



Original Research

An exploration of the factors predicting clinical responses to customized foot orthoses in individuals with plantar heel pain

Pavinee Harutaichun^a, Ninwisan Hengsomboon^a, Pichaya Hengsomboon^a,
Prasert Sakulsriprasert^a, Jim Richards^b, Sunee Bovonsunthonchai^{a,*}

^a Faculty of Physical Therapy, Mahidol University, Nakhon Pathom, Thailand

^b Allied Health Research Unit, University of Central Lancashire, Preston, UK

ARTICLE INFO

Keywords:

Foot orthoses
Physical examination
Plantar fasciitis
Prognosis

ABSTRACT

Background: Customized foot orthoses (CFOs) are commonly used to manage plantar heel pain (PHP); however, individual responses vary. This study aimed to evaluate the effects of CFOs on pain and foot function and identify predictors of treatment response.

Methods: A total of 120 individuals with PHP underwent baseline assessments, including demographics, pain, foot function, and physical examination. Participants wore CFOs for at least 6 hours daily over six months and were reassessed for pain and foot function. Treatment response was assessed using a 15-point Global Rating of Change (GRC) scale, with responders defined as those reporting GRC $\geq +4$. Baseline variables were analyzed to identify predictors of treatment response.

Results: Of the 120 participants, 107 (89.2%) were classified as responders. Significant improvements in pain and function were observed at six months ($p < 0.05$), with large effect sizes. Logistic regression identified four significant predictors of a positive response: higher pain during barefoot walking (OR = 1.84, 95% CI, $p = 0.018$), lower low back disability (OR = 0.69, 95% CI, $p = 0.007$), greater calcaneal eversion on the asymptomatic side (OR = 4.17, 95% CI, $p = 0.014$), and absence of neural tension on the symptomatic side (OR = 0.05, 95% CI, $p = 0.022$). The model explained 51.1% of the variance and correctly classified 90.4% of cases.

Conclusion: Most participants who received CFOs demonstrated significant improvements in pain and function at six months. Both local and remote physical factors predicted response, highlighting the value of a comprehensive physical assessment in guiding orthotic treatment.

Introduction

Plantar heel pain (PHP), commonly resulting from plantar fasciitis, is one of the most prevalent foot disorders worldwide, with more than one million cases treated annually in the United States.¹ Increasing health-care utilization has also been reported in South Korea and the Netherlands, where incidence rates range from 3.83 cases per 1000 patient-years in primary care.^{2,3} Clinically, PHP is characterized by localized heel pain that is most prominent during the first steps after rest and often recurs with prolonged standing or walking, affecting daily activities and duties.^{4,5}

The etiology of PHP is multifactorial, involving mechanical, anatomical, and systemic factors.^{6,7} Repetitive overload of the plantar fascia may lead to tissue thickening, increased collagen deposition,

reduced elasticity, and altered foot mechanics, including reduced arch height and increased midfoot pronation.^{8,9} Although these mechanical changes are well documented, growing evidence suggests that clinical and systemic factors also contribute to symptom presentation and treatment response. These include pain intensity,¹⁰ symptom duration,¹¹ higher BMI,^{6,10} fear-avoidance beliefs,¹⁰ prolonged weight-bearing,^{6,10} and reduced ankle dorsiflexion,¹⁰ which may influence pain perception, weight-bearing strategies, and response to conservative treatment.

Foot orthoses, particularly custom foot orthoses (CFOs), are widely used and have demonstrated short-term pain relief and potential long-term functional benefits, although effects on foot function remain inconsistent.^{12–15} Evidence suggests that CFOs are most effective when combined with multimodal rehabilitation programs such as stretching,

* Corresponding author at: Faculty of Physical Therapy, Mahidol University, 999 Phuttamonthon Sai 4 Rd, Salaya, Nakhon Pathom 73170, Thailand.

E-mail addresses: pavinee.har@mahidol.ac.th (P. Harutaichun), ninwisan.sku@mahidol.ac.th (N. Hengsomboon), pichaya.hen@mahidol.ac.th (P. Hengsomboon), prasert.sak@mahidol.ac.th (P. Sakulsriprasert), JRichards@uclan.ac.uk (J. Richards), sunee.bov@mahidol.ac.th (S. Bovonsunthonchai).

<https://doi.org/10.1016/j.bjpt.2026.101647>

Received 8 July 2025; Received in revised form 12 July 2026; Accepted 13 August 2026

Available online 11 September 2026

1413-3555/© 2026 The Authors. Published by Elsevier España, S.L.U. on behalf of Associação Brasileira de Pesquisa e Pós-Graduação em Fisioterapia. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

taping, or strengthening exercises.^{13–15} However, in clinical practice, CFOs are often prescribed as a stand-alone intervention, resulting in variable outcomes. This highlights the need to identify predictors of treatment response to improve patient selection and clinical decision-making.

Previous studies have identified several predictors of treatment outcomes, including shorter symptom duration,¹¹ higher BMI, and reduced ankle dorsiflexion.¹⁰ These findings suggest that both clinical and biomechanical factors contribute to treatment response. However, most studies have focused on isolated local foot variables, and broader musculoskeletal and functional factors remain underexplored. Therefore, the present study aimed to evaluate the effects of CFOs on pain and foot function and to investigate whether a comprehensive set of variables, including musculoskeletal alignment, joint mobility, foot posture, movement quality, dynamic balance, neural tension, and plantar fascia thickness, can predict treatment response in individuals with PHP.

Methods

Study design

This study employed a prospective, single-group, pre-post treatment design to investigate the effects of CFOs on pain and foot function and to identify predictors of treatment response in individuals with PHP.

