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Investigation of the Relationship Between Flatfoot and Patellar Subluxation in Adolescents

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ABSTRACT

Patellar subluxation is common in adolescents, and a variety of factors are related to this condition, with valgus of the knee joint an important factor. The results of many studies suggest that flatfoot can cause an abnormality of the lower limb power line. Structural abnormalities of the foot caused by the high stresses exerted by body weight can lead to structural deformity of the knee and can also cause knee valgus. Screening for foot problems can help determine the risk of patellar subluxation, and early intervention can lessen the incidence of this condition. The purpose of the present study was to investigate the effects of flatfoot on the structure and function of the knees and, especially, the risk of patellar subluxation. A total of 72 participants were recruited for this cross-sectional study. The mean age at examination was 15.4 ± 4.0 (range 9 to 22) years. The measured parameters were heel valgus angle, arch index, and quadriceps angle (Q-angle). Overall, the mean values of the heel valgus angle, arch index, and Q-angle were 5.9° ± 2.4° (range 1° to 11°), 0.33 ± 0.07 (range 0.23 to 0.46), and 19.1° ± 3.5° (range 9° to 26°), respectively. The Q-angle was directly associated with the heel valgus angle ($r = 0.818$, $p < .001$) and arch index ($r = 0.655$, $p < .001$). We found that flatfoot can affect the morphology of the knee joint and increase the risk of patellar subluxation.

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Flatfoot deformity is a common condition that can lead to chronic and debilitating foot and ankle problems. Flatfoot is a developmental or acquired deformity that is progressive and characterized by plantar and medial rotation of the talus, a decrease in medial arch height, and supination and abduction of the forefoot (1,2).

Patellar subluxation is also a common syndrome that is a common cause of knee joint pain (3) and plays an important role in adolescent knee pain. The causes of patellar subluxation are currently unclear (4). Many researchers believe that the condition has some congenital factors involving the femoral condyle, the lateral ligament of the patella, patellar shape abnormalities and, an important factor, an incorrect patellar line of force, which might occur after acute sprain or trauma (3,5,6). Thus, patients might visit the hospital because of knee swelling and pain (7).

In our clinic, we treated 24 patients with patellar subluxation using an arthroscopic patellar lateral retinacular release and medial repair from December 2013 to July 2015. All these patients had flatfoot. The aim of the present research was to determine whether a correlation exists between the presence of flatfoot and the occurrence of patellar subluxation.

Patients and Methods

Design

The present cross-sectional study was conducted from December 2015 to February 2016. Using the patient history and clinical evaluation findings, patients with a diagnosis of planovalgus deformity were considered suitable candidates for the present study. The condition was diagnosed by 1 of us (D.D.). All participants volunteered to participate in this research and provided informed consent before the examination session. The patients signed the institutional review board-approved consent form to allow release of their data for publication. The Union Hospital (Wuhan, China) reviewed and approved the present study. Four examiners performed the data collection process. The examiners were taught how to obtain the required measurements to ensure a consistent measurement protocol. The assessors were 2 orthotists and 2 doctors who were familiar with the common clinical assessments of flatfoot (1). All participants completed the testing process in the following order. The first examiner (G.L.) checked the inclusion and exclusion criteria and noted the demographic characteristics (i.e., age, sex, height, dominant side, and weight). The second examiner (O.L.) completed the questionnaire based on any history of pain in the foot and knee. The third examiner (K.Z.) completed the physical examination to find and record any predisposing deformity in the lower limb, including heel valgus, arch index, and genu valgum (especially

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the quadriceps angle [Q-angle]). Electronic ink footprints were obtained by the final examiner (Y.H.) (8,9).

Participants

A total of 72 individuals (32 males, 40 females) with a mean age of 15.4 ± 4.0 (range 9 to 22) years participated in this study (Table 1). The participants were selected consecutively from the outpatient department of Union Hospital (Wuhan, China). Those patients whose arch collapsed in a standing position and whose medial arch angle was >130° on radiologic examination were considered to have planovalgus deformity. Planovalgus deformity was diagnosed by 1 of us (D.D.). The patients with planovalgus deformity who were <24 years old were considered suitable candidates for the present study. Patients with any congenital deformities, previous operations, or fractures or dislocations of the lower leg or foot were excluded. The level of confidence was set at 95%.

