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Effectiveness of passive stretching of the Achilles tendon with the continuous passive stretching (CPS) instrument in patients with plantar heel pain

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Background : *Previous studies have shown that stretching of the Achilles tendon is effective for treating patients with plantar heel pain.*

Objective : *To evaluate the effectiveness of the continuous passive stretching (CPS) instrument in patients with plantar heel pain.*

Methods : *Fifteen subjects aged 40 - 60 years with a history of plantar heel pain longer than 1 month were recruited. They were instructed to use CPS instrument for 5 days per week for 4 consecutive weeks. Six variables which included plantar heel pain at first step in the morning, average pain over the past 24 hours, pressure pain threshold, foot and ankle disability, passive ankle range of motion, and global perceived effect were taken before and after 4 weeks of treatment.*

Results : *After 4 weeks of stretching, the subjects showed significant decreases in pain intensity ($P < 0.001$) as well as foot and ankle disability ($P < 0.001$) whereas there were significant increases in pressure pain threshold ($P < 0.001$) and ankle passive dorsiflexion range of motion ($P < 0.001$).*

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Conclusion : *Passive stretching of the Achilles tendon with the CPS instrument is effective in alleviating symptoms in patients with plantar heel pain.*

Keywords : *Achilles tendon, plantar heel pain, stretching.*

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ภูมิชัย อิงคนานุวัฒน์, รสลัย กัลยาณพจน์พร, นิธิมา เพียวพงษ์. ประสิทธิภาพของการยืดเอ็นร้อยหวายด้วยเครื่องมือยืดแบบทำให้อย่างต่อเนื่อง (CPS) ในผู้ที่มีอาการปวดฝ่าเท้า. จุฬาลงกรณ์เวชสาร 2560 พ.ย. – ธ.ค.;61(6): 703 – 13

เหตุผลของการทำวิจัย : *การยืดเอ็นร้อยหวายเป็นวิธีในการรักษาอาการปวดฝ่าเท้า*

วัตถุประสงค์ : *เพื่อทดสอบประสิทธิภาพของการยืดเอ็นร้อยหวายด้วยเครื่อง continuous passive stretching (CPS) ในผู้ป่วยที่มีอาการปวดฝ่าเท้า*

วิธีการทำวิจัย : *ผู้ที่มีอาการปวดฝ่าเท้าอย่างน้อย 1 เดือน อายุ 40 - 60 ปี จำนวน 15 ราย ผู้เข้าร่วมงานวิจัยได้รับคำแนะนำให้ใช้เครื่อง CPS เป็นเวลา 5 วันต่อสัปดาห์ ต่อเนื่องกัน 4 สัปดาห์ โดยวัดระดับความเจ็บปวดก้าวแรกของการลงน้ำหนักในตอนเช้า, ระดับความเจ็บปวดโดยเฉลี่ยตลอด 24 ชั่วโมงที่ผ่านมา, ค่าแรงกดที่เริ่มรู้สึกเจ็บ, ระดับความทุพพลภาพของเท้าและข้อเท้า, องศาการเคลื่อนไหวของข้อเท้า และการรับรู้โดยรวมต่อการรักษา ก่อนและหลังการรักษา 4 สัปดาห์*

ผลการศึกษา : *หลังการรักษาด้วยการยืด 4 สัปดาห์พบมีการลดลงอย่างมีนัยสำคัญของระดับความเจ็บปวด ($P < 0.001$) และระดับความทุพพลภาพของเท้าและข้อเท้า ($P < 0.001$) ในขณะที่พบมีการเพิ่มขึ้นอย่างมีนัยสำคัญของค่าแรงกดที่เริ่มรู้สึกเจ็บ ($P < 0.001$) และองศาการเคลื่อนไหวของการกระดกข้อเท้าขึ้น ($P < 0.001$)*

สรุป : *การยืดเอ็นร้อยหวายด้วยเครื่อง CPS มีประสิทธิภาพช่วยบรรเทาอาการให้ผู้ป่วยที่มีอาการปวดฝ่าเท้าได้*