Setting and participants

The study was conducted at Mahidol University in Thailand. Participants with a clinical diagnosis of PHP were recruited from the Faculty of Physical Therapy. All participants were screened by licensed physical therapists using standardized clinical criteria.¹⁶

Eligibility criteria included: (1) localized tenderness at the medial calcaneal tubercle or plantar fascia along the medial longitudinal arch; (2) heel pain most pronounced during initial steps after waking or prolonged inactivity, with symptoms improvement during the day but exacerbation with prolonged weight-bearing; (3) symptoms duration ≥ 6 weeks,¹⁷ and (4) maximum pain intensity ≥ 3 on a 10-point visual analog scale (VAS) within the past week. Leg length discrepancy was measured using a tape measure from the anterior superior iliac spine to the medial malleolus. Participants with a discrepancy > 1.5 cm were excluded, as well as those with a history of lower limb fracture or surgery, or diagnosis of gout, diabetic neuropathy, or rheumatoid arthritis.

Ethics approval and consent to participate

This study was approved by the Institutional Review Board of Mahidol University (COA No. MU-CIRB 2023/013.0102). Written informed consent was obtained from all participants before enrollment. Participants were informed about the study objectives, procedures, potential risks and benefits, and their right to withdraw at any time without consequence. The study was conducted in accordance with the Declaration of Helsinki.

Procedure and outcome measures

Eligible participants provided written informed consent and underwent baseline assessment by a licensed physical therapist, with follow-up at 6 months. Baseline data included demographics (age and BMI) and clinical information. Pain intensity was assessed using a VAS (cm) in four contexts (worst pain, morning pain, pain during barefoot standing, and pain during barefoot walking). Foot function was assessed using the Thai version of the 23-item Foot Function Index (FFI), comprising pain, disability, and activity limitation subscales, as well as a total score.¹⁸ Comorbid musculoskeletal conditions were assessed using the Thai versions of the Roland-Morris Disability Questionnaire (RMDQ),¹⁹ Hip Disability and Osteoarthritis Outcome Score (HOOS),²⁰

and Knee Injury and Osteoarthritis Outcome Score (KOOS).²¹

A comprehensive physical examination assessed musculoskeletal alignment, joint mobility, foot posture, movement quality, dynamic balance, neural tension, and plantar fascia thickness. Musculoskeletal alignment was assessed bilaterally using a handheld goniometer to measure the quadriceps angle, tibiofemoral angle, knee recurvatum angle, foot progression angle, calcaneal inversion and eversion range, rearfoot and forefoot alignment (based on Root et al.²² and Monaghan et al.²³ methods), hallux valgus angle, and first metatarsophalangeal (1st MTP) joint dorsiflexion range. Ankle dorsiflexion range of motion was assessed using the weight-bearing lunge test. Foot posture was assessed using the Foot Posture Index (FPI), which classifies each foot as neutral, pronated, or supinated based on six observational criteria during relaxed bipedal standing.²⁴ Movement quality was assessed using the lateral step-down test based on standardized criteria evaluating arm strategy, trunk alignment, pelvic control, knee position, and overall steadiness.²⁵ Dynamic balance was assessed using the Y Balance Test (YBT), including anterior, posteromedial, and posterolateral reach distances and a normalized composite score calculated from the three reach directions relative to leg length.²⁶ Neural tension was assessed using the slump test. A positive result was defined as reproduction or increase of posterior thigh symptoms with cervical flexion during knee extension, with or without ankle dorsiflexion. Plantar fascia thickness was assessed bilaterally using ultrasonography (Philips Affiniti 50, NV, USA) with a 4 cm depth setting.²⁷ The transducer was aligned longitudinally from the second metatarsal head to the medial calcaneal tubercle, following the European Society of Musculoskeletal Radiology guidelines.²⁸ Thickness was measured at a point 5 mm distal to the calcaneal border. Three measurements were taken and averaged.

All physical measurements were performed by a well-trained examiner. Intra-rater reliability was interpreted using Koo and Li criteria,²⁹ where values < 0.50 indicate poor reliability, $0.50–0.75$ moderate reliability, $0.75–0.90$ good reliability, and > 0.90 excellent reliability. Overall reliability ranged from moderate to excellent (ICC(3, 1): $0.69–0.98$). Excellent reliability was found for the quadriceps angle (0.98), tibiofemoral angle (0.97), hallux valgus angle (0.97), and knee recurvatum angle (0.93). Good reliability was observed for the foot progression angle (0.89), calcaneal range of motion (0.88), lateral step-down scores (0.85), reaching distance (0.80), and plantar fascia thickness (0.76). Moderate reliability was observed for the rearfoot angle (0.74), FPI (0.72), and forefoot angle (0.69).

Treatment

The CFOs were prescribed and fitted by a licensed physical therapist with over 10 years of clinical experience in foot orthotic management for musculoskeletal conditions. Following established protocols,^{30,31} each orthosis was heat-molded to the individual's unique foot contour using a standardized non-weight-bearing casting technique. Participants were positioned prone with knees fully extended and ankles maintained in neutral dorsiflexion (90 degrees), carefully avoiding inversion and eversion. The molding process was designed to replicate the medial longitudinal arch in a non-weight-bearing position, optimizing support during weight-bearing activities. The orthoses featured a dual-layer thermoplastic design, consisting of a three-quarter-length base layer made of 3 mm polycaprolactone for structural support and customization, and a full-length top layer made of ethylene propylene diene monomer rubber with 34 shore O hardness to enhance cushioning and comfort. The base design incorporated medial arch support using rigid thermoplastic and heel cushioning (Fig. 1), features recommended for reducing heel loading and plantar fascia strain in individuals with PHP.^{32,33}

Participants were instructed to wear the CFOs on both feet during daily weight-bearing activities for at least 6 hours/day over a 6-month period. All participants received CROCS off Court Clog footwear for indoor and outdoor use, with the option to use alternative footwear if



Fig. 1. A customized foot orthosis.

desired. Compliance was monitored using daily logbooks, in which participants recorded days when CFO use exceeded 6 hours/day, and monthly follow-up contacts via the LINE application were conducted to encourage adherence. Following 6 months of CFO use, pain and foot function were reassessed by the same physical therapist who performed the baseline assessment. This assessor was not involved in treatment provision, thereby minimizing potential bias from treatment expectations and ensuring consistency in outcome measurements. Participants were then classified as responders or non-responders based on the Global Rating of Change (GRC) scale, which ranges from -7 ("a very great deal worse") to $+7$ ("a very great deal better"), with 0 indicating no change. Participants with a GRC score of $\geq +4$ were classified as responders, whereas those with scores $< +4$ were classified as non-responders.³⁴

