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ORIGINAL RESEARCH

COMPARISON OF ISOMETRIC ANKLE STRENGTH BETWEEN FEMALES WITH AND WITHOUT PATELLOFEMORAL PAIN SYNDROME

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ABSTRACT

Introduction: Proximal and distal influences on the knee may be related as etiological factors of patellofemoral pain syndrome (PFPS). The distal factors include subtalar excessive pronation as well as medial tibia rotation, but no study has investigated whether ankle weakness could lead to alterations that influence the patellofemoral joint. Thus, the purpose of this study was to compare the ankle dorsiflexor and invertor muscles strength, as well as rearfoot eversion and the Navicular Drop Test (NDT) in females with PFPS to a control group of females of similar demographics without PFPS.

Methods: Forty females, between 20 and 40 years of age (control group: n = 20; PFPS group: n = 20) participated. Rearfoot eversion range of motion and the NDT were assessed for both groups. The Numeric Pain Rating Scale and the Anterior Knee Pain Scale were used to evaluate the level of pain and the functional capacity of the knee during activities, respectively. Isometric ankle dorsiflexor and invertor strength was measured using a handheld dynamometer as the dependent variable.

Results: The isometric strength of the dorsiflexor and invertor muscle groups in females with PFPS was not statistically different ($P > 0.05$) than that of the control group. There was no statistically significant difference between groups for rearfoot eversion and NDT ($p > 0.05$).

Discussion/Conclusion: These results suggest that there is no difference between isometric ankle dorsiflexion and inversion strength, the NDT, and rearfoot eversion range of motion in females with and without PFPS.

***Key words*:** Ankle, handheld dynamometer, knee, patella, strength

Level of evidence: 3-b

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INTRODUCTION

Patellofemoral pain syndrome (PFPS) is the most common source of anterior knee pain in athletes and sedentary women, representing 20 to 40% of all individuals that are treated for knee injuries in orthopedic rehabilitation centers.[1] Traditionally, the treatment of PFPS has focused on addressing structures about the knee joint, including quadriceps strengthening and hamstring and iliotibial flexibility, in order to decrease patellar maltracking and normalize patellofemoral contact.[2]

Recently, PFPS has been related to dynamic lower limb malalignment including excessive femoral medial rotation and adduction during eccentric daily activities, resulting in reduction of contact area in the patellofemoral joint.[3-6] However the dynamic increase of tibiofemoral internal rotation could also decrease the patella to femur contact.[7] Excessive or prolonged rearfoot eversion during gait could lead to a compensatory mechanism, causing an increase tibiofemoral internal rotation and consequently an excessive dynamic valgus.[3,8,9] Baldon et al[10] observed that greater rearfoot eversion (pronation of the foot) was associated with greater tibial internal rotation in subjects with PFPS. Based upon these biomechanical findings, many authors have recommended the use of foot orthoses to positively affect the alignment of the lower extremities, resulting in significant short and long-term satisfactory clinical outcomes.[11-13] Thus, controlling excessive foot pronation may decrease the tibial and femoral internal rotation, thereby decreasing overload of the patellofemoral joint.[5,14,15]

The authors of this study believe that excessive foot pronation and calcaneal eversion during the mid-stance phase of gait could be the result of a muscular imbalance, related to dorsiflexor and invertor musculature weakness, especially the tibialis posterior muscle, which is assists in maintaining the medial longitudinal arch.[16] With these concepts in mind, Barton et al[17] and Powers et al[18] suggested that increased foot pronation may be contributing factor in PFPS. Therefore, the aim of the current study was to compare the ankle dorsiflexor and invertor muscles strength, as well as rearfoot eversion and NDT in females with PFPS to a control group of females of similar demographics without PFPS. The authors hypothesized that when compared to a pain-free control group, females with PFPS would exhibit decreased ankle strength and increased rearfoot eversion and navicular drop. This study may help in the clinical understanding of the relationship between ankle muscle strength and PFPS.

METHODS

Subjects

Twenty females between the ages of 20 and 40 years (mean 23.0 ± 3.0 years; height 162.0 ± 7.0 cm; body mass 56.8 ± 10.0 kg) diagnosed with unilateral (n = 7) or bilateral (n = 13) PFPS were recruited from the Physical Therapy sector of the Irmandade Santa Casa de Misericordia de São Paulo Hospital. The inclusion criteria for the PFPS group were the same criteria described by Thomee et al.[19] Pain during at least 3 of the following activities: squatting, climbing up or down stairs, kneeling, sitting for long periods, or when performing resisted isometric knee extension at 60 degrees of knee flexion; insidious onset of symptoms unrelated to trauma and persistence for at least 4 weeks; and pain on palpation of the medial or lateral facet of the patella.

Twenty control females (mean ± SD age, 24.0 ± 3.0 years; height, 163.0 ± 6.0 cm; body mass, 61.9 ± 10 kg), who presented with upper extremity tendinopathies and without lower extremity involvement were recruited from the same sector to serve as the control group. The exclusion criteria for both groups included the presence of any other associated knee conditions including patellar instability, patellofemoral joint dysplasia, meniscal or ligament injuries, tendon or cartilage injury, a decrease of range of motion in dorsiflexion, and a history of inversion injuries within the last 2 years. Subjects were also excluded if they had any neurological diseases, previous surgery of the lower limbs, lumbar pain, sacroiliac joint pain, rheumatoid arthritis, or were pregnant.

