Patellofemoral Pain Syndrome and Its Association with Hip, Ankle, and Foot Function in 16- to 18-Year-Old High School Students

A Single-blind Case-control Study

Carsten Mølgaard, MHS, PT*
Michael Skovdal Rathleff, BSc, PT†
Ole Simonsen, MD†

Background: An increased pronated foot posture is believed to contribute to patellofemoral pain syndrome (PFPS), but the relationship between these phenomena is still controversial. The objectives of this study were to investigate the prevalence of PFPS in high school students and to compare passive internal and external hip rotation, passive dorsiflexion, and navicular drop and drift between healthy high school students and students with PFPS.

Methods: All 16- to 18-year-old students in a Danish high school were invited to join this single-blind case-control study (N = 299). All of the students received a questionnaire regarding knee pain. The main outcome measurements were prevalence of PFPS, navicular drop and drift, passive ankle dorsiflexion, passive hip rotation in the prone position, and activity level. The case group consisted of all students with PFPS. From the same population, a randomly chosen control group was formed.

Results: The prevalence of knee pain was 25%. Of the 24 students with knee pain, 13 were diagnosed as having PFPS. This corresponds to a PFPS prevalence of 6%. Mean navicular drop and drift were higher in the PFPS group versus the control group (navicular drop: 4.2 mm [95% confidence interval (CI), 3.2–5.3 mm] versus 2.9 mm [95% CI, 2.5–3.3 mm]; and navicular drift: 2.6 mm [95% CI, 1.6–3.7 mm] versus 1.4 mm [95% CI, 0.9–2.0 mm]). Higher passive ankle dorsiflexion was also identified in the PFPS group (22.2° [95% CI, 18°–26°] versus 17.7° [95% CI, 15°–20°]).

Conclusions: This study demonstrated greater navicular drop, navicular drift, and dorsiflexion in high school students with PFPS compared with healthy students and highlights that foot posture is important to consider as a factor where patients with PFPS diverge from healthy individuals. (J Am Podiatr Med Assoc 101(3): 215-222, 2011)

Patellofemoral pain syndrome (PFPS) is often considered one of the most vexatious clinical challenges in rehabilitation medicine because it occurs frequently and is multifactorial. A few studies have investigated the prevalence of PFPS in selected populations. These studies have shown that PFPS is highly prevalent and accounts for as much as 25% of all knee injuries treated in sports medicine clinics. The prevalence of PFPS in young people is still not thoroughly investigated, but some studies indicate a high prevalence of general musculoskeletal pain in the lower extremity in young people. Prospective and retrospective studies have shown that a long duration of symptoms and older age decrease the chance of treatment success in the rehabilitation of patients with PFPS. Therefore, it is important to investigate the prevalence of PFPS in young people.

The alignment of the lower extremity is important to the forces transmitted through the lower extrem-
ity and the patellofemoral joint. A complex two-way interaction of the kinematics and kinetics exists in the lower extremity, which indicates that the kinematics and kinetics around the knee joint are affected by distal and proximal factors. This implies that foot, knee, and hip alignment might all be important for the pathogenesis of PFPS.

The linkage between excessive pronation and PFPS is based on the coupling mechanism between foot pronation and tibial rotation. During pronation, the tibia rotates inward and the pressure in the lateral part of the patellofemoral joint increases, which could increase the risk of PFPS. Together with foot movement, the movement of the hip can also contribute to altered dynamics in the patellofemoral joint. Abnormal hip movement can increase the lateral component of the quadriceps force vector and thereby increase the tendency for lateral maltracking of the patella. A significant correlation between tibial and femoral rotation and patellofemoral pressure has been established, and hip muscle weakness has been coupled with excessive hip adduction and internal rotation, which are associated with PFPS.

Despite the various causal mechanisms in PFPS, there still is a need for simple clinical tests to evaluate the lower extremity as a functional unit in a clinical setting. Hence, the objectives of the present study were to investigate the prevalence of PFPS in high school students and to compare passive internal and external hip rotation, passive dorsiflexion, navicular drop and drift, and activity levels between healthy high school students and students with PFPS.

**Methods**

**Selection and Description of Participants**

The study was designed as a single-blind case-control study and was approved by the local ethics committee of North Denmark Region. Before the study, oral and written information were provided to the participants, and written consent was obtained from all of the participants and their guardians.