Sample size calculation

The required sample size for this study was determined using the widely accepted rule of thumb for multiple logistic regression, which recommends a minimum of 10 participants per predictor variable included in the final model.³⁵ In this study, a total of 12 potential predictor variables were identified for inclusion: age, BMI, pain, foot function, knee alignment, ankle dorsiflexion range of motion, foot posture, first metatarsophalangeal joint alignment, dynamic balance, quality of movement score, neural tension, and plantar fascia thickness. Assuming an approximately 80% response rate, a minimum of 120 events would require approximately 150 total participants to ensure adequate statistical power and model stability. This sample size was expected to provide sufficient statistical power to detect meaningful associations between the proposed predictors and the outcome variable while minimizing the risk of model overfitting.

Statistical analysis

All statistical analyses were performed using SPSS version 23 (IBM Corp., Armonk, NY, USA). For participants with bilateral pain, the foot with the most severe symptoms was selected for analysis. If pain severity was equal on both sides, the study side was randomly selected to avoid unit-of-analysis errors and ensure statistical independence.³⁶ Descriptive statistics are presented as means (standard deviations) or medians [interquartile ranges] for continuous variables and frequencies (percentages) for categorical variables. Data normality was assessed using the Kolmogorov-Smirnov test. To evaluate the effectiveness of CFOs, changes in pain and foot function between baseline and 6-month follow-up were analyzed using the paired t -test for normally distributed data or the Wilcoxon signed-rank test otherwise. Differences in demographic and physical characteristics between responders and

non-responders were analyzed using the independent samples t -test or Mann-Whitney U test, as appropriate. Multiple logistic regression analysis was performed to identify clinical and physical predictors of treatment response among individuals with PHP. Variables entered into the model were selected based on clinical relevance and the results of univariate analysis.

Results

A total of 120 individuals with PHP met the eligibility criteria and were enrolled. All participants received CFOs and were instructed to use them for 6 months, with a daily usage target of 6 hours. Adherence was defined as the proportion of days with CFO use ≥ 6 hours, with a mean adherence of 70.69% (SD 2.55; range 20–100%). No participants were lost to follow-up, and all completed the study, with no missing data. The participants included 31 males (25.8%) and 89 females (74.2%), with a mean age of 44.29 (10.06) years and a BMI of 26.51 (4.93) kg/m². The mean FPI scores indicated a generally normal foot posture on both symptomatic and asymptomatic sides (3.21 (3.72) and 3.63 (3.97), respectively).

Pain and foot function after 6 months of CFO use

Table 1 presents changes in pain and functional outcomes after 6 months of CFO use. Significant improvements were observed in all pain-related measures, including worst pain, morning pain, and pain during barefoot standing and walking (all $p < 0.001$). All FFI subscales and total scores significantly decreased after intervention (all $p < 0.001$). Significant improvements were also observed in RMDQ ($p < 0.001$), HOOS ($p = 0.015$), and KOOS ($p = 0.001$). Large effect sizes were observed for pain and foot function outcomes.

Comparison of demographics and physical characteristics between responders and non-responders

Based on the GRC score ($+4$ or higher indicating at least moderate improvement),^{11,34} 107 participants were classified as responders and 13 as non-responders after 6 months of CFO use. Table 2 presents the baseline demographics and physical characteristics comparisons between groups. Variables with $p \leq 0.20$ were considered potential predictors and entered into the multivariate logistic regression with backward Wald test. These included pain during barefoot walking ($p = 0.159$), activity limitation subscale of FFI ($p = 0.131$), RMDQ ($p = 0.030$), KOOS ($p = 0.183$), range of calcaneal eversion on the symptomatic side ($p = 0.177$) and asymptomatic side ($p = 0.189$), forefoot angle on the asymptomatic side ($p = 0.125$), hallux valgus angle on the asymptomatic side ($p = 0.087$), FPI on the symptomatic side ($p = 0.002$)

Table 1

Pain and foot function after 6 months of CFO use in individuals with PHP (n = 120).

Variables	Mean (SD)		p-value	Effect size (Cohen's d)
	Baseline	6-month		
Pain (cm):				
Worst pain	4.56 (2.20)	1.68 (1.81)	< 0.001*	2.459
Morning pain	3.90 (2.49)	1.43 (1.77)	< 0.001*	2.077
Pain during barefoot standing	4.73 (2.27)	1.75 (1.67)	< 0.001*	2.246
Pain during barefoot walking	4.28 (2.32)	1.58 (1.61)	< 0.001*	2.742
Foot function (scores):				
Pain subscale of FFI	40.85 (17.76)	13.10 (13.55)	< 0.001*	2.944
Disability subscale of FFI	35.09 (21.77)	12.51 (14.45)	< 0.001*	2.587
Activity limitation subscale of FFI	15.56 (19.16)	5.14 (9.66)	< 0.001*	1.374
Total score of FFI	32.42 (16.81)	11.12 (12.10)	< 0.001*	2.911
RMDQ (scores)	3.58 (3.92)	1.64 (2.55)	< 0.001*	0.559
HOOS (scores)	87.90 (17.12)	92.07 (14.74)	0.015*	-0.261
KOOS (scores)	82.46 (17.87)	88.64 (15.46)	0.001*	-0.368

Note:

* Significance tested by the paired *t*-test at $p < 0.05$; SD: standard deviation; FFI: Foot Function Index

and asymptomatic side ($p = 0.027$), reaching distance on the asymptomatic side ($p = 0.091$), positive neural tension test with knee extension on the asymptomatic side ($p = 0.125$), and positive neural tension test with knee extension and ankle dorsiflexion on the symptomatic side ($p = 0.037$).

