Effect of a SERF Strap on Pain and Knee-Valgus Angle During Unilateral Squat and Step Landing in Patellofemoral Patients

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Context: A valgus position of the knee on functional loading tasks has been reported to be associated with patellofemoral-joint pain. Training programs to reduce knee valgus have been shown to be effective but take time. It would appear logical to use a brace or strap to help control this knee motion to reduce symptoms. Objective: To assess the impact of the SERF strap on knee valgus and patellofemoral-joint pain. Design: Repeated measures. Setting: University human performance laboratory. Participants: 12 women with patellofemoral pain (mean age 24 ± 3.2 y). Intervention: Application of SERF strap. Main Outcome Measures: Knee-valgus angle on single-leg squat and step landing and visual analog scale pain score. Results: The application of the SERF brace significantly reduced the pain (P < .04) and knee valgus (P < .034) during both tasks. Conclusion: The SERF brace brings about a significant reduction in pain during functional tasks. Although the brace brought about a significant reduction in knee valgus, this failed to exceed the smallest-detectable-difference value, so the difference is likely to be related to measurement error. The mechanism as to why this the reduction in pain occurs therefore remains unclear, as this study in line with many others failed to demonstrate meaningful changes in kinematics that could provide an obvious explanation.

Keywords: patellofemoral joint pain, bracing, landing mechanics, motion control

A valgus position of the knee on functional loading tasks has been reported to be associated with a number of different knee injuries.1–3 Females have been found to present with greater knee valgus during loading tasks than males,4 and this is believed at least in part to explain the higher incidence of patellofemoral pain in females.3,4 The presence of a valgus knee position has been associated with muscle weakness in the hip abductors and external rotators.5 Considerable attention has been given to how best to train these muscles with some success.5 However, these neuromuscular changes take time, with training programs lasting 4 to 6 weeks.5 As the changes brought about by training take time to occur, clinicians have sought means of bringing about immediate improvements in limb alignment and so reducing patellofemoral stress by using means such as external supports.

External supports have been used to aid performance of patients with a number of knee pathologies. The research into the role of braces in treating patellofemoral joint pain is limited.6 Some studies have used knee braces to provide local control to the patellofemoral joint,6,7 but the findings are mixed. One of the main reasons for the mixed results might be the nature of the braces. The sleeve-type braces, though creating increased compression and so improved contact area, also increase joint pressure, with the combination of these effects possibly creating no net reduction in stress.8 While the wrap-style patellar-stabilization brace allows knee pressure to be decreased in magnitude and creates a proximal shift in the location of the peak patellofemoral pressure,8 improving stress loading on the patellofemoral joint, these effects can be inconsistent and depend on optimal application of the brace.

The Stability Through External Rotation of the Femur (SERF) strap (Don Joy Orthopedics Inc, Vista, CA) was developed with the aim of assisting lower limb kinematics, decreasing knee valgus through supporting

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femoral abduction and external rotation. To date there has been no published literature on the effectiveness of this brace in either improving lower limb kinematics or relieving pain in patients with patellofemoral pain. The purpose of this study was to assess the influence of the SERF strap on lower limb kinematics and pain during single-leg squat and step-down task in patients with patellofemoral pain.

**Method**

**Participants**

Twelve women with patellofemoral pain (mean age 24 ± 3.2 years) participated in the study. The inclusion and exclusion criteria for the study subjects are as follows.10

*Inclusion Criteria*

- Symptoms of anterior knee pain for at least 1 month
- Average pain level of 3 or more on a 10-cm visual analog scale (VAS) during stepping up and down off a 30-cm-high bench
- Anterior or retropatellar knee pain on at least 2 of the following activities: prolonged sitting, climbing stairs, squatting, running, kneeling, and hopping/jumping
- Presence of 2 of the following clinical criteria on assessment: pain during apprehension test, pain during the patellar-compression test, and crepituation during the compression test

*Exclusion Criteria*

- Previous knee surgery or arthritis
- History of patellar dislocation, patellar subluxation, or ligament laxity
- Patellar-tendon pathology or chondral damage
- Referred spinal pain
- History of other abnormalities such as leg-length inequality (>2 cm)
- Medication as a part of the treatment
- Previous physical therapy or acupuncture treatment for the knee within the previous 30 days

All subjects gave written informed consent, and the study was approved by the university research ethics committee.