**Population**

All of the 16- to 18-year-old students (N = 299) at a local high school were presented with a questionnaire asking whether they had experienced non-trauma-related knee pain during the past month during daily activities. At the same time, they were asked to undergo a clinical examination. Of the 227 students (76%) who answered the questionnaire, 57 (25%) admitted to knee pain during the past month, and 24 of them consented to enter the study (PFPS group). One hundred seventy students denied having any knee pain. Of those willing to enter the study as participants in the control group, 24 were randomly selected for this group (Fig. 1).

**Patellofemoral Pain Syndrome**

All of the participants underwent a clinical examination to verify the diagnosis of PFPS. The diagnostic criteria for PFPS were anterior knee pain during physical activity for at least 1 month and pain in at least two of the following four tests: 1) isometric contraction of the quadriceps during approximately 30° of flexion, 2) concentric extension of the lower leg against resistance from 90° flex to full extension, 3) palpation along the patellofemoral joint line, and 4) compression of the patella against the femur during full extension with the participant in a supine position. Individuals were excluded if they showed any sign of meniscal tear or ligamentous instability. If individuals had bilateral knee pain, they were asked to choose the most painful side, and only the most painful side was measured for each person. For the control group, the percentages of left and right knees were matched to the PFPS group. Only one side was measured and included in the trial (Table 1).

**Technical Information**

**Clinical Exam ination.** In both groups, three medical students performed the clinical examinations. They received practical training by an experienced physiotherapist (C.M.) in measuring navicular drop and drift, dorsiflexion, and hip rotation ability. They were blinded to whether the test participants had reported knee pain. The students were specifically told not to inform the investigators to which group they belonged. Tester 1 measured navicular drop and drift, tester 2 measured hip rotation and dorsiflexion, and tester 3 acquired informed consent and handled logistics.

**Navicular Drop and Drift.** Foot pronation was quantified by navicular drop and drift. The top point of the navicular tuberosity was marked with a ballpoint pen. Navicular height was defined as the distance from the navicular mark to the floor. Navicular drop was defined as the difference between the unloaded and loaded positions. In the
unloaded position, students were seated with the knee at a 90° angle vertically above the ankle and with the foot in a relaxed position. In the loaded position, students stood in a relaxed one-legged standing position (Fig. 2). They were allowed to place two fingers on the wall to maintain support.

Navicular drift was defined as the movement in the frontal plane of the navicular tuberosity from an

Figure 1. Distribution of participants in the trial. PFPS indicates patellofemoral pain syndrome.

Table 1. Demographic Data by Study Group

<table>
<thead>
<tr>
<th></th>
<th>PFPS Group (n = 13)</th>
<th>Control Group (n = 22)</th>
<th>t Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female sex (No. [%])</td>
<td>9 (69)</td>
<td>15 (68)</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>16.9 (16.3–17.2)</td>
<td>16.7 (16.5–17.3)</td>
<td>NS</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>170 (164–176)</td>
<td>171 (168–174)</td>
<td>NS</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>60.0 (54.4–63.2)</td>
<td>60.3 (59.3–67.5)</td>
<td>NS</td>
</tr>
<tr>
<td>BMI</td>
<td>20.7 (19.3–21.2)</td>
<td>21.4 (20.6–22.7)</td>
<td>NS</td>
</tr>
<tr>
<td>Investigated right leg (No. [%])</td>
<td>9 (69)</td>
<td>15 (68)</td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by the square of the height in meters); NS, nonsignificant difference; PFPS, patellofemoral pain syndrome.

aData are given as mean (95% confidence interval) except where indicated otherwise.
unloaded to a loaded position. A custom-made slat with a groove in which the measurement unit could be moved across a ruler was used for measuring navicular drift in the frontal plane (Fig. 3).

Test-Retest. Test-retest reliability for navicular drop and drift was examined in 20 healthy individuals. The foot examinations were performed with 7 days between test and retest. The test-retest was independently performed by two experienced physiotherapists. All of the measurements were performed three times, and the average results were used. The intraclass correlation coefficient (ICC) was calculated using a two-way random effect model, with total agreement in SPSS (SPSS Inc, Chicago, Illinois). Intertester reliability was ICC[2.1] = 0.86 (95% confidence interval [CI], 0.70–0.93) for navicular drop and ICC[2.1] = 0.76 (95% CI, 0.47–0.89) for navicular drift.

Hip Rotation. Passive hip rotation was measured in the prone position at 90° of knee flexion. The pelvis was fixed with a strap, and hip rotation was measured with a handheld goniometer. Rotation was measured as the angle between maximum rotation of the lower leg and vertical. Maximum range of motion was found at a firm end-feel or when the pelvis started to move. High intratester reliability for hip rotation has been described earlier (ICC[2.1] > 0.95).

