The immediate effects of foot orthoses on functional performance in individuals with patellofemoral pain syndrome

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ABSTRACT

Objective Patellofemoral pain syndrome (PFPS) often results in reduced functional performance. There is growing evidence for the use of foot orthoses to treat this multifactorial condition. In this study, the immediate effects of foot orthoses on functional performance and the association of foot posture and footwear with improvements in function were evaluated.

Methods Fifty-two individuals with PFPS (18–35 years) were prescribed prefabricated foot orthoses (Vasyli Pro; Vasyli International, Labrador, Australia). Functional outcome measures evaluated included the change in (1) pain and (2) ease of a single-leg squat on a five-point Likert scale, and change in the number of (3) pain-free step downs and (4) single-leg rises from sitting. The association of foot posture using the Foot Posture Index, navicular drop and calcaneal angle relative to subtalar joint neutral; and the footwear motion control properties scale score with improved function were evaluated using Spearman's ρ statistics.

Results Prefabricated foot orthoses produced significant improvements ($p<0.05$) for all functional outcome measures. A more pronated foot type and poorer footwear motion control properties were found to be associated with reduced pain during the single-leg squat and improvements in the number of pain-free single-leg rises from sitting when wearing foot orthoses. In addition, a more pronated foot type was also found to be associated with improved ease of completing a single-leg squat when wearing foot orthoses.

Conclusion Prefabricated foot orthoses provide immediate improvements in functional performance, and these improvements are associated with a more pronated foot type and poorer footwear motion control properties.

Keywords: foot orthoses; patellofemoral pain syndrome; functional performance; knee pain; insoles.

Patellofemoral pain syndrome (PFPS) is the most common presentation of knee pain to sports medicine clinics among adolescents and young adults.[1] Symptoms as a result of PFPS often lead to recurrent or chronic knee pain[2 3] and significantly affect functional performance.[4] One intervention commonly considered for treatment of this multifactorial condition is the prescription of foot orthoses. It is thought that foot orthoses may reduce pain by limiting foot pronation and associated lower limb rotation, thereby reducing lateral patellofemoral joint (PFJ) forces.[5 6] In a recent systematic review,[7] we identified a number of studies supporting the efficacy of foot orthoses in reducing pain in individuals with PFPS.[8–14] However, none of these studies investigated changes to functional performance with foot orthoses, indicating this is an area of research that needs to be addressed.

Foot orthoses are frequently prescribed based on assessment of foot structure or function. Most studies evaluating foot orthoses in individuals with PFPS included participants with "excessive" foot pronation,[9–12 14] presumably based on the belief that this subpopulation will receive the greatest benefit. However, the only high-quality randomised clinical trial identified[8] in our systematic review[7] recruited participants regardless of foot type. Despite this, a significantly greater number of patients in the group receiving prefabricated foot orthoses reported perceived clinical success at 6 weeks compared to the group receiving flat inserts.[8] Supporting traditional theory that orthoses derive their effectiveness from the control of excessive foot motion,[5 6] Vicenzino *et al*[15] observed that greater foot mobility was associated with larger improvements with prefabricated foot orthoses in this same cohort.[8] However, the sensitivity of this measure was only 0.56, indicating that nearly half of the participants who benefited from foot orthoses would not have received them if foot type alone was used to guide prescription. Interestingly, the only other clinical prediction rule study of foot orthoses for PFPS reported that a less pronated foot (as measured by calcaneal angle and navicular drop) was associated with greater improvements with prefabricated foot orthoses.[13] These conflicting findings indicate that additional evaluation of the link between foot type and foot orthoses efficacy in individuals with PFPS is needed.

The appropriateness of an individual's footwear may also be an important consideration when prescribing foot orthoses. When considering foot orthoses prescription, the Australian Podiatry Council's clinical guidelines[16] state that the influence of footwear on the patient's clinical condition and potential for orthotic prescription should be considered.[16] However, footwear evaluation has not been included in previous studies evaluating foot orthoses efficacy for individuals with PFPS.[8–14]

The current study was designed to determine the immediate effects of prefabricated foot orthoses on functional performance in individuals with PFPS. In addition, the influence of foot posture, change in foot posture and footwear characteristics on immediate changes to function with foot orthoses was evaluated.