คำสำคัญ : *เอ็นร้อยหวาย, พังผืดฝ่าเท้า, อาการปวดฝ่าเท้า, การยืด.*

Plantar heel pain is characterized by pain along the medial plantar aspect of the heel or at the insertion site of the plantar fascia at the medial tuberosity of the calcaneal bone.[1-3] Plantar heel pain accounts for approximately 11 - 15% of all foot pains and 33.4% of those complaining of chronic plantar heel pain.[4] It commonly affects those between 40 and 60 years of age.[5]

Causes of plantar heel pain can be divided namely into intrinsic and extrinsic factors.[5, 6] The intrinsic factors include advanced age, abnormal foot posture, overweight, and tightness of the Achilles tendon, while the extrinsic factors include the use of poor footwear as well as the type and intensity of daily activity. Together with repetitive use of the foot, the plantar fascia is placed under mechanical overload. As a result, this may produce a microtear within the fascia which causes an inflammatory response and pain.

Several non-operative treatments have been proposed for plantar heel pain such as rest, therapeutic exercise, massage, physical modalities, therapeutic orthotic insoles, injections, and medications.[2, 7, 8] Among these treatments, stretching of the tight calf and plantar tissues has been proven effective for relieving the symptoms.[9] Both the sustained and intermittent techniques of stretching the Achilles tendon were found to be equally effective in improving the pain and ankle range of motion as well as foot and ankle function.[10] Pain is also lessened when adding trigger point manual therapy over the gastrocnemius and soleus muscles to stretching of the Achilles tendon.[11] However, one recent study has shown that stretching exercise specific to the plantar fascia is superior to the standard Achilles tendon stretching.[12]

With self-stretching technique such that reported in the literature, the force and angle of the stretching are difficult to be maintained steadily. The effectiveness of the stretching might be reduced. With an instrument that can control force and angle of the stretching, the effectiveness of the stretching might be improved. The purpose of this study was to evaluate the effectiveness of the continuous passive stretching (CPS) instrument in patients with plantar heel pain.

Methods

Subjects

The study protocol has been approved by the Ethics Committee for Research Involving Human Subjects, Health Sciences Group, Chulalongkorn University (number 098.2/58). Subjects aged 40 - 60 years with a history of plantar heel pain longer than 1 month were recruited. To be eligible for inclusion, the subjects had to have localized pain on palpation at the medial plantar calcaneal region. The pain at the first step in the morning had to be greater than or equal to 4 out of 10 on the 11-point Numeric Pain Rating Scale (NPRS) which had to decrease with movement such as walking. Furthermore, the subjects were requested to decline from the application of other treatments or medications during the study period. Exclusion criteria were as follows: individuals with red flags (i.e., tumor, rheumatoid arthritis, severe vascular disease, etc.), a history of fractures of lower extremities, prior surgery of lower extremities, neural problems in lower extremities, diabetes mellitus, and pregnancy.

The sample size was calculated based on the standard deviation of 2.2 points from a previous

study[10] and the magnitude of the minimum clinically significant difference of 2 points on 11-point NPRS.[13] Configuration error and power were set at 0.05 and 0.80, respectively. A total sample size of 10 subjects was therefore required for this study.

Materials

The CPS instrument (Figure 1A), an innovative stretching instrument developed by our research team,[14] was used in this study. The instrument was devised for stretching the Achilles tendon by taking the benefits from the standard Achilles tendon stretching in weight bearing condition with less strain on a subject's back. It consists of 2 wooden bases covered with a Bene-feet mat which is composed of many long flexible spikes with the shorter spikes located at the front and the back and the taller ones in the middle. Each wooden base is equipped with a goniometer and a motor that can move the base up and down independently for each foot in the range of 0 - 60 degrees ankle dorsiflexion at the speed of 0.8 - 1.3 degrees per second. This velocity is aimed to provide a gentle stretch to the Achilles tendon with a minimal risk of injury.