Clinical Assessments

Each participant's sex, age, and dominant side were recorded. The examiner evaluated any indication of heel valgus, arch index, and Q-angle of the knee and ankle joints. Heel valgus was determined with the subject standing in the test position with photographs taken from the rear. The angle of heel valgus was then measured. The present study used a combination of an imaging technique (electronic footprint) and a clinical measurement (arch angle) for a more robust evaluation of flatfoot. The diagnosis of flatfoot was determined using an electronic inked plantar impression technique (electronic footprint), and calculation of the arch index was consistent with the method introduced by Cavanagh and Rodgers (9). The toeless foot length was divided into 3 parts. The arch index was calculated by dividing the middle part by the entire foot area (8). The patella was examined with the patient standing to evaluate the Q-angle (defined as the angle between the anterior superior iliac spine to the midpoint of the patella connection and the midpoint of the patella to the tibial tuberosity connection) (10). The participants stood in the test position and asked to maintain their lower limbs without rotation while photographs were taken from the front. The anterior superior spine, patellar midpoint, and pretibial nodules were marked, and attachments were made to these marks. The Q-angle (normal range 15° to 22°) was then measured.

Statistical Analysis

Descriptive and graphic statistics were used to present an overview of the data set. Both knees and feet were checked for all participants, and the data, including heel valgus, arch index, and genu valgum (Q-angle), were recorded (Table 2). We evaluated whether the heel valgus and arch index were associated with the Q-angle. Statistical analyses were performed using SPSS, version 19.0 (IBM Corp, Somers, NY) by 1 of us (Y.H.). Statistical significance was defined at the 5% level ($p < .05$).

Results

All measurements showed good-to-excellent interobserver reliability. Overall, the mean values of the heel valgus angle, arch index, and Q-angle were 5.9° ± 2.4° (range 1° to 11°), 0.33 ± 0.07 (range 0.23 to 0.46), and 19.1° ± 3.5° (range 9° to 26°), respectively (Table 2). The Q-angle was directly associated with the heel valgus angle ($r = 0.818$, $p < .001$) and arch index ($r = 0.655$, $p < .001$; Table 3 and Figs. 1 to 3).

The influence of the heel valgus angle and arch index on the Q-angle was estimated using an ordinal regression model. This showed that the heel valgus and arch index can increase the Q-angle, which, in turn, will increase the risk of patellar subluxation. Therefore, we found that flatfoot could affect the morphology of the knee joint and increase the risk of patellar subluxation.

Table 1
Demographic data

Variable	Value
Patients (N)	72 (144 feet and knees)
Sex	
Male	32
Female	40
Age (yr)	
Mean	15.4 ± 4.0
Range	9 to 22

A total of 72 patients underwent the procedure.

Table 2
Clinical and examination outcomes (N = 72)

Variable	Mean ± Standard Deviation
Heel valgus angle (°)	5.9 ± 2.4
Arch index	0.34 ± 0.06
Q-angle (°)	19.0 ± 3.5

Discussion

Flatfoot deformity is a condition characterized by medial longitudinal arch collapse or partial collapse and has a variety of causes. Most people are asymptomatic or only experience mild discomfort (11). If pain or swelling develops in the foot, it is known as painful flatfoot. Flatfoot affects not only the morphology of the foot but also its function and the function of other parts of the body. When a patient has long-standing flatfoot, the foot will be uncomfortable and, concomitantly, the patient will have a special walking gait (12).

As time passes and symptoms worsen, collapse of the medial longitudinal arch will increase the load on the foot and also affect other areas, such as the knees, hips, and lower back (13). Flatfoot is considered to be a condition with a variety of predisposing factors, especially lower extremity musculoskeletal disorders such as plantar fasciitis, Achilles tendonitis, and patellofemoral arthritis (14).

Regarding patellar subluxation, one should be aware that many types of patellofemoral joint disorders exist (15), with patellar subluxation one common form. It is characterized by partial lateral movement of the patella out of the trochlea but with the presence of articular contact between the patella and the trochlea (determined by symptoms, signs, or radiographic observations) (16). Joint structures (joint morphology and limb alignment) and normal patellar articular soft tissue structures constitute the normal anatomy of the patellofemoral joint and confer stability to the patella (5,17,18). Studies have shown that the stability of the patellofemoral joint depends on the shape of the bone and the line of force (5,19). The quadriceps tendon plays an important role in activities of the knee joint (18). In the course of knee extension, the quadriceps tendon provides tremendous power and forms an angle with the patellar ligament, known as the Q-angle (10). This angle provides the outward force for movement of the patella. Therefore, if the Q-angle is large, the femoral condyle form is relatively flat, which is likely to be the case for patients with patellar subluxation.