It is important to highlight that all females included in both groups were active, but not competitive athletes.[20] Before taking part in this study, the subjects were informed of the procedures and signed an informed consent approved by the Ethics Committee on Research of the ISCMSP.

Procedures

A senior physical therapist determined subject participation in both groups based on the inclusion and exclusion criteria. The subjects completed the Anterior Knee Pain Scale (AKPS) and a verbal numeric pain rating scale (NPRS). Another evaluator, who was blinded to group assignment, measured all subjects for the NDT and rearfoot eversion bilaterally, followed by ankle manual muscle strength assessment. The data for pain, function, duration of symptoms, ankle strength, rearfoot eversion and NDT for the PFPS group were obtained from the affected limb of the subjects with unilateral PFPS and the most affected limb of subjects with bilateral PFPS. In relation to control, the authors used the mean value of both sides for data analysis.

Functional Evaluation

The Anterior Knee Pain Scale (AKPS) was used to measure self-reported function.[21] The AKPS contains 13 items, each based on a 6-point scale, where the highest score represents no difficulty when performing the task and the lowest score represents complete inability to perform the activity. The maximum score is 100 and indicates that there is no deficiency; a score below 70 suggests moderate pain and disability. This questionnaire is reliable and valid, and has been widely used for patients with PFPS.[22,23] Pain was measured with an verbal 11-point Numeric Pain Rating Scale (NPRS) where 0 corresponded to no pain and 10 corresponded to "worst imaginable pain".[1,24]

Foot evaluation

Foot pronation was assessed using the NDT.[25,26] This test measures the difference in millimeters of the navicular tuberosity from the ground between a relaxed, weight bearing position, and a position of "imposed" subtalar neutral in standing. Initially, the subjects were placed on a rigid surface and placed in a neutral subtalar joint position, and the navicular height was measured. Next, the subjects were asked to relax and stand in their preferred posture, and the measurement was repeated.[25] In the authors' laboratory the reliability for NDT, was 0.80 ($ICC_{2,1}$) and SEM 0.20mm. Then, the therapist passively positioned the calcaneus in maximum eversion and motion was measured with a goniometer, and named rearfoot eversion.[27] The reliability for rearfoot eversion in the authors' laboratory[28] was 0.82 ($ICC_{2,1}$) and SEM 0.75 degrees.

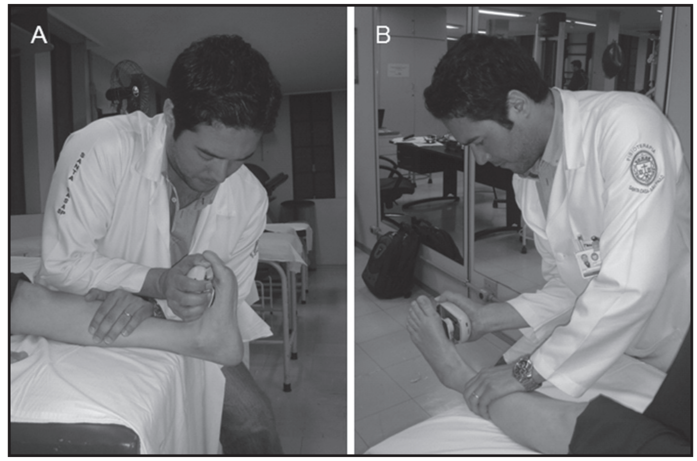

Figure 1. *Strength measurement for the dorsiflexor (A) and invertor (B) musculature*

Isometric Muscle Strength

A Nicholas hand-held dynamometer (Lafayette Instrument Company, Lafayette, IN) was used to measure isometric strength during a "make test" of the ankle dorsiflexors and invertors. This instrument is widely used clinically to measure muscle isometric strength.[29-31]

The dorsiflexor ankle strength was assessed while the subject lying in a supine position. The evaluated limb was positioned with the extended knee and the ankle joint remained in an unrestrained and neutral position. The dynamometer was placed against the dorsal surface of the foot near the metatarsal heads (FIGURE 1-A).[32] In the authors' laboratory, reliability for isometric muscle strength measurement of the dorsiflexors[28] was 0.95 ($ICC_{2,1}$) and SEM of 1.00 kg.

The invertor muscles were evaluated with the subject in the same position and the dynamometer was placed on the medial border of the foot at the shaft midpoint of the first metatarsal (FIGURE 1-B).[32] In the authors' laboratory, reliability for isometric muscle strength measurement of the invertors[28] was 0.77 ($ICC_{2,1}$) and SEM 1.97 kg.