Ankle Dorsiflexion. In the supine position, maximum passive ankle dorsiflexion was measured by a handheld goniometer. Dorsiflexion has previously shown good intrarater reliability (ICC = 0.80–0.90) in individuals with orthopedic disorders. The knee was extended, and extension was maintained by a strap.

Activity Level. Participants were asked how many hours they had participated in moderate to heavy physical activity during the previous week. The answers were categorized in three groups: 0 to 2, 3 to 4, and 5 or more hours per week.
Statistics
Results are expressed as mean (95% CI) and are compared using the Student t test. The assumption that the data were normally distributed was confirmed by visual inspection of Q-Q plots, and no unambiguous homogeneity between the groups was confirmed by the Levene test. The difference in activity level was tested with a nonparametric rank-sum test. For all statistical tests, a significance level of 5% was used. A statistical software program (SPSS 15.0; SPSS Inc) was used for all of the data analysis.

Results
The study showed that 57 of 227 students reported knee pain during the previous week, corresponding to a prevalence of knee pain of 25%. Forty-two percent of those with knee pain agreed to enter the study. Of the 24 students with knee pain, 13 were diagnosed as having PFPS. This corresponds to a population prevalence of PFPS of 6% (Fig. 1). The sex distribution, age, height, and weight in the PFPS group (n = 13) were comparable with those in the control group (n = 22) (Table 1).

Navicular Drop and Drift
Navicular drop and drift were significantly larger in the PFPS group compared with the control group. Mean ± SD navicular drop in the PFPS group was 4.2 ± 1.8 mm and in the control group was 2.9 ± 0.9 mm (P = .007). Mean ± SD navicular drift was 2.6 ± 1.7 mm in the PFPS group and 1.4 ± 1.2 mm in the control group (P = .021) (Table 2).

Ankle Dorsiflexion
Ankle dorsiflexion was significantly larger in the PFPS group (P = .047). Mean ± SD dorsiflexion was 22.2° ± 5.7° in the PFPS group and 17.7° ± 5.6° in controls (Table 2).

Hip Rotation
There was no significant difference in hip rotation between the groups. Mean ± SD external rotation was 59.2° ± 4.0° in the PFPS group and 62.3° ± 6.9° in the control group. The PFPS and control groups were alike regarding mean ± SD internal rotation: 62.3° ± 6.0° versus 64.6° ± 7.2°, respectively (Table 2). The range of hip rotation was similar in both groups, and no statistically significant or meaningful difference was observed (Table 2).

Activity Level
On average, moderate to heavy physical activity for at least 5 hours weekly was seen in 23% of participants with PFPS and 36% in the control group. However, there was no overall difference in activity level between the two groups (P = .14, rank-sum test).

Discussion
Prevalence
The prevalence of PFPS found in the present study was 6%, which is lower than the prevalence found by Tallay et al in Hungarian adolescents aged 12 to 20 years (20.7%). Although Kaufman et al described an injury incidence of PFPS of 7.8% among 449 trainees at the Naval Training Centre, all of the participants in their study were men, were physically fit, and were older than the students in the present study. The primary reasons for discrepancies in prevalence are most likely to be different diagnostic criteria and the age of the study participants. Several diagnostic criteria for PFPS exist. Powers et al defined PFPS as pain originat-

Table 2. Lower-Limb Measures in the PFPS and Control Groups

<table>
<thead>
<tr>
<th></th>
<th>PFPS Group (n = 13)</th>
<th>Control Group (n = 22)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navicular drop (mm)</td>
<td>4.2</td>
<td>2.9</td>
<td>.007a</td>
</tr>
<tr>
<td>Navicular drift (mm)</td>
<td>2.6</td>
<td>1.4</td>
<td>.021a</td>
</tr>
<tr>
<td>Internal hip rotation (°)</td>
<td>62.3</td>
<td>64.6</td>
<td>.344</td>
</tr>
<tr>
<td>External hip rotation (°)</td>
<td>59.2</td>
<td>62.3</td>
<td>.152</td>
</tr>
<tr>
<td>Hip rotation (°)²</td>
<td>61.0</td>
<td>63.0</td>
<td>.177</td>
</tr>
<tr>
<td>Dorsiflexion (°)</td>
<td>22.2</td>
<td>17.7</td>
<td>.047a</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; PFPS, patellofemoral pain syndrome.

aStatistically significant (P < .05).