Multiple logistic regression analysis

Table 3 presents the final multiple logistic regression analysis, revealing a statistically significant model ($\chi^2 = 32.841$, $p < 0.001$), explaining 51.1% of the variance in response to CFOs and correctly classifying 90.4% of the participants. Significant independent predictors included pain during barefoot walking, RMDQ score, range of calcaneal eversion on the asymptomatic side, and a positive slump test with ankle dorsiflexion on the symptomatic side.

Higher pain during barefoot walking was associated with increased odds of response (OR = 1.835, 95% CI 1.109–3.036, $p = 0.018$), whereas higher RMDQ scores were associated with decreased odds of response (OR = 0.691, 95% CI 0.527–0.905, $p = 0.007$). Greater calcaneal eversion range on the asymptomatic side was associated with increased odds of response (OR = 4.168, 95% CI 1.338–12.980, $p = 0.014$), while a positive slump test with ankle dorsiflexion on the symptomatic side was associated with decreased odds of response (OR = 0.046, 95% CI 0.003–0.644, $p = 0.022$). Other variables, including the activity limitation subscale of FFI, calcaneal eversion on the symptomatic side, and FFI on both sides, were not retained as significant predictors in the final model.

Discussion

This study demonstrated that individuals with PHP experienced significant improvements in pain and foot function after 6 months of CFO use. Reductions in worst pain, morning pain, and pain during barefoot standing and walking exceeded previously reported minimal clinically important differences (MCID) for VAS pain (0.85 or 0.9

Table 2

Comparison of demographics and physical characteristics between responders (n = 107) and non-responders (n = 13) at baseline.

Variables	Mean (SD) or n (%) or Median [IQR]		p-value	Effect size (Cohen's d or r)
	Responders (n = 107)	Non-responders (n = 13)		
Age (years) ^a	44.07 (9.82)	44.82 (13.41)	0.880	0.044
BMI (kg/m ²) ^a	26.53 (5.30)	25.99 (3.30)	0.994	0.002
Pain (cm)				
Worst pain ^a	4.54 (2.14)	4.93 (2.03)	0.691	0.117
Morning pain ^b	3.70 [4.35]	3.75 [2.83]	0.996	< 0.001
Pain during barefoot standing ^a	4.41 (2.36)	3.92 (1.45)	0.302	0.316
Pain during barefoot walking ^a	4.88 (2.30)	4.41 (1.05)	0.159*	0.449
FFI (scores):				
Pain subscale of FFI ^a	41.16 (17.61)	40.97 (11.25)	0.485	0.209
Disability subscale of FFI ^b	33.11 [35.51]	35.35 [16.40]	0.732	0.031
Activity limitation subscale of FFI ^b	9.30 [23.75]	3.70 [15.30]	0.131*	0.139
Total score of FFI ^b	32.70 [26.99]	31.29 [16.74]	0.664	0.040
RMDQ (scores) ^b	2.00 [5.00]	4.50 [7.75]	0.030*	0.198
HOOS (scores) ^b	100.00 [17.50]	78.75 [27.50]	0.215	0.114
KOOS (scores) ^b	86.81 [30.56]	82.29 [18.06]	0.183*	0.122
Quadriceps angle (degrees)	25.12 (8.76)	25.55 (4.91)	0.918	0.030
Symptomatic side ^a	(8.76)	24.00 [17.50]	0.707	0.034
Asymptomatic side ^b	24.50 [11.00]			
Tibiofemoral angle (degrees)	10.00 [6.00]	10.00 [5.50]	0.760	0.028
Symptomatic side ^b	[6.00]	10.00 [6.00]	0.773	0.026
Asymptomatic side ^b	11.00 [6.50]			
Knee recurvatum angle (degrees)	5.00 [2.00]	4.00 [3.00]	0.787	0.025
Symptomatic side ^b	4.00 [2.00]	5.00 [3.00]	0.637	0.043
Asymptomatic side ^b				
Foot progression angle (degrees)	6.35 (4.36)	6.91 (3.94)	0.910	0.033
Symptomatic side ^a	6.50 [6.00]	5.50 [4.00]	0.469	0.066
Asymptomatic side ^b				
Range of calcaneal inversion (degrees)	14.00 [4.00]	13.00 [3.50]	0.769	0.027
Symptomatic side ^b	[4.00]	13.64 (3.78)	0.208	0.096
Asymptomatic side ^a	13.00 (3.13)			
Range of calcaneal eversion (degrees)	6.00 [3.00]	5.00 [2.00]	0.177*	0.123
Symptomatic side ^b	7.00 [3.00]	5.00 [2.00]	0.189*	0.120
Asymptomatic side ^b				
Rearfoot angle from Root et al. method (degrees)	3.00 [3.00]	3.00 [4.50]	0.406	0.076
Symptomatic side ^b	3.00 [3.00]	3.00 [2.00]	0.536	0.057
Asymptomatic side ^b				
Forefoot angle from Root et al. method (degrees)	15.00 [7.00]	15.50 [6.50]	0.816	0.021
Symptomatic side ^b	15.00 [7.50]	11.00 [5.00]	0.125*	0.140
Asymptomatic side ^b				
Rearfoot angle from Monaghan et al. method (degrees)	6.00 [3.00]	5.00 [4.50]	0.431	0.072
Symptomatic side ^b	6.00 [4.00]	6.00 [4.30]	0.261	0.103
Asymptomatic side ^b				
Forefoot angle from Monaghan et al. method (degrees)	19.00 [9.30]	17.00 [6.30]	0.963	0.004
		21.18 (7.92)	0.342	0.260

(continued on next page)

Table 2 (continued)