One study found that in patients with patellar subluxation, the Q-angle was larger than normal by ≈0.8° to 0.9° (20). The Q-angle is maximal when the knee is fully extended, and the force pulling the patella back from the quadriceps is reduced (21,22). Therefore, the patella moves away from the femoral condyle and easily relocates (23). Patellar subluxation injury occurs in a slightly buckled position and obviously has a relationship with the structure of the knee (24).

In our clinic, we treated 24 patients with patellar subluxation using an arthroscopic patellar lateral retinacular release and medial repair from December 2013 to July 2015. All 24 patients had flatfoot. Thus, we began this research to determine whether a correlation exists between the presence of flatfoot and the occurrence of patellar subluxation.

Table 3
Pearson's correlation between Q-angle and arch index and heel valgus angle (N = 72)

Q-angle	*r* Value	*p* Value
Arch index	0.655	<.01*
Heel valgus angle	0.818	<.01*

* Statistically significant correlation.

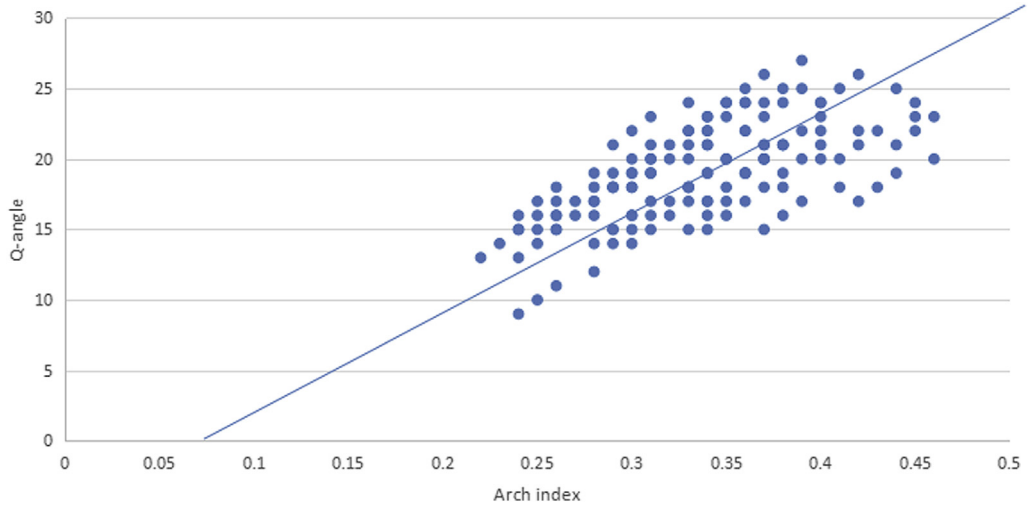


Fig. 1. Scatter plot for quadriceps angle (Q-angle) associated with arch index ($r = 0.655$, $p < .001$).

Our data showed a direct relationship between the presence of flatfoot and the development of patellar subluxation. This result is consistent with those from other studies, which proposed a positive association (5,24). We hypothesized that flatfoot could cause foot valgus deformity, which, in turn, could affect the lower limb power line. That would increase both the Q-angle and the knee valgus angle, both of which could increase the risk of patellar subluxation.

An argument exists against using the footprint method to measure flatfoot. The method can provide erroneous results because of variability in the thickness of the plantar pad among participants (25). However, research has shown that subjects do not have a thicker (or thinner) plantar pad but instead a flatter plantar arch (26). Another issue is that the Q-angle is only a part of the reason for patellar subluxation (18). Many other reasons exist. One important factor is trauma (3). The first episode of patellar dislocation will always be traumatic and can lead to knee effusion. Many studies have shown that patellar subluxation is a common condition caused by congenital and acquired factors (27–29). Severe congenital factors, even without damage, can cause wear between the patella and the lateral femoral condyle (30,31).