²Hip rotation was calculated as follows: (internal rotation + external rotation) / 2.
ing from the patellofemoral joint and pain during at least two of the following tasks: squatting, stair climbing, kneeling, prolonged sitting, and isometric quadriceps contraction. Levinger and Gilleard used subjective complaint of retropatellar knee pain and a physical examination. Witvrouw et al. used the criteria from Insall, as in the present study. The results of the present study indicate that the prevalence of PFPS in adolescents could be as high as 25% (students reporting any knee pain) or as low as 6% depending on the criteria. Previously reported prevalences of PFPS confirm a large variation of 4% to 28.5%.

**Static Measures**

The present case-control study revealed a significant difference in static foot pronation in a group of students with PFPS compared with a control group. Students with PFPS had larger navicular drop and navicular drift. Foot pronation involves motion of the navicular in three planes simultaneously. Although the largest amount of motion occurs in the sagittal plane, it has been suggested that measurement of medial drift of the navicular (frontal plane) may provide further insight into the mechanics of the talonavicular joint. A recent article by Vicenzino et al. attempted to determine predictors that could be used to identify patients with patellofemoral pain who would benefit from the use of foot orthoses. Vicenzino et al. identified the change in midfoot width from weightbearing to nonweightbearing as one of four predictors of treatment success. Their use of the change in midfoot width from nonweightbearing to weightbearing resembles the technique used in the present study to examine navicular drift. The finding of a 1.3-mm-larger navicular drop in individuals with PFPS resembles the finding of a decrease in midfoot movement that Kitaoka et al. observed in a cadaver study when they applied orthoses with a built-in arch support. These findings indicate the importance of controlling frontal plane movement of the foot in the rehabilitation of patients with PFPS.

**Ankle and Hip**

Participants with PFPS had significantly higher dorsiflexion compared with individuals in the control group (22.2° versus 17.7°, P = .047). Similar differences have previously been reported during walking and were associated with timing alterations of rearfoot inversion and heel-off. Powers et al. demonstrated greater ankle dorsiflexion when walking fast, descending stairs, and descending ramps in patients with PFPS compared with the control group. No differences, however, were found in knee motion between groups for any phase of the gait cycle, regardless of the condition. Increased ankle dorsiflexion could possibly be part of a strategy to reduce knee flexion during the stance phase, which would minimize the patellofemoral joint reaction force.

No significant difference was demonstrated between individuals in the study group and those in the control group in passive hip rotation ability. This is in accordance with recent findings suggesting that increased internal hip rotation during walking in women with PFPS seems to be the result of diminished hip-muscle performance as opposed to altered femoral structure.

As a consequence of the anticipated association between foot movement and PFPS, motion control shoes and orthoses have been suggested as an integral part of rehabilitation. In 1993, Eng and Pierrynowski demonstrated in a randomized design that the addition of orthoses to an exercise program provided significantly greater reductions in pain than did exercise alone in individuals with PFPS. An inclusion criterion in their study was that study participants should have more than 6° of rearfoot valgus or forefoot varus. A recent study by Collins et al. showed in a randomized design that the combination of orthosis and exercise did not add any additional effect compared with physiotherapy alone. However, the study by Collins et al. did not have any inclusion or exclusion criteria based on foot posture. This could indicate that individuals with PFPS with different foot postures respond differently to treatment and why clinical examination of the foot and lower extremity is important.

**Activity Level**

It has previously been suggested that chronic overloading and temporary overuse of the patellofemoral joint contribute to PFPS because of an increased activity level rather than malalignment. In the present study, it was not possible to confirm or reject the connection between physical activity and PFPS owing to limitation in sample size. It would be of great interest to follow a large cohort of children in a prospective study to better understand the importance of activity level in the development of PFPS.

**Limitations of the Study**

The present study used static measurements to examine differences between individuals with PFPS
and those in a control group. Static measurements show only a moderate correlation with dynamic assessments,\textsuperscript{39, 40} which is why it is not possible to conclude that these differences are measurable in a dynamic setting. The study did not have sufficient power to conclude that hip rotation and activity level are irrelevant to adolescents with PFPS. Because the present study used a case-control design, it is not possible to reject or confirm that the differences in static measurements are a causative factor in the development of PFPS.

**Conclusions**

The present study found a prevalence of PFPS of 6% in high school students. Furthermore, this study showed that individuals with PFPS have increased navicular drop and drift. A static clinical evaluation of navicular drop and drift may be useful in routine examination of patients with PFPS. However, larger clinical studies are now required to determine whether navicular drop and drift are predictive of outcome and whether they can help guide clinicians in determining the optimal treatment strategy for adolescents with PFPS.

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**Financial Disclosure:** None reported.

**Conflict of Interest:** None reported.

**References**

25. **Powers CM, Chen PY, Reischl SF, et al:** Comparison of foot pronation and lower extremity rotation in persons...