Variables	Mean (SD) or n (%) or Median [IQR]		p-value	Effect size (Cohen's d or r)
	Responders (n = 107)	Non-responders (n = 13)		
Symptomatic side ^b	18.62			
Asymptomatic side ^a	(9.72)			
Hallux valgus angle (degrees)	13.00	14.50 [12.30]	0.269	0.101
Symptomatic side ^b	[12.00]	16.50 [6.00]	0.087*	0.156
Asymptomatic side ^b	12.00			
	[11.30]			
1 st MTP joint extension (degrees)	51.50	49.50 [10.80]	0.528	0.058
Symptomatic side ^b	[11.00]	49.27 (11.82)	0.691	0.117
Asymptomatic side ^a	50.77			
	(9.78)			
Ankle dorsiflexion lunge test (cm)	11.54	10.86 (3.51)	0.779	0.083
Symptomatic side ^a	(3.20)	10.96 (3.37)	1.000	< 0.001
Asymptomatic side ^a	11.54			
	(3.24)			
FPI				
Symptomatic side ^b	2.00 [6.00]	6.00 [9.00]	0.002*	0.278
Asymptomatic side ^a	3.22 (4.07)	6.27 (3.64)	0.027*	0.660
Lateral step down (scores)	3.00 [1.00]	3.00 [1.00]	0.498	0.062
Symptomatic side ^b	3.00 [1.00]	3.00 [1.00]	0.497	0.062
Asymptomatic side ^b				
Reaching distance (normalized to leg length)	69.59	68.77 (9.09)	0.489	0.204
	(10.68)	66.00 (7.91)	0.091*	0.501
Symptomatic side ^a	70.21			
Asymptomatic side ^a	(11.29)			
Having a positive test for neural tension with knee extension	24 (22.43 %)	4 (30.77 %)	0.357	0.123
Symptomatic side ^c	15 (14.02 %)	4 (30.77 %)	0.125*	0.288
Asymptomatic side ^c				
Having a positive test for neural tension with knee extension and ankle dorsiflexion	50 (46.73 %)	10 (76.92 %)	0.037*	0.382
	49 (45.79 %)	6 (46.15 %)	0.604	0.006
Symptomatic side ^c				
Asymptomatic side ^c				
Plantar fascia thickness (cm)	0.28 [0.10]	0.29 [0.10]	0.797	0.024
Symptomatic side ^b	0.29 [0.08]	0.28 [0.05]	0.691	0.036
Asymptomatic side ^b				

Note: FFI: Foot Function Index; RMDQ: Roland–Morris Disability Questionnaire; HOOS: Hip Disability and Osteoarthritis Outcome Score; KOOS: Knee Injury and Osteoarthritis Outcome Score; 1st MTP: First metatarsophalangeal; FPI: Foot Posture Index; SD: Standard deviation; IQR: Interquartile range; Significant tested by

^a Independent sample *t*-test;

^b Mann–Whitney U test

^c Chi-square test;

* Potential predictors with $p \leq 0.2$

cm).^{37,38} The reduction in morning pain also exceeded the MCID reported for first-step pain (1.92 cm).³⁸ Similarly, improvements in pain, disability, and total scores of the FFI exceeded established MCID values (12, 7, and 7 points, respectively),³⁷ indicating that the observed changes were not only statistically significant but also clinically important. The large effect sizes across all variables (Cohen's $d = 1.374$ – 2.944) further support the magnitude of the observed improvements. These findings align with previous studies suggesting that conservative interventions and CFOs may produce meaningful improvements in pain and foot function in individuals with PHP.^{39–43} Although improvements were observed in low back, hip, and knee pain, the magnitude of these changes did not meet the MCID threshold identified in previous studies (5 points for RMDQ,⁴⁴ 12.2 for HOOS,⁴⁵

and 11.5 for KOOS⁴⁵). Nevertheless, this study provides the first evidence describing changes in pain-related outcomes beyond the foot region following CFO use in individuals with PHP. The absence of a control group should be acknowledged, as it limits causal interpretation of the observed improvements.

Based on the GRC score $\geq +4$ as the response criterion in this study, the responder rate after 6 months of CFO use was 89.2% (107/120). Wrobel et al.⁴⁶ reported a response rate of 56.5% based on $\geq 50\%$ pain reduction, whereas McClinton et al.¹¹ reported response rates of 48.3–63.3% using pain scale, Foot and Ankle Ability Measure, or GRC criteria. However, these rates cannot be directly comparable due to differences in responder definitions. A comparison between responders and non-responders identified several physical characteristics that were potentially associated with treatment response. Although no significant demographic differences were observed, variables with $p \leq 0.20$ from the univariate analyses were considered candidate predictors and entered into the multivariate logistic regression model. The final logistic regression model identified four independent predictors of response to CFOs: higher pain during barefoot walking, lower low back functional disability, greater calcaneal eversion range on the asymptomatic side, and absence of neural tension on the symptomatic side. The model was statistically significant, explaining 51.1% of the variance and correctly classifying 90.4% of participants. Although FPI differed significantly between responders and non-responders in univariate analyses, it was not retained as an independent predictor in the final model. These findings highlight that treatment response may be influenced by a combination of local foot characteristics and remote factors related to the lumbar region and neural system.

Higher pain during barefoot walking was associated with a favorable response, suggesting that individuals with more pronounced mechanical loading-related symptoms are more likely to benefit from CFOs. This aligns with the biomechanical rationale that orthoses reduce plantar fascia stress and improve foot function during weight-bearing activities.^{42,43} In contrast, higher low back functional disability, assessed using the RMDQ, was associated with a lower likelihood of a favorable response, suggesting that individuals with higher lumbar spine-related impairments may be less responsive to localized interventions such as CFOs alone. These individuals may have more complex centrally mediated pain mechanisms or altered movement patterns that CFOs may not adequately address. Interestingly, a greater range of calcaneal eversion on the asymptomatic side was associated with an increased likelihood of response. This may indicate that individuals with greater foot mobility or flexibility are better able to accommodate the mechanical effects of CFOs. The finding suggests that contralateral foot mechanics may influence treatment outcomes, supporting the need for bilateral assessment.

A positive slump test with ankle dorsiflexion on the symptomatic side, indicative of neural tension or mechanosensitivity, was strongly associated with a reduced likelihood of response. This may reflect contributions from neuropathic pain, arising from altered nerve function or sensitization, and nociplastic pain, related to central pain processing, indicating that individuals with neural involvement may require additional or alternative therapeutic strategies, such as neural mobilization or spinal interventions targeting low back dysfunction.⁴⁷ Compared with previous findings by Whittaker et al.,¹⁰ who identified lower BMI, greater ankle dorsiflexion, and lower fear-avoidance beliefs as predictors of improved outcomes following foot orthoses over 4–12 weeks, the present study identified different predictors after 6 months of CFO use. These differences may be explained by variations in study design, participant characteristics, orthosis type, and follow-up duration, suggesting that predictors of orthosis responsiveness may vary across clinical contexts.