METHODS

Participants

Fifty-two individuals with PFPS (16 males and 36 females) were recruited via advertisements placed at La Trobe University and in the surrounding community. Mean age, height and weight of participants was 26 (5) years, 1.70 (0.09) m and 69 (±12) kg, respectively. The study was approved by La Trobe University's Faculty of Health Sciences Human Ethics Committee, and each participant gave written informed consent before participation. Diagnosis of PFPS was based on definitions used in previous randomised clinical trials.[8 17] Inclusion criteria were aged 18–35 years; insidious onset of peripatellar or retropatellar knee pain of at least 6 weeks duration; worst pain in the previous week of at least 30 mm on a 100-mm visual analogue scale; pain provoked by at least two activities from running, walking, hoping, squatting, stair negotiation, kneeling, or prolonged sitting; pain elicited by patellar palpation, PFJ compression or resisted isometric quadriceps contraction. Exclusion criteria were use of foot orthoses in the previous 5 years, physiotherapy treatment in the previous 6 months, current use of anti-inflammatory medications, concomitant injury or pain arising from the lumbar spine or hip; knee internal derangement; knee ligament insufficiency; previous knee surgery; PFJ instability; or patellar tendinopathy.

Procedures

All 52 participants attended a data collection session that involved evaluation of baseline characteristics (foot posture, change in foot posture with a prefabricated foot orthoses and footwear characteristics) and clinical measurements of changes to functional performance with the addition of prefabricated foot orthoses to participants' footwear. Only the symptomatic (in those with unilateral symptoms) or most symptomatic (in those with bilateral symptoms) limb was assessed. In addition, 20 participants returned 1 week after the initial data collection session to establish the between-day reliability for the functional performance tests.

Baseline characteristics

Footwear

Each participant wore footwear in which they most commonly experienced their pain. The motion control properties scale from the Footwear Assessment Tool[18] was used to evaluate each individual's footwear by a single rater with previously established intrarater (intraclass correlation coefficient (ICC) 0.93) and inter-rater reliability (0.93 to 0.95).[18] The scale evaluates the motion control quality of an individual's footwear, providing a score between 0 and 11, where a higher score indicates better motion control properties. Items within the scale include evaluation of fixation method, presence of dual-density soles, heel counter stiffness, and midfoot sagittal and torsional stiffness.[18]

Foot posture and change in foot posture

Three clinical measurements of foot posture were recorded with and without prefabricated foot orthoses under participant's feet by a single rater with previously established intrarater (ICC 0.88 to 0.97) and inter-rater reliability (0.78 to 0.93) in a PFPS population.[19] These included:

Foot Posture Index. The Foot Posture Index (FPI) is a six-item foot posture assessment tool, with each item scored between −2 and +2 to give a sum total between −12 (highly supinated) and +12 (highly pronated).[20] Items include talar head palpation, curves above and below the lateral malleoli, calcaneal angle, talonavicular bulge, medial longitudinal arch and forefoot to rearfoot alignment.[20]

Normalised navicular drop. Navicular drop was calculated by subtracting vertical navicular height in subtalar joint neutral (STJN) from vertical navicular height in relaxed stance[21] with the aid of a metal bracket to stabilise the card. This was then normalised as a percentage of the participant's foot length.

Calcaneal angle relative to STJN. The difference between relaxed stance and STJN for calcaneal angle measured relative to a line perpendicular from the floor using a digital inclinometer (Mitutoyo Pro 360, Aurora, Illinois, USA) positioned along the calcaneal bisection.

Clinical measurements of functional performance

The effects of prefabricated foot orthoses on functional performance were evaluated during three tasks. The orthoses were unmodified, commercially available three-quarter length devices with lateral cut-outs (Vasyli Pro; Vasyli International, Labrador, Australia), made of ethelene-vinyl acetate of medium (Shore A 55) density, containing built-in arch supports and 4° varus wedging (see fig 1). The order of the conditions was not randomised as the tests were designed to be repeatable in a clinical setting where randomising the condition order for each new patient would not be appropriate.