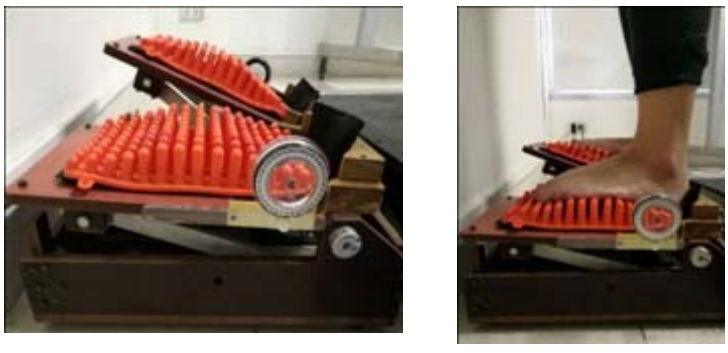
Outcome measures

Pain intensity

An 11-point NPRS[13] was used for measuring pain at first step in the morning and the average pain at the medial plantar calcaneal region over the past 24 hours. On the scale, 0 represents no pain and 10 represents the worst pain imaginable.

Pressure pain threshold

A pressure algometer (JTech) with 1 cm^2 surface area was used to measure the pressure pain threshold at the tender point of the plantar fascia at the medial plantar calcaneal region. The instrument was found to be highly reliable with a Cronbach's alpha of 0.94 - 0.98.[15] The researcher gradually applied pressure through the pressure algometer over the tender point until the subject started to feel pain and the amount of pressure force shown on the screen was recorded. In this study, the tender point was defined as the point where the subject was unable to tolerate a pressure of more than 3 kg/cm^2 or where the pressure threshold was at least 2 kg/cm^2 lower than the asymptomatic side. Once the tender point was established, the pressure was then applied 3 times with 10-second intervals in between and the average data were used for analysis.



A B

Figure 1. The continuous passive stretching (CPS) instrument (A). Setting of the subjects in the CPS instrument (B).

Ankle passive ranges of motion

Passive ankle dorsiflexion and plantar flexion were measured when the subjects lay supine with the knees extended. A universal goniometer was aligned with a pivot point over lateral malleolus, a stationary arm parallel to the fibula bone, and a movable arm parallel to the fifth metatarsal bone. Then the subjects' ankle was passively dorsiflexed (the foot lifted up towards the shin) and plantar flexed (the foot moved down towards the bed) 3 times in each direction, and the average values were used for analysis.

Foot and ankle disability

The Thai version of the visual analogue scale foot and ankle questionnaire (VAS-FA) was used for assessing foot and ankle disability. It has been shown to be highly reliable with an intraclass correlation coefficient of 0.995 and the Cronbach's alpha of 0.995.[16] The questionnaire consists of 20 items.[17] Four items are related to pain, 11 items to functional limitation, and 5 items to the quality of life due to impairment of the foot and ankle-related problems. Each question was scored 0 - 100 points by asking subjects to draw an "X" along the scale of a 100-mm line based on individuals' feeling for each question. Zero represents the most severe disability while 100 represents no disability. The total score for VAS-FA ranges from 0 -2,000 points. As for analysis, the total score was divided by 20 so the final score would range from 0 - 100 points; the lower score the higher the foot and ankle disability.

Global perceived effect questionnaire

The global perceived effect questionnaire measures subjects' perceived change after the intervention.[18] It consists of a 7-point scale ranging from 1 to 7 (1 = completely recovered, 2 = much improved, 3 = slightly improved, 4 = no change, 5 = slightly worsened, 6 = much worsened, and 7 = worse than ever).

Procedure

All subjects received stretching using the CPS instrument. The baseline data which consisted of pain at the first step in the morning, average pain intensity over the past 24 hours, pressure pain threshold, ankle passive ranges of motion, and foot and ankle disability were measured by an assessor. Next, a physical therapist who was blinded to the subjects' baseline data asked the subjects to step onto each wooden base of the CPS instrument which was initially set at 0 degrees dorsiflexion. The subjects were instructed to keep their hips and knees straight. Then, the wooden base of the symptomatic side was raised up first until the subjects started to feel tolerable tension in their Achilles tendon. Subsequently, the wooden base on the asymptomatic side was raised up to the same angle (Figure 1B). The stretch was held for 20 seconds for 5 sets. A 20-second rest was allowed between sets in which the wooden bases were lowered to the initial 0 degree dorsiflexion. Then, the subjects stepped off the CPS instrument and walked around for 10 minutes and returned for another 5 sets. All subjects were required to attend the laboratory 5 days per week for 4 consecutive weeks. The same assessor examined average pain intensity over the past 24 hours at the end of each week. Pain at first step in the morning, pressure pain threshold, ankle passive ranges of motion, foot and ankle disability, and global perceived effect were measured at the end of the 4-week intervention period.