Taken together, these findings support a multidimensional approach to PHP management. While CFOs can be effective for individuals with mechanical pain features, particularly those with higher barefoot walking pain and favorable foot mobility, our findings additionally

Table 3

Multiple logistic regression analysis of variables to predict the response of CFOs (n = 120).

Variables	B	SE	Wald	df	p-value	Exp (B)	95% CI for Exp (B)
Pain during barefoot walking	0.607	0.257	5.574	1	0.018*	1.835	1.109–3.036
Activity limitation subscale of FFI	0.053	0.033	2.513	1	0.113	1.054	0.988–1.125
RMDQ	– 0.370	0.138	7.187	1	0.007*	0.691	0.527–0.905
Range of calcaneal eversion							
Symptomatic side	– 0.518	0.318	2.650	1	0.104	0.596	0.320–1.111
Asymptomatic side	1.427	0.580	6.065	1	0.014*	4.168	1.338–12.980
FPI							
Symptomatic side	– 0.263	0.148	3.160	1	0.075	0.769	0.576–1.027
Asymptomatic side	– 0.411	0.211	3.803	1	0.051	0.663	0.439–1.002
Having a positive test for the slump test with ankle dorsiflexion in the symptomatic side	– 3.075	1.344	5.232	1	0.022*	0.046	0.003–0.644
Constant	0.688	2.105	0.107	1	0.744	1.989	–

Note:

* Significance tested by the Multiple logistic regression at $p < 0.05$; a Model Chi-square test, $\chi^2(8) = 32.841$ ($p < 0.001$); Overall percentage of correctly predicted = 90.4%; Goodness of fit (Hosmer and Lemeshow test) = 0.957. Pseudo- $R^2 = 0.511$; FFI: Foot Function Index; RMDQ: Roland–Morris Disability Questionnaire; FPI: Foot Posture Index.

suggest that those with more complex clinical profiles (e.g., high low back disability or neural tension) may require additional or alternative therapeutic interventions. Future research should explore integrating CFOs with other therapeutic modalities to address the broader spectrum of contributing factors in individuals with PHP.

Some limitations should be acknowledged in this study. First, the relatively small number of non-responders ($n = 13$) and an overall sample size below the estimated requirement may limit statistical power to identify indicators of poor response and reduce the ability to draw comprehensive conclusions. Second, all assessments were performed by a single examiner who was not blinded to the assessment time point (pre- or post-intervention), introducing potential measurement bias despite not being involved in treatment delivery. Third, self-reported outcome measures, including the GRC scale and FFI, are susceptible to recall bias and subjective interpretation. Fourth, the absence of a control group precludes determining whether improvements were attributable to CFOs or to the natural course of symptoms, and the findings should therefore be interpreted with caution. Finally, although a range of physical and clinical factors was evaluated, other potentially influential variables, such as psychosocial factors and adherence to CFO use, were not comprehensively assessed. Future studies should include larger, more diverse populations with sufficient numbers of non-responders, longer follow-up periods, and more comprehensive evaluations of psychosocial, adherence, and biomechanical factors to improve understanding of treatment responsiveness.

Conclusion

Most individuals with PHP experienced clinically significant improvement in pain and function over a 6-month period of CFO use, although the absence of a control group limits the ability to attribute these changes solely to the intervention. Key factors associated with a positive response include higher pain intensity during barefoot walking, lower low back disability, greater range of calcaneal eversion, and the absence of neural tension sign, highlighting the importance of a comprehensive assessment of both local foot mechanics and related musculoskeletal factors. These findings support the role of CFOs as an effective treatment for PHP and suggest that individualized evaluation of physical and neural factors may enhance treatment outcomes.

Funding

This research project was funded by Mahidol University (Fundamental Fund: fiscal year 2024, supported by the National Science Research and Innovation Fund (NSRF)).

CRediT authorship contribution statement

Pavinee Harutaichun: Conceptualization, Formal analysis, Investigation, Funding acquisition, Methodology, Writing – original draft, Writing – review & editing. **Ninwisana Hengsomboon:** Conceptualization, Investigation, Methodology. **Pichaya Hengsomboon:** Investigation, Methodology. **Prasert Sakulsriprasert:** Investigation. **Jim Richards:** Formal analysis, Writing – original draft, Writing – review & editing. **Sunee Bovonsunthonchai:** Conceptualization, Supervision, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The author(s) declared no potential conflicts of interest.

Acknowledgment

The authors would like to express our sincere gratitude to all participants for their involvement in the study, and to the research assistants, Mr. Katayan Klahan and Ms. Narana Onsri, for their valuable support in the data collection process.