Change in number of pain-free step downs (20-cm step)

This clinical test was designed to replicate stair descent, a functional task often limited by PFPS.[22] Each participant stood on a 20-cm step and moved from a position of bipedal stance to tap the foot of their non-testing limb below and return to bipedal stance repeatedly at a rate of 48 steps/min until pain onset (or increase from resting), or until they completed 25 repetitions. Each participant completed this test without foot orthoses and then with foot orthoses after a 3-min break.

Change in number of pain-free single-leg rises from sitting (45-cm stool)

Previous research has indicated that a lower number of maximum single-leg rises from sitting is predictive of knee osteoarthritis development in people with chronic knee pain at a 5-year follow-up.[23] To improve the clinical applicability of the test, modifications were made to its original descriptions.[23 24] Each participant crossed their arms and repeatedly completed the task at a rate of 20 repetitions/min until pain onset (or increase from resting), or until they completed 20 repetitions.

Figure 1 Prefabricated foot orthoses (Vasyli Pro; Vasyli International, Labrador, Australia) prescribed to each participant.

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Each participant completed this test without foot orthoses and then with foot orthoses after a 3-min break.

Change in pain and ease of completing a single-leg squat

With arms crossed, participants were asked to complete five single-leg squats with and without the foot orthoses, with conditions alternated (at least twice per condition) until the participant was confident of their decision. Participants rated change in pain and ease of task completion on a five-point Likert scale. The five options given for "ease" were markedly harder, somewhat harder, same, somewhat easier and markedly easier. The five options given for "pain" were markedly more, somewhat more, same, somewhat less and markedly less.

Statistical analysis

All statistical analysis was completed using SPSS V.17.0 (SPSS Inc, Chicago, Illinois, USA). Between-day reliability for the change in number of step downs and single-leg rises from sitting was evaluated using ICCs (model 2.1). For statistical purposes, the effects of foot orthoses on pain and ease of task during a single-leg squat were given numerical values. Negative orthoses effects were given negative values (markedly harder/more painful=−2, somewhat harder/more painful=−1), absent orthoses effects were given 0, and positive orthoses effects were give positive values (somewhat easier/less painful=+1, markedly easier/less painful=+2). Between-day reliability for the change in ease and pain during a single-leg squat was evaluated using κ statistics.[25 26]

Paired t tests were used to compare the number of pain-free step downs and single-leg rises from sitting completed with and without foot orthoses. Participants who were able to complete 25 step downs and/or 20 single-leg sit to stands were excluded from this analysis. Data were screened for normality graphically and using the Kolmogorov–Smirnov statistic. Pain-free step-down data with and without the foot orthoses was normally distributed. However, single-leg rises from sitting data was found to be positively skewed for both conditions and therefore transformed by using a log10 conversion. Changes in pain and ease of task during a single-leg squat were compared using frequency statistics and Wilcoxon's signed-rank tests with the comparison variable set as 0 (ie, no change). Participants who did not report pain during a single-leg squat were excluded from this analysis. The association of changes to functional performance with footwear and foot posture measures were evaluated using Spearman's ρ correlation coefficients with significance set at $p < 0.05$.

RESULTS

Reliability

Moderate between-days reliability was found for the change in number of step downs (ICC=0.65) and single-leg rises from sitting (ICC=0.74).[27] Substantial between-day reliability was found for the change in pain (κ=0.79) and ease (κ=0.79) during a single-leg squat.[26]

Foot orthoses effects on pain and function

Of the 52 participants, 37 (71%) were unable to complete 25 pain-free step downs, 41 (79%) were unable to complete 20 pain-free single-leg rises from sitting and 43 (83%) experienced pain during the single-leg squat task. The frequency of outcomes (positive, unchanged and negative) with foot orthoses, and mean change with foot orthoses during the step down and single-leg rise from sitting tasks can be found in table 1. The frequency of outcomes with foot orthoses, and comparisons for change in pain and ease of task during the single-leg squat test are shown in table 2. Results indicated that prefabricated foot orthoses enhanced function during the step down ($p=0.005$) and single-leg rises from sitting ($p=0.040$) tasks, and improved pain ($p=0.002$) and ease of task ($p<0.001$) during the single-leg squat test.