During isometric strength testing, two submaximal trials were allowed for the subject to become familiar with each test position. This was followed by two trials with the subject providing maximal isometric effort for each muscle group, using consistent verbal encouragement. The interval between the second submaximal contraction and the first maximum isometric contraction was 10 seconds. The duration of each maximum isometric contraction was standardized at 5 seconds, with a rest time of 30 seconds between maximum isometric contractions. Testing order for the muscle groups was randomized. After evaluation of a muscle group, a standard 1-minute rest period was given before evaluating the other muscle group. When the examiner observed any compensation or combined movements during a test, the values were disregarded and the test was repeated after 20 seconds of rest. The mean values of the two maximal effort trials (one mean for each of the tested muscle groups) were utilized for data analysis.

Data Reduction

Isometric strength measurements, measured in kilograms (Kg), were normalized to body mass, also reported in Kg by using the following formula:

(Kg strength / Kg body weight) x 100.[29,33]

Data Analysis

Normality was assessed using Shapiro-Wilk test. Independent t-test were used to measure and compare demographics data, NPRS scores, AKPS scores, normalized dorsiflexor and invertor isometric strength; and the Mann-Whitney test was used to compare the NDT and rearfoot eversion measurements between groups. SigmaStat 3.5 was used for data analysis and the alpha level was set at 0.05.

RESULTS

Demographic data for the PFPS group and the control group are provided in Table 1. The PFPS and the control group were not statistically different in terms of age, weight, and height ($p > 0.05$).

Dorsiflexor and invertor muscle strength, NDT measurements, and the rearfoot eversion measurements of both groups are presented in Table 2. There were no statistically significant differences in normalized

Table 1. *Baseline characteristics (Mean ± SD) of the subjects in the control group (n = 20) and PFPS group (n = 20).*

	Age*	Height* (cm)	Body mass* (Kg)	Duration of Symptoms‡ (months)	NPRS‡ (0-10)	AKPS‡ (0-100)
Control	24.1 ± 2.6	163.0 ± 6.0	61.9 ± 10.0	0.0	0.0	98.4 ± 2.3
PFPS	22.8 ± 2.8	162.0 ± 7.0	56.8 ± 10.0	28.0 ± 18.0	6.0 ± 1.8	78.9 ± 17.2

Abbreviations: AKPS, Anterior Knee Pain Scale; NPRS, Numerical Pain Rating Scale; PFPS, Patellofemoral Pain Syndrome
** No difference between groups (p>0.05)*
‡ Statistically significant difference between groups (p<0.01)

Table 2. *Results for ankle strength of dorsiflexors and invertors, Navicular Drop Test, and rearfoot eversion (mean ± SD).*

	Dorsiflexors‡ (kg)	Invertors‡ (kg)	Navicular Drop Test (mm)	Rearfoot eversion (degrees)
Control (n = 20)	31.2 ± 11.4	29.0 ± 7.5	0.8 ± 0.3	9.0 ± 2.2
PFPS (n = 20)	32.4 ± 11.0	30.0 ± 8.4	0.9 ± 0.5	7.6 ± 2.5
p Value*	0.8	0.6	0.4	0.3

PFPS= Patellofemoral pain syndrome
** Note: There were no significant differences between groups.*
‡ Reported normalized to body weight

dorsiflexor ($p = 0.80$) and invertor ($p = 0.60$) muscle strength between the PFPS group and the control group. Moreover, the NDT and the rearfoot eversion measurements were not significantly different ($p = 0.40$ and $p = 0.30$, respectively) between groups.

DISCUSSION

The purpose of this study was to compare ankle dorsiflexion and inversion isometric strength, measures of foot pronation and rearfoot eversion between sedentary women with and without PFPS. There were no differences between groups, thus rejecting the authors' initial hypothesis.

Faulty mechanics at the hip have been correlated with PFPS, particularly excessive femoral adduction and internal rotational.[3,4] Strengthening of the hip abductor and external rotators is commonly recommended in the management of this disorder.[29,34,35] Similarly, faulty mechanics of the foot and ankle distally have been implicated in PFPS including excessive foot pronation and internal tibial rotation resulting in medial femoral rotation and increased patellofemoral stress.[4,5,18,36,37]

It is not surprising that the subjects in this study did not differ in ankle strength from the control group. Piazza[38] stated that when the foot is in a pronated position, the anterior tibialis would present an active restraint to pronation, thereby losing it is function as a rearfoot invertor. Then, one possible reason for the lack of differences between groups in the current study is the fact that the invertor muscles did not lose their function, since the subjects and controls did not differ in relation to foot pronation (as measured using the NDT) or rearfoot eversion.[38]

In contrast to the current findings, Barton et al[39] inferred that subjects with PFPS would present with greater navicular drop measurement when compared to controls. However, even if a difference had been found in NDT between groups, maybe that would not interfere with isometric strength of the chosen ankle muscles, since Snook[40] did not find a positive correlation between excessive pronation and ankle muscle weakness in healthy population.

Some authors have reported that the foot remains pronated when it should already be supinated during closed chain activities such as walking, running and other functional activities in subjects with PFPS, resulting in excessive internal tibial rotation.[3,41] So, this suggests a possible delay in the activation time of rearfoot inversion during these activities.[11,12,41] Many authors have surmised that this inversion