References

- Riddle DL, Schappert SM. Volume of ambulatory care visits and patterns of care for patients diagnosed with plantar fasciitis: a national study of medical doctors. *Foot Ankle Int.* 2004;25(5):303–310. <https://doi.org/10.1177/107110070402500505>.
- Ahn J, Yeo J, Lee SH, et al. Healthcare usage and cost for plantar fasciitis: a retrospective observational analysis of the 2010–2018 health insurance review and assessment service national patient sample data. *BMC Health V Res.* 2023;23(1):546. <https://doi.org/10.1186/s12913-023-09443-2>.
- Rasenber N, Bierma-Zeinstra SM, Bindels PJ, van der Lei J, van Middelkoop M. Incidence, prevalence, and management of plantar heel pain: a retrospective cohort study in Dutch primary care. *Br J Gen Pr.* 2019;69(688):e801–e808. <https://doi.org/10.3399/bjgp19x706061>.
- Landorf KB. Plantar heel pain and plantar fasciitis. *BMJ Clin Evid.* 2015;2015.
- Mork M, Soberg HL, Hoksrud AF, Heide M, Groven KS. The struggle to stay physically active—a qualitative study exploring experiences of individuals with persistent plantar fasciopathy. *J Foot Ankle Res.* 2023;16(1):20. <https://doi.org/10.1186/s13047-023-00620-4>.
- Irving DB, Cook JL, Menz HB. Factors associated with chronic plantar heel pain: a systematic review. *J Sci Med Sport.* 2006;9(1–2):11–22. <https://doi.org/10.1016/j.jsams.2006.02.004>. discussion 23–4.
- Sullivan J, Pappas E, Burns J. Role of mechanical factors in the clinical presentation of plantar heel pain: implications for management. *Foot.* 2020;42, 101636. <https://doi.org/10.1016/j.foot.2019.08.007>.
- Bolgla LA, Malone TR. Plantar fasciitis and the windlass mechanism: a biomechanical link to clinical practice. *J Athl Train.* 2004;39(1):77–82.
- Caravaggi P, Pataky T, Gunther M, Savage R, Crompton R. Dynamics of longitudinal arch support in relation to walking speed: contribution of the plantar aponeurosis. *J Anat.* 2010;217(3):254–261. <https://doi.org/10.1111/j.1469-7580.2010.01261.x>.
- Whittaker GA, Landorf KB, Munteanu SE, Menz HB. Predictors of response to foot orthoses and corticosteroid injection for plantar heel pain. *J Foot Ankle Res.* 2020;13(1):60. <https://doi.org/10.1186/s13047-020-00428-6>.