Similar to all clinical studies, we realize that the present investigation had certain limitations, including that number of participants was relatively low. Also, our research included only static measurements; thus, we were unable to predict the dynamic foot and knee behavior during locomotion. The present study had some other limitations. Despite efforts to control for interference, many another factors are associated with patellar subluxation. This limitation can be addressed in future research with long-term follow-up examinations. We are ready to perform a further prospective cohort study about the incidence of patellar subluxation in patients with flatfoot.

The present findings suggest that flatfoot, especially heel valgus and arch index, are explanatory factors that predict patellar subluxation. Those with flatfoot are more prone to related knee conditions. This finding suggests that healthcare professionals should give more attention to flatfoot and other foot deformities. When a clinical orthopedic doctor is faced with a patient with patellar subluxation or a patellofemoral joint injury, the orthopedist should determine whether a problem exists with the patient's foot and whether that problem affects the knee joint. If the answer is yes, it would be sensible to address the foot problems (e.g., by having the patient use an

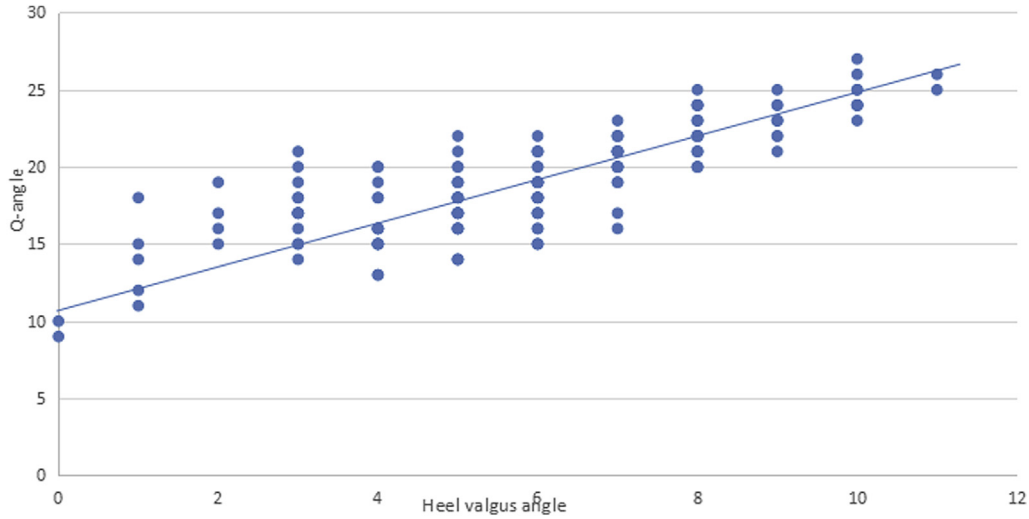


Fig. 2. Scatter plot for quadriceps angle (Q-angle) associated with heel valgus angle ($r = 0.818$, $p < .001$).

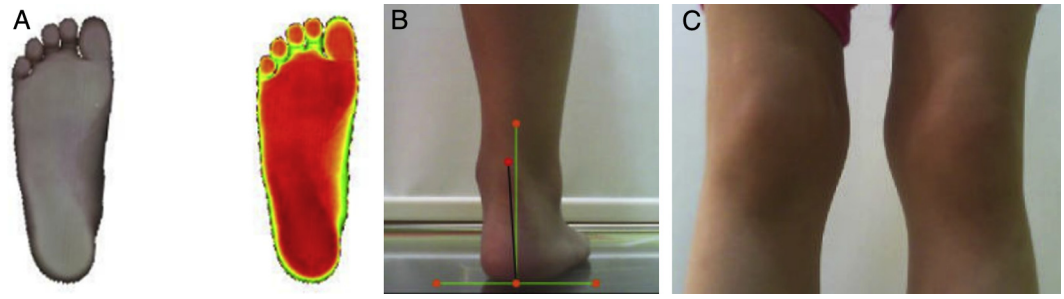


Fig. 3. (*A*) An examiner's electronic footprint, (*B*) heel valgus angle, and (*C*) knee joint appearance.

arch pad or custom insoles). A good foot shape is advantageous to the lines of force of the lower limbs and also to knee joint activities (32). Early interventions in such patients could be advantageous for preventing patellar subluxation and other conditions of the knee joint.

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