**Procedures**

Subjects performed a single-leg squat and unilateral step-landing task on their symptomatic leg. They performed 3 test trials both with and without the SERF strap. For each task, the sequence of either braced or unbraced was block ordered, with alternate subjects carrying out testing unbraced first. The brace was applied by the same researcher each time (brace is shown in Figure 1). Each subject had 3 practice trials of both tasks and then a 3-minute recovery; the same 3-minute recovery was used between all the test trials.

The procedure for single-leg squat involved subjects standing on the test limb, facing the video camera. Participants were asked to squat down as far as possible, to at least 45° knee flexion, over a period of 5 seconds. Knee-flexion angle was checked during practice trials (maximum of 3) using a standard goniometer (Gaiam-Pro, Physiomed, UK) by the same examiner throughout the trials. There was also a counter for each participant over this 5-second period; the first count initiates the movement, the third indicates the lowest point of the squat, and the fifth indicates the end of the movement with the subject returning to the start position. This standardized the test for each participant, therefore reducing the effect of velocity on knee angles. Trials were only accepted if the subjects squatted to the minimum degree of knee flexion (45°) and maintained balance throughout while keeping their hands on their iliac crests.11 While the task was carried out, perceived pain was recorded using a 10-cm VAS.

Step landing involved stepping off a 30-cm-high bench, landing on a mark 30 cm from the bench (this standardized depth and distance of the step and landing), and holding the landing for a minimum of 3 seconds. Subjects were asked to take a unilateral stance on the contralateral limb and to step forward to drop onto the
mark corresponding, ensuring that the contralateral leg made no contact with any other surface. While carrying out each task, the subject recorded perceived pain on a 10-cm VAS.

Two-dimensional (2D) frontal-plane projection angle of knee-valgus alignment was measured. A digital video camera (Sony Handycam DCR-HC37, Sony Corp, Japan, filming at 25 frames/s) was placed at each subject’s knee height, 2 m anterior to the landing target, and aligned perpendicular to the frontal plane. The digital images were imported into a digitizing software program (Quintic 4, Quintic Consultancy Ltd, UK). The knee-valgus angle was acquired from the angle formed between the line formed between markers at the anterosuperior iliac spine and middle of the tibiofemoral joint, and the line drawn between markers on the middle of the tibiofemoral joint to the middle of the ankle mortise. Markers were placed by the same researcher for all subjects. The angle was captured from the frame that corresponded to the lowest point of the landing or squatting phase—the frame before the initiation of upward movement. The same individual digitized all the data from all subjects. The average knee-valgus-angle value from 3 trials was used for further analysis.

### Analysis

All statistical analysis was conducted using SPSS for Windows version 16.0 (SPSS Inc, Chicago, IL). The effect of the brace on knee-valgus angle for each of the tasks was analyzed using paired t tests with α = .05, and the effect of brace on VAS score was similarly analyzed.

Pilot work was carried out to ascertain intratester reliability of angle capture from the video. Ten knee-valgus-angle images (5 from single-leg squat, 5 from step landing) were selected randomly for reassessment of angle; comparison of first and second measurement revealed a strong correlation (ICC3,1) of $r = .90$ ($P < .001$) and $r = .92$ ($P < .001$) between the 2 measurements (single-leg squat and step landing, respectively). The test–retest reliability of this method for assessing knee valgus has been established from our laboratory and has been reported elsewhere. The findings of this study showed good reliability ICC3,1 of .72 with a smallest detectable difference (SDD) of 8.9° for single-leg squat and ICC of .82 and SDD of 7.9° for step landing.

### Results

The results of the study are shown in Table 1 and Figures 2 and 3. Mean knee-valgus angle during single-leg squat was 16.8° ± 5.4°. The application of the SERF brace significantly reduced the knee valgus ($P = .023$); mean decrease in knee valgus was 8.9° ± 2.3°. Reported pain during single-leg squat was reduced significantly ($P = .001$) with the application of the brace, from a mean score of 5 ± 1.3 unbraced to 1.1 ± 1.1 with the brace in situ.

Mean knee-valgus angle during single-leg step landing was 13.9° ± 6.8°. The application of the SERF brace significantly reduced the knee valgus ($P = .034$); mean decrease in knee valgus was 6.9° ± 4.1°. Reported pain during single-leg step landing was reduced significantly ($P = .04$) with the application of the brace, from a mean score of 4 ± 1.9 unbraced to 1.0 ± 1.3 with the brace in situ.

### Discussion

The application of the SERF brace in female patients with patellofemoral pain would appear to improve knee-valgus angle, bringing about a significant reduction in angle during both tasks. The presence of the brace also significantly reduced pain in female patients with patellofemoral pain during unilateral functional loading tasks.