11. McClinton SM, Cleland JA, Flynn TW. Predictors of response to physical therapy intervention for plantar heel pain. *Foot Ankle Int.* 2015;36(4):408–416. <https://doi.org/10.1177/1071100714558508>.
12. Martin RL, Davenport TE, Reischl SF, et al. Heel pain–plantar fasciitis: revision 2014. *J Orthop Sports Phys Ther.* 2014;44(11):A1–A33. <https://doi.org/10.2519/jospt.2014.0303>.
13. Koc Jr TA, Bise CG, Neville C, Carreira D, Martin RL, McDonough CM. Heel pain – plantar fasciitis: revision 2023. *J Orthop Sports Phys Ther.* 2023;53(12):CPG1–CPG39. <https://doi.org/10.2519/jospt.2023.0303>.
14. Lourenco BM, Campos MGM, Maia L, Castro B, Trede RG, Oliveira VC. Efficacy of pharmacological and non-pharmacological therapies on pain intensity and disability for plantar fasciitis: a systematic review and meta-analysis. *Br J Sports Med.* 2023;57(23):1516–1521. <https://doi.org/10.1136/bjsports-2022-106403>.
15. Wang D, Lin Z, Tan G, Han X, Huang Y. Efficacy and safety of foot orthoses for improving pain and function in patients with plantar fasciitis: a systematic review and meta-analysis of randomized controlled trials. *Disabil Rehabil.* 2026;48:1231–1245. <https://doi.org/10.1080/09638288.2025.2563763>.
16. McPoil TG, Martin RL, Cornwall MW, Wukich DK, Irrgang JJ, Godges JJ. Heel pain—plantar fasciitis: clinical practice guidelines linked to the international classification of function, disability, and health from the orthopaedic section of the American physical therapy association. *J Orthop Sports Phys Ther.* 2008;38(4):A1–A18. <https://doi.org/10.2519/jospt.2008.0302>.
17. Morrissey D, Cotchett M, Said J'Bari A, et al. Management of plantar heel pain: a best practice guide informed by a systematic review, expert clinical reasoning and patient values. *Br J Sports Med.* 2021;55(19):1106–1118. <https://doi.org/10.1136/bjsports-2019-101970>.
18. Bovonsunthonchai S, Thong-On S, Vachalathiti R, Intravaranont W, Suwannarat S, Smith R. Thai version of the foot function index: a cross-cultural adaptation with reliability and validity evaluation. *BMC Sports Sci Med Rehabil.* 2020;12:56. <https://doi.org/10.1186/s13102-020-00206-8>.
19. Jirarattanaphochai K, Jung S, Sumananont C, Saengnipanthkul S. Reliability of the roland – morris disability questionnaire (Thai version) for the evaluation of low back pain patients. *J Med Assoc Thai.* 2005;88(3):407–411.
20. Trathitiphan W, Paholpak P, Sirichativapee W, et al. Cross-cultural adaptation and validation of the reliability of the Thai version of the Hip disability and osteoarthritis outcome score (HOOS). *Rheumatol Int.* 2016;36(10):1455–1458. <https://doi.org/10.1007/s00296-016-3505-4>.
21. Chaipinyo K. Test–retest reliability and construct validity of thai version of knee osteoarthritis outcome score (KOOS). *Thai J Phys Ther.* 2009;31:67–76.
22. Root MI. Biomechanical examination of the foot. *J Am Podiatry Assoc.* 1973;63(1):28–29. <https://doi.org/10.7547/87507315-63-1-28>.
23. Monaghan GM, Lewis CL, Hsu WH, Saltzman E, Hamill J, Holt KG. Forefoot angle determines duration and amplitude of pronation during walking. *Gait Posture.* 2013;38(1):8–13. <https://doi.org/10.1016/j.gaitpost.2012.10.003>.
24. Keenan AM, Tennant A, Fear J, Emery P, Conaghan PG. Impact of multiple joint problems on daily living tasks in people in the community over age fifty-five. *Arthritis Rheum.* 2006;55(5):757–764. <https://doi.org/10.1002/art.22239>.
25. Piva SR, Fitzgerald K, Irrgang JJ, et al. Reliability of measures of impairments associated with patellofemoral pain syndrome. *BMC Musculoskelet Disord.* 2006;7:33. <https://doi.org/10.1186/1471-2474-7-33>.
26. Filipa A, Byrnes R, Paterno MV, Myer GD, Hewett TE. Neuromuscular training improves performance on the star excursion balance test in young female athletes. *J Orthop Sports Phys Ther.* 2010;40(9):551–558. <https://doi.org/10.2519/jospt.2010.3325>.
27. Karabay N, Toros T, Hurel C. Ultrasonographic evaluation in plantar fasciitis. *J Foot Ankle Surg.* 2007;46(6):442–446. <https://doi.org/10.1053/j.jfas.2007.08.006>.
28. Martinoli C. Musculoskeletal ultrasound: technical guidelines. *Insights Imaging.* 2010;1(3):99–141. <https://doi.org/10.1007/s13244-010-0032-9>.
29. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J Chiropr Med.* 2016;15(2):155–163. <https://doi.org/10.1016/j.jcm.2016.02.012>.
30. Landorf KB, Keenan AM, Herbert RD. Effectiveness of different types of foot orthoses for the treatment of plantar fasciitis. *J Am Podiatr Med Assoc.* 2004;94(6):542–549. <https://doi.org/10.7547/0940542>.
31. Redmond AC, Landorf KB, Keenan AM. Contoured, prefabricated foot orthoses demonstrate comparable mechanical properties to contoured, customised foot orthoses: a plantar pressure study. *J Foot Ankle Res.* 2009;2:20. <https://doi.org/10.1186/1757-1146-2-20>.
32. Bishop C, Thewlis D, Hillier S. Custom foot orthoses improve first-step pain in individuals with unilateral plantar fasciopathy: a pragmatic randomised controlled trial. *BMC Musculoskelet Disord.* 2018;19(1):222. <https://doi.org/10.1186/s12891-018-2131-6>.
33. Whittaker GA, Munteanu SE, Menz HB, Tan JM, Rabusin CL, Landorf KB. Foot orthoses for plantar heel pain: a systematic review and meta-analysis. *Br J Sports Med.* 2018;52(5):322–328. <https://doi.org/10.1136/bjsports-2016-097355>.
34. Menz HB, Auhl M, Tan JM, Levinger P, Roddy E, Munteanu SE. Predictors of response to prefabricated foot orthoses or rocker-sole footwear in individuals with first metatarsophalangeal joint osteoarthritis. *BMC Musculoskelet Disord.* 2017;18(1):185. <https://doi.org/10.1186/s12891-017-1558-5>.
35. Peduzzi P, Concato J, Kemper E, Holford TR, Feinstein AR. A simulation study of the number of events per variable in logistic regression analysis. *J Clin Epidemiol.* 1996;49(12):1373–1379. [https://doi.org/10.1016/s0895-4356\(96\)00236-3](https://doi.org/10.1016/s0895-4356(96)00236-3).
36. Mork M, Soberg HL, Heide M, et al. Predictors for pain and functioning in patients with plantar fasciopathy one year after inclusion in a treatment trial in specialist care. *BMC Musculoskelet Disord.* 2024;25(1):1049. <https://doi.org/10.1186/s12891-024-08187-2>.
37. Landorf KB, Radford JA. Minimal important difference: values for the foot health status questionnaire, foot function index and visual analogue scale. *Foot.* 2008;18(1):15–19. <https://doi.org/10.1016/j.foot.2007.06.006>.
38. Landorf KB, Twyford GN, Cotchett MP, Whittaker GA. Revised minimal important difference values for the visual analogue scale and foot health status questionnaire when used for plantar heel pain. *J Foot Ankle Res.* 2024;17(4), e70021. <https://doi.org/10.1002/jfa2.70021>.
39. McClinton SM, Heiderscheit BC, McPoil TG, Flynn TW. Effectiveness of physical therapy treatment in addition to usual podiatry management of plantar heel pain: a randomized clinical trial. *BMC Musculoskelet Disord.* 2019;20(1):630. <https://doi.org/10.1186/s12891-019-3009-y>.
40. Boob Jr MA, Phansopkar P, Somaiya KJ. Physiotherapeutic interventions for individuals suffering from plantar fasciitis: a systematic review. *Cureus.* 2023;15(7), e42740. <https://doi.org/10.7759/cureus.42740>.
41. Harutaichun P, Vongsirinarat M, Sathianpantari P, Thong-On S, Richards J. The clinical and biomechanical effects of customized foot orthoses in individuals with plantar heel pain: a pre-post intervention study. *Gait Posture.* 2023;105:163–170. <https://doi.org/10.1016/j.gaitpost.2023.08.003>.
42. Anggriani AF, Kristiyanto A, Rahardjo SS. The effect of foot orthosis use in reducing pain in patients with plantar fasciitis: a meta-analysis. *J Epidemiol Public Health.* 2020;5(3):309–319.
43. Lee SY, McKeon P, Hertel J. Does the use of orthoses improve self-reported pain and function measures in patients with plantar fasciitis? A meta-analysis. *Phys Ther Sport.* 2009;10(1):12–18. <https://doi.org/10.1016/j.ptsp.2008.09.002>.
44. Jordan K, Dunn KM, Lewis M, Croft P. A minimal clinically important difference was derived for the roland–morris disability questionnaire for low back pain. *J Clin Epidemiol.* 2006;59(1):45–52. <https://doi.org/10.1016/j.jclinepi.2005.03.018>.
45. Solomito MJ, Carangelo R, Makanji H. The minimal clinically important difference (MCID) for total joint arthroplasty outcome measures varies substantially by calculation method. *J Bone Jt Surg Am.* 2025;107(9):994–999. <https://doi.org/10.2106/JBJS.24.00916>.
46. Wrobel JS, Fleischer AE, Matzkin-Bridger J, et al. Physical examination variables predict response to conservative treatment of nonchronic plantar fasciitis: secondary analysis of a randomized, placebo-controlled footwear study. *PM R.* 2016;8(5):436–444. <https://doi.org/10.1016/j.pmrj.2015.09.011>.
47. Chen Q, Wang Z, Zhang S. Mechanism, application and effect evaluation of nerve mobilization in the treatment of low back pain: a narrative review. *Medicine.* 2023;102(34), e34961. <https://doi.org/10.1097/MD.00000000000034961>.