynamic proprioception using "real-life" movements with everyday objects (supplementary material).[17,19]

Clinical Outcome Measures

This pilot study involved 3 outcome measures: pinch strength, pain intensity during activity as assessed with a

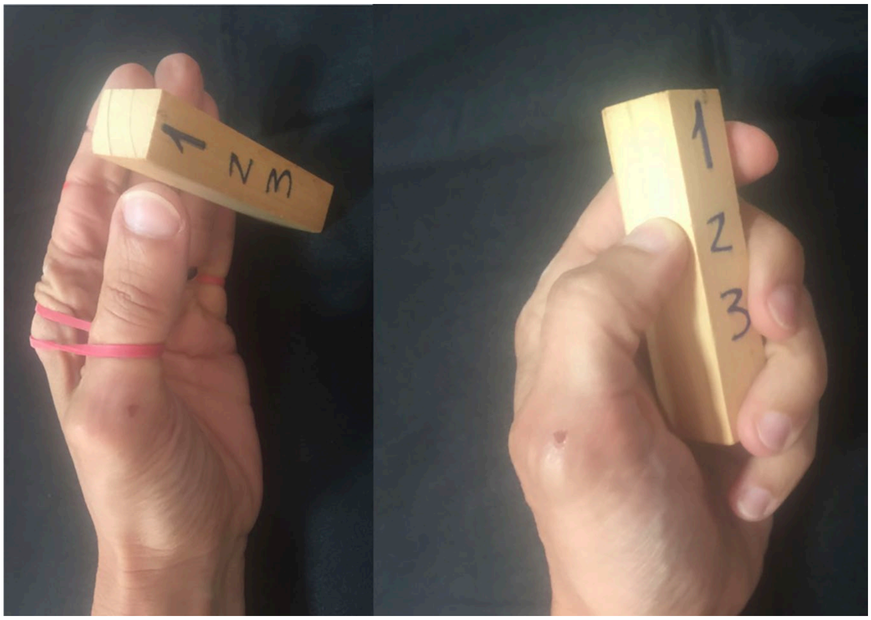

Figure 3. Phase 2, step 2 of the proprioceptive training program where the patient moves his or her thumb to the numbers on the stick with/without elastic resistance.

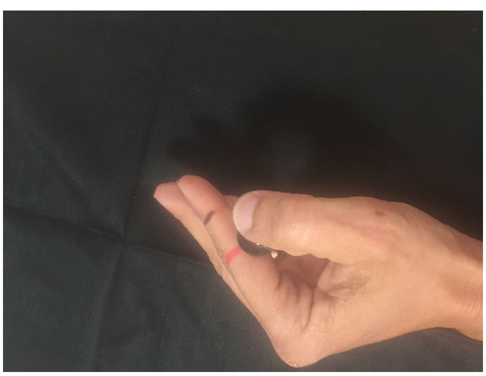

Figure 4. Phase 2, step 5 of the proprioceptive training where the first dorsal interosseous muscle is strengthened and a marble is rolled along the marked lines on the index by the thumb.

Figure 5. In phase 2, step 6 of the proprioceptive training program, using a dynamometer, the patient should perform active resistive movement to the number chosen by the therapist.

VAS, and proprioceptive response measured with JPS testing. All outcomes measures were assessed before and after treatment (baseline and 3 months, respectively). During the assessment, participants were seated at a table on an adjustable chair, back supported, feet on the floor, elbows flexed to approximately 90°, and forearms in neutral.

Key pinch strength was assessed using a pinch gauge dynamometer, which is valid and reliable for individuals with thumb CMC joint OA.[20] Participants were instructed to compress the pinch dynamometer with the thumb as hard as possible for 3 seconds. Three trials were completed with 1-minute rest period between each measurement, and the average of 3 trials was reported in kilograms.[20]

The VAS is a pain assessment scale involving a 10-cm line that represents a continuum between "no pain" (0/10) and "worst pain" (10/10) and is a valid and reliable tool for the assessment of pain.[21]

Joint position sense testing was used to evaluate conscious proprioception of the thumb CMC joint using the technique described in a previous study for thumb CMC joint OA.[22] The JPS testing protocol was explained and demonstrated to participants. The thumb was passively placed in 30° abduction with vision occluded, that position was maintained for 3 seconds, and the participant was then asked to move into full abduction. Next, each participant was asked to actively reproduce the target of 30° abduction with vision still occluded, and the measurement of his or her angle was assessed once he or she verbally confirmed that the target angle was attained. Each joint angle was determined using a plastic finger goniometer via methods described in previous research.[22] The difference between the first position (passive positioning by therapist) and the reproduced angle (actively attained by participant) was used as the JPS deficit criterion value. Joint position sense testing has been found to be a reliable[23] and responsive[24] assessment for the wrist after injury.

Data Analysis

Demographic data were summarized using means and standard deviations. Unpaired Student *t* tests were performed to determine the similarity of groups at baseline. Paired Student *t* tests were used to determine the level of statistical significance of the differences between the pretreatment and posttreatment scores. Between-group comparison of scores over time was performed with an analysis of variance (ANOVA). Statistical significance was set at less than .05. Cohen's *d* was interpreted using Cohen's interpretation of effect size.[25] Cohen suggested that $d = 0.2$ be considered a "small" effect size, 0.5 a "medium" effect size, and 0.8 a "large" effect size. This means that if 2 groups' means do not differ by 0.2 SDs or more, the difference is trivial, even if it is statistically significant.

Results

Between October 2019 and February 2020, 12 patients participated in the study. The participants were aged between 58 and 73 years with a diagnosis of thumb CMC OA. The mean age was 66.25 years (SD 5.12). Unpaired *t* tests found no statistically significant difference between groups at baseline. No patients were lost to follow-up. See Table 1 for baseline comparison.

The mean pain score at baseline was 5.67 for participants in the experimental group (SD 1.21) and 5.83 (SD 1.17) for participants in the control group. The experimental group's mean current pain score at the 3-month follow-up was 3.67 (SD 0.87) compared with the control group's mean pain score of 3.50 (SD 1.05). The mean change score was −2.0 for the experimental group and −2.33 for the control group, and the effect size was calculated to be 2.10 for both groups.

Table 1. Baseline Comparison.

Variable	Experimental	Control	*P* value
Age	67.17	65.33	.56
VAS pain	5.67	5.83	.81
Pinch force, kg	1.90	1.77	.58
JPS error, deg	12.5	11.67	.79

Note. VAS = Visual Analogue Scale; JPS = joint position sense.

The paired *t* tests comparing the mean scores of both groups were statistically significant ($P < .001$). The effect sizes for the reduction in pain in both groups were considered large. The ANOVA comparison between groups was not statistically significant (Table 2).

The mean lateral pinch force at baseline for the experimental group was 1.90 kg (SD 0.35) and for the control group was 2.28 kg (SD 0.28). The mean change score was 0.38 kg for the experimental group and 0.33 kg for the control group. The effect size for the change score in the experimental group was 1.20 and in the control group was 0.83, which are considered large. The paired *t* tests comparing the mean scores of both groups were statistically significant ($P < .001$). The ANOVA comparison between groups was not statistically significant.

The mean JPS degrees of error at baseline for the experimental group was 12.5 (SD 5.24) and for the control group was 11.67 (SD 5.16). The mean change score was −9.67° for the experimental group and −0.5° for the control group. The effect size for the change score in the experimental group was 2.36, which is considered large. The effect size for the control group was 0.11, which indicates a trivial difference. The paired *t* tests comparing the mean scores of the experimental group over time were statistically significant ($P < .001$). The ANOVA comparison between groups was statistically significant ($P < .001$).

Discussion

The focus of this study was to provide information on the effectiveness of a 12-week proprioception training program for individuals with stage I or II thumb CMC joint OA. Proprioception enables neuromuscular control of dynamic restraints and segmental movements, and delivers positional information to the motor control system.[26] Trauma and pathological processes can impact the feedback system, creating an increased risk of injuries with reduced motor control as often seen in the OA process.[27]

Thumb CMC joint OA is a degenerative pathology that creates an imbalance and eventual functional deformity. In addition to the current concept of joint position and controlled isometric muscle contraction, this study has also considered proprioceptive exercises as a part of the rehabilitation program to improve thumb stability. Proprioception plays an

Table 2. Outcomes at Pretreatment and Posttreatment.

Outcome	Pretest Experimental	Pretest Control	Posttest Experimental	Posttest Control	Difference within groups Experimental	Difference within groups Control	Mean difference between groups
Pain	5.67 (SD 1.21)	5.83 (SD 1.17)	3.67 (SD.0.81)	3.5 (SD 1.05)	−2.0* (–1.06 to 2.94)	−2.33* (–1.79 to 2.88)	0.33
Pinch force, kg	1.90 (SD 0.35)	1.77 (SD 0.45)	2.28 (SD 0.28)	2.1 (SD 0.33)	0.38* (0.09 to 0.67)	0.33* (0.15 to 0.51)	0.05
JPS error, deg	12.5 (SD 5.24)	11.67 (SD 5.16)	2.83 (SD 2.48)	11.17 (SD 3.76)	−9.67* (–6.24 to 13.09)	−0.5 (–4.06 to 3.05)	9.17*

Note. JPS = joint position sense.
*Statistically significant $P < .001$.

important role in the rehabilitation process as identified in studies on the ankle, shoulder, and knee pathologies.[26] Proprioception studies for the upper limb are limited and have focused on the elbow and the evaluation of JPS but not rehabilitation.[28]

The relationship between the clinical presentation of sensorimotor (SM) impairment and the functional impact in patients diagnosed with CMC joint OA has yet to be reported. A 3-phase proprioceptive rehabilitation program for thumb OA has been proposed, which was included in this study.[29] There is a lack of evidence specific to exercises and tests for SM deficits for thumb CMC joint arthritis and its relationship to patient-rated function and pain. However, this study addresses those areas, although the small sample size limits the ability to draw a strong conclusion.

A descriptive cross-sectional study determined the magnitude of wrist and hand SM impairment following distal radius fracture (DRF). The authors concluded that JPS and total grip force were the most clinically useful tests for assessing SM status as well as explaining functional disability levels for patients following a DRF. Pain was also found to be an influential factor on SM function in other investigations.[30,31]

In this study, effect size for the reduction in pain in both groups was considered large; however, the ANOVA comparison between groups was not statistically significant. Therefore, a relationship between proprioceptive training and pain intensity cannot be established. These results differ from previous studies which conclude that pain alters movement and posture.[36,38] Weerakkody et al assessed whether muscle pain and subcutaneous pain distort proprioception in the human thumb.[18] The investigators concluded that accurate thumb movement requires not only knowledge of the relative muscle lengths and joint angles but also information about the dimensions of the body segments that may be disrupted because of pain.[18] Due to the artificial induction of pain in various sites of healthy subjects and given the known importance for the origin site of pain, this negates a relevant comparison with our study.

In a chronic process such as thumb CMC joint OA, the relationship between the central actions of nociceptive inputs and their influence on proprioception and motor control should be confirmed before establishing a relationship between pain reduction and proprioception. Proprioceptive deficits are related not only to musculoskeletal injury but also to recurrent and persistent symptoms and disability.[26] Although there is conflicting evidence, studies have shown that patients with OA may have impaired proprioceptive accuracy (for both position and motion sense) as found in studies regarding knee OA and proprioception. A narrative review was supportive of a proprioception rehabilitation program for patients with knee OA who had impaired position or motion sense.[33] Due to the chronic pathology associated with thumb CMC joint OA, there is often a correlation to loss of function and significant pain over an extended period of time. The results of this study suggest that a proprioception program may be advantageous in the rehabilitation process for thumb CMC joint OA.

Previous study on knee OA has concluded that there is greater proprioceptive accuracy in individuals with earlier OA as opposed to more severe OA, and individuals with early stages of OA have better improvement in proprioceptive sense after training.[33] This may be the reason for improvement on the JPS test for the participants in this study following a proprioceptive rehabilitation program. Future studies with larger sample sizes and in individuals with more advanced OA are needed. Our results, which are supported by previous investigations, propose that proprioception programs for thumb OA should be introduced in rehabilitation programs in the first stage of the OA process.

The lack of standardization of proprioception terminology and the complexity of evaluation methods found in the literature make it difficult to determine whether the assessment method used in this study is the best approach for the evaluation of thumb proprioception.[16,18,34] In addition, there is wide variation in the testing approach and testing conditions. There are also a variety of procedures and protocols making ecological validity, test validity, and data validity different among studies.[35] Previous research of the OA process has found that position sense and motion sense represent different aspects of proprioception and likely stimulate different receptors. Nevertheless, position sense tests are thought to be a measure closer to real-life proprioceptive accuracy, whereas motion sense tests seem to be more reliable.[36] A cross-sectional study used the thumb localization test in a cerebrovascular accident population and found poor interrater reliability and sensitivity, along with poor or absent normal value criteria for this proprioceptive test.[37] In a descriptive comparison study, the JPS test was used and found to be a clinically meaningful measure of conscious SM impairment and a useful tool for evaluating function and setting rehabilitative goals for patients with thumb CMC joint OA.[22] Future studies addressing thumb proprioception should investigate the validity of these assessments for measuring thumb proprioception. Our findings suggest that a new measurement protocol needs to be developed. Ideally, such a protocol would combine the benefits of both motion sense tests (reliable) and position sense tests (functional relevance). Although the impact of age-related OA changes on JPS of the hand is not clear, proprioception protocols based on the level of pathology may be helpful. It appears that traumatic injuries and degenerative pathology should be treated with different proprioceptive protocols. Degenerative OA frequently affects the elderly, and findings suggest proprioception is affected by age. Similarly, the literature finds that movement detection thresholds increase with advancing age, as shown in the knee, ankle, and MCP joints of the upper limb, making this a concept for consideration in the future treatment approach for the thumb CMC joint OA.[32]

Conclusion

This pilot study demonstrated that proprioceptive training significantly improved JPS and thus proprioceptive function in patients diagnosed with thumb CMC joint OA at stages I and II. A proprioceptive exercise program for patients with thumb OA was introduced based on recent insights into SM control principles and thumb kinematics.

The proposed exercise program does not focus on pain but rather on functional reeducation of the neuromusculoskeletal system based on SM control principles. The effectiveness of the proposed program has yet to be determined by proper prospective, matched case-control studies or randomized clinical trials.

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Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

Statement of Informed Consent

Informed consent was obtained from all individual participants included in the study.

Declaration of Conflicting Interests

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