All subjects were requested to continue their normal activities and avoid other forms of treatment while receiving the intervention. However, any received medications and other treatments were recorded.

Statistical analysis

SPSS 17.0 (SPSS, Chicago, IL) was used for statistical analysis. Means and standard deviations were calculated for each variable. A pained student *t*-test was used to test the effects of stretching using CPS instrument on pain at first step, pressure pain threshold, ankle passive ranges of motion, and foot and ankle disability between baseline and the end of the 4-week intervention period. The one-way repeated measures ANOVA were used to test the effects of stretching using CPS instrument on average pain intensity over the past 24 hours between baseline and at the end of each week. Bonferonni Correction was used as post hoc analysis to identify the pair(s) that was responsible for the significant difference. *P*-value was set at < 0.05 for all statistical analyses.

Results

Fifteen subjects took part in this study. The means (standard deviations) of subjects' clinical and demographic data at baseline are shown in Table 1. None of the subjects reported any adverse effects due to the stretching technique. At the end of the 4-week intervention, a significant increase in pressure pain threshold and ankle passive dorsiflexion range of motion was demonstrated whereas there was a significant decrease in pain at first step in the morning as well as foot and ankle disability ($P < 0.001$) (Table 2).

The average pain intensity over the past 24 hours at the end of each treatment week decreased significantly from baseline ($P < 0.05$) (Figure 2). All subjects reported positive responses on their global perceived effect scores. Seven subjects (46.7%) rated their global perceived effect as completely recovered while 8 subjects (53.3%) regarded their effect to be much improved.

Table 1. Means (standard deviations) of subjects' clinical and demographic data at baseline (n = 15)

Variables	
Gender (male/female)	3/12
Symptomatic side (left/right)	9/6
Walking duration (mins/day)	120-240
Age (years)	50.8 (6.5)
BMI (kg/m^2)	24.4 (3.0)
Pain duration (months)	8.9 (8.3)

BMI = body mass index

Table 2. Means (standard deviations) at baseline and after 4-week intervention (n = 15)

Variables	Baseline	4-week intervention	*p*-value
Pain intensity			
- Pain at first step	5.6 (1.2)	2.1 (0.9)	< 0.001
- Average over the past 24 hours	3.6 (1.2)	0.8 (0.3)	< 0.001
Pressure pain threshold (kg/cm^2)	2.2 (1.0)	6.3 (2.6)	< 0.001
Ankle passive range of motion (degrees)			
- Dorsiflexion	10.7 (5.4)	14.7 (3.9)	< 0.001
- Plantarflexion	36.3 (5.9)	36.3 (5.9)	0.882
VAS-FA	83.1 (4.3)	92.3 (3.0)	< 0.001

VAS = visual analogue scale foot and ankle questionnaire.

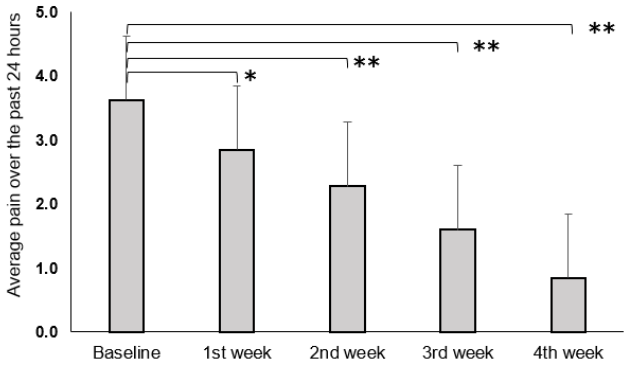


Figure 2. Changes in the average pain intensity over the past 24 hours at the end of each week (**P* < 0.05 and ***P* < 0.001).