The decrease in pain associated with the application of the SERF brace is consistent with the findings of other studies where either local knee braces or patella tape were applied to the patellofemoral joint. The change in femoral alignment found in this study may create sufficient change in internal tissue homeostasis to relieve symptoms, as has been hypothesized previously in relation to patella taping.

There must be caution applied when interpreting our results in relation to the change in knee-valgus angle. The mean change in knee-valgus angle brought about using the brace during both tests did not exceed the SDD value previously reported from our laboratory for these tests. The SDD was 8.9° for single-leg squat and 7.9° for step landing, with mean change found in the study being 8.9° and 6.9°, respectively. The SDD statistic is useful for distinguishing real changes from meaningless fluctuation. It represents reliability in context of measurement error, with SDD being the minimal change required to be 90% confident that difference between individual subjects is real.

**Table 1** Effect of Brace on Knee-Valgus Angle and Pain Score

<table>
<thead>
<tr>
<th>Condition</th>
<th>Single-Leg Squat</th>
<th>Step Landing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Knee-valgus angle (°)</td>
<td>Pain score</td>
</tr>
<tr>
<td>Braced</td>
<td>8.2 ± 2.6</td>
<td>1.1 ± 1.1</td>
</tr>
<tr>
<td>Unbraced</td>
<td>16.8 ± 5.4</td>
<td>5 ± 1.3</td>
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</tbody>
</table>
Figure 2 — Mean (± SD) knee-valgus angle during both tasks with and without the brace.

Figure 3 — Mean (± SD) visual-analog-scale (VAS) pain scores for both tasks with leg braced and unbraced.
pre-post measures is due to real change. This would indicate that the differences between the prebracing and postbracing values in knee valgus are more likely to be due to measurement error (or random chance) than an actual effect of the brace itself, despite the statistically significant difference.

McLean et al. reported that 2-D video analysis was suitable to screen individuals with excessive knee valgus and the effects of interventions to improve knee valgus in those individuals. Both McLean et al. and Willson and Davis stated that this conclusion should be viewed with caution, as this method lacks sensitivity to small changes in angle. McLean et al. found average peak 2-D knee-valgus angle accounted for 58% to 64% of the variance in average peak 3-dimensional knee-valgus angle between subjects during side-step and side-jump activities. Willson and Davis stated that this conclusion should be viewed with caution, as this method lacks sensitivity to small changes in angle. McLean et al. found average peak 2-D knee-valgus angle reflected 23% to 30% of the variance of 3-dimensional measurements during single-leg squat but found knee valgus to be significantly correlated with knee external rotation ($r = .54$, $P = .001$) and hip adduction ($r = .32$, $P = .04$), which are major components of the “medial collapse” 2-D knee-valgus angle aims to represent. As Souza and Powers found femoral internal rotation to be the significant discriminator between controls and patients with patellofemoral pain, as opposed to hip adduction; the role of abnormal transverse-plane motion must not be discounted. The SERF strap, by the nature of its orientation and direction of pull, is likely to have an influence, predominantly on hip rotation. It may be that 2-D video analysis is insensitive to changes in this plane, even though the knee-valgus-angle measure is a composite movement including hip rotation. It may be that analysis of any changes brought about in the transverse plane would require 3-dimensional motion-capture systems.

The changes reported by this study in pain with brace application cannot be clearly linked to the change in knee valgus, as explained herein, because of the possibility of the differences occurring due to random chance. However, small changes in position are likely to have occurred. It may be that the change in perceived pain could be explained by Dye et al. and Dye, who believed that bracing allowed an expansion of the “envelope of function,” helping the patient overcome the initial metabolic homeostatic crisis, taking normal activities of daily living out of the zone of traumatic supraphysiological loading. The level of tissue offloading required to bring about relief of stress is not known but may prove to be only a small change in the local joint environment.

In the clinical context, the findings of this study have value, as they indicate that use of this brace will bring about an immediate reduction in pain during a number of limb-loading tasks. If the patient is able to participate in limb-loading tasks without pain, this will allow the clinician to further progress the patient down a loading continuum, increasing their envelope of function.

## Conclusion

In common with a number of other interventions such as local knee braces and patella taping, the SERF brace brings about a significant reduction in pain during functional tasks. The mechanism by which this occurs, though, remains unclear, as this study in line with many others failed to demonstrate valid changes in kinematics that could provide an obvious explanation.

## References


11. Munro A, Herrington L, Carolan M. Reliability of 2-dimensional video assessment of frontal-plane dynamic knee...