Factors influencing changes in pain and function

Correlations between the immediate effects of the foot orthoses and baseline measurements are shown in table 3. Greater calcaneal eversion relative to STJN, greater reduction in calcaneal eversion relative to STJN with the foot orthoses

Table 1 Frequency of outcomes (positive, unchanged and negative) with foot orthoses, and mean change with foot orthoses including 95% CI and p values related to between-condition comparisons during the step-down and single-leg rise from sitting tasks

	Participants with positive outcomes % (frequency)	Participants unchanged % (frequency)	Participants with negative outcomes % (frequency)	Mean difference (SD)	95% CI	p Value*
Step downs (n=37)	57 (21)	16 (6)	27 (10)	2.4 (4.9)	0.8 to 4.0	0.005
Single-leg STS (n=41)	38 (16)	42 (17)	20 (8)	0.7 (3.1)	−0.2 to 1.7	0.040†

*Calculated using paired samples t test.
†Calculated using transformed data (log10).

Table 2 Frequency of foot orthosis changes, and p values related to between-condition comparisons for change in pain and ease of task during the single-leg squat test

	Marked improvement % (frequency)	Moderate improvement % (frequency)	No change % (frequency)	Moderate worsening % (frequency)	Marked worsening % (frequency)	p Value*
Change in pain (n=43)	11.6 (5)	30.2 (13)	48.8 (21)	9.3 (4)	0 (0)	0.002
Change in ease (n=52)	11.5 (6)	57.7 (30)	19.2 (10)	11.5 (6)	0 (0)	<0.001

*Calculated using Wilcoxon's signed-rank test.

Table 3 Correlations between the immediate effects of the foot orthoses and baseline measurements (foot posture, change in foot posture with foot orthoses, ankle range of motion and footwear properties)

		Step downs		Single-leg rises from sitting		Pain SLSq		Ease SLSq	
	Mean (range)	R value†	p Value	R value†	p Value†	R value†	p Value	R value†	p Value
Foot posture									
FPI	3.9 (−1 to 10)	−0.090	0.596	0.310	0.065	0.308*	0.045	0.358**	0.009
NND (% FL)	2.5 (−1.3 to 6.8)	−0.173	0.305	0.329	0.050	0.232	0.135	0.129	0.366
Calcaneal angle relative to STJN (°)	3.9 (−2.3 to 13.0)	−0.118	0.486	0.437**	0.008	0.232	0.134	0.218	0.124
Change in foot posture									
FPI	1.8 (0.0 to 4.0)	−0.083	0.624	0.228	0.182	0.378*	0.012	0.337*	0.015
NND (% FL)	1.3 (−0.4 to 5.0)	−0.059	0.728	0.307	0.068	0.175	0.261	0.140	0.326
Calcaneal angle relative to STJN (°)	1.8 (−0.4 to 5.8)	−0.110	0.516	0.395*	0.017	0.125	0.423	0.207	0.145
Footwear									
Motion control properties	6.3 (1 to 11)	0.046	0.794	−0.338*	0.016	−0.424*	0.009	−0.107	0.468

Positive correlations indicate that improvements are associated with a more pronated foot type, greater reduction in pronation and greater footwear motion control properties.
*$p<0.05$.
**$p<0.01$.
†Calculated using Spearman's ρ.
FL, foot length; FPI, Foot Posture Index; NND, normalised navicular drop; SLSq, single-leg squat; STJN, subtalar joint neutral.

and lower footwear motion control properties were found to be associated with greater improvement in the number of pain-free single-leg rises from sitting, explaining 19.1%, 15.6% and 11.4% of the variance, respectively. During the single-leg squat test, a more pronated foot as measured by the FPI, greater reduction in pronation with the foot orthoses as measured by the FPI and lower footwear motion control properties were found to be associated with a reduction in pain, explaining 9.5%, 14.3% and 18.0% of the variance, respectively. In addition, a more pronated foot as measured by the FPI and a greater reduction in pronation with the foot orthoses as measured by the FPI were associated with improved ease of completing a single-leg squat, explaining 12.8% and 11.4% of the variance, respectively. None of the baseline variables evaluated were found to be associated with improved function during the step-down task.