Discussion

The results of this study indicate that the passive stretching of the Achilles tendon with the CPS instrument is effective intervention for alleviating pain and improving foot and ankle disability in subjects with plantar heel pain. Several outcome measures changed significantly after 4 weeks of the intervention.

This 4-week intervention resulted in a significant decrease in both pain at first step in the morning and average pain at the medial plantar calcaneal region over the past 24 hours (Table 2). An average reduction of 3.5 points in pain at first step in the morning was greater than the 1.3 and 3.1 points reductions reported after the 8-week stretching of the Achilles tendon and the plantar fascia alone, respectively.[12] The greater pain reduction after half of the intervention period suggests that stretching with the CPS instrument is superior to conventional stretching methods. Since none of the previous studies examined the average pain intensity at the medial plantar calcaneal region over the past 24 hours, a direct comparison of the results was inappropriate.

Nonetheless, the magnitude of reduction in the average pain intensity of 2.8 points in the current study was considered clinically significant. This average pain intensity decreased steadily from the baseline until the end of the 4-week intervention. Pain intensity could therefore further decrease over a longer period of intervention (Figure 2). This hypothesis should be confirmed by future studies.

The increase in pressure pain threshold after the intervention concurs with another finding from a previous study in which the Achilles tendon and the plantar fascia were consecutively stretched for 4 weeks. In that study, the pressure pain threshold over the calcaneal area increased slightly from 2.3 to 2.6 kg/cm^2 on average.[11] However, the stretching with the CPS instrument, a significant increase in pressure pain threshold – three-fold from baseline (2.2 to 6.3 kg/cm^2) – was demonstrated. The change in pressure pain threshold indicates a hypoalgesic effect of stretching on the plantar heel pain. Although the mechanism of the increase in pressure pain threshold is unclear, the results suggest that the control of force and angle during stretching of the Achilles tendon would provide more therapeutic benefits.

This current study found an increase in the passive ankle dorsiflexion range of motion but no change in passive ankle plantarflexion. This was in line with one study that measured passive ankle dorsiflexion after 4 weeks of Achilles tendon stretching.[10] Nevertheless, this result should be interpreted with caution. The reported changes of 2 - 4 degrees tend to be within a measurement error and have no clinical significance.

To the authors' knowledge, the first study that employed VAS-FA for measuring foot and ankle disability after stretching of the Achilles tendon or the plantar fascia in patients with plantar heel pain. Direct comparison of the results with the previous studies is therefore difficult. Nonetheless, all previous studies showed improvement in foot and ankle disability with their stretching methods.[10, 11] At the end of the 4-week intervention in the current study, VAS-FA score increased towards the 94.5 average normative score for non-pathology individuals.[17] The decrease in foot and ankle disability corresponds with the global perceived effect score of 100% of the subjects as completely recovered and much improved. In comparison to the only other study that examined the subjects' satisfaction with treatment over 8 weeks, the subjects who were totally satisfied or satisfied with minor reservations accounted for 91.3% for plantar fascia stretching and 60.0% for Achilles tendon stretching.[12]

These results suggest that the duration and frequency of the Achilles tendon stretching protocol used in this study which was also found to be effective for self-stretching of the Achilles tendon in the previous study[10] were effective. In terms of pain and disability reductions as well as the patients' satisfaction with treatment, the stretching with the CPS instrument provide a better outcomes than other self-stretching techniques.

This study has a few limitations, however. The study utilized a one-group pretest-posttest design to investigate the changes in pain and disability after 4 weeks of application of the intervention with the CPS instrument in subjects with plantar heel pain. A further study should be conducted to compare the effectiveness of this intervention with the control or other interventions. Furthermore, all subjects had

suffered from plantar heel pain for less than 1 month so future study should examine subjects with longer chronicity. Besides, this study evaluated the outcomes after 4 weeks. A long-term follow-up study is needed.

Conclusion

The passive stretching of the Achilles tendon via the CPS instrument can improve pain and function in patients with plantar heel pain. The results suggest that the CPS instrument could provide an effective management for the plantar heel pain.

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