DISCUSSION

There is growing evidence to support the efficacy of foot orthoses in the treatment of PFPS.[8–14] However, there is a paucity of research evaluating the effectiveness of foot orthoses on functional performance in this group. Despite the premise that foot orthoses derive their effectiveness from the control of excessive pronation in individuals with PFPS,[5 6] research that has scientifically evaluated this theory is limited and has produced inconsistent findings.[13 15] This study described reliable clinical tests of functional performance, which may assist clinical decisions when considering prescription of foot orthoses for individuals with PFPS. The three functional tasks were selected as each was considered likely to replicate loading of the PFJ during activities of daily living. Validity of each of the functional outcome measures is strengthened by the limitations observed in most individuals with PFPS evaluated in this study (71% to 83%).

Prefabricated foot orthoses significantly improved the PFPS group's performance during each of the functional tasks evaluated. Control of pronation with foot orthoses in individuals with PFPS is thought to optimise lower limb alignment, prevent medial collapse of the knee and reduce lateral PFJ stress.[5 6] Supporting this theory, a more pronated foot type was found to be associated with functional improvements in three of the four outcome measures, including reduced pain and improved ease during a single-leg squat, and a greater number of pain-free single-leg rises from sitting.

Although supportive of traditional theory,[5 6] the associations of foot posture and change in foot posture with functional improvements were only fair (r=0.308–0.437).[27] This may illustrate that the clinical tests of static foot posture evaluated may not be indicative of dynamic foot function. Kinetic and kinematic evaluation at the foot and more proximal segments during dynamic tasks may be better able to predict functional changes with foot orthoses. However, this evaluation requires sophisticated equipment and is therefore not feasible in a clinical setting. Alternatively, other mechanisms that were not evaluated may also contribute to foot orthoses effects. It is possible that enhanced neuromuscular activation patterns as a result of altered plantar cutaneous sensory feedback may explain part of the mechanism(s) behind foot orthoses efficacy in individuals with PFPS.[28] This is an area that also requires further investigation.

Previous research evaluating foot orthoses in individuals with PFPS has failed to investigate the effect of footwear on outcomes.[8–14] Replicating a clinical setting, this study did not seek to control footwear, instead instructing participants to wear footwear in which they most commonly experienced knee pain. Interestingly, poorer footwear motion control properties were associated with reductions in pain during a single-leg squat and improvement in the number of pain-free single-leg rises from sitting with the addition of prefabricated foot orthoses. This may indicate that foot orthoses have greater effects in poorer-quality shoes, possibly as a result of a greater potential to improve motion control properties. In addition, changing footwear in PFPS individuals who wear poor-quality footwear could be of equal or perhaps greater importance than foot orthoses prescription. However, further research evaluating the effects of various footwear characteristics and modification on patient outcomes in individuals with PFPS is still required.

Limitations

This study was not a randomised controlled trial, and neither the examiner nor the participants were blinded to the presence or absence of foot orthoses when the functional tests were performed. This invariably would have resulted in some placebo and/or Hawthorne affects contributing to the positive

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findings with the foot orthoses, particularly during the single-leg squat test. However, this is less likely to have been a problem during the step-down and single-leg rise from sitting tests, where a possible buildup of residual pain during the foot orthoses condition may have instead had a detrimental effect on functional performance. This methodological problem may have been avoided through condition randomisation during the step-down and single-leg rise from sitting tests. However, randomisation was considered inappropriate for these tests because they were designed to be directly transferable to the clinical setting. Although the functional tests used in this study were designed with the clinical setting in mind, their ability to predict longer-term success with foot orthoses (eg, 6-, 12- and 52-week follow-ups) still requires evaluation.

CONCLUSION

This study has developed and clearly described clinically applicable tests to evaluate changes in functional performance with foot orthoses prescription in individuals with PFPS. The large percentage of participants with limitations to each of the functional tasks (71% to 83%) strengthens the validity of these tests for further use in clinical and research settings. The prefabricated foot orthoses used in this study were found to provide significant, immediate improvements in pain and function for each of the tests evaluated. A significant association of improved pain and function with a more pronated foot type and poorer motion control properties of footwear worn was also found. This highlights the importance of foot posture and footwear assessment when considering foot orthoses prescription in individuals with PFPS. Further research evaluating the association between functional improvements and changes to lower limb kinetics, kinematics and neuromuscular activation; footwear modification; and long-term treatment success is now required.

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Competing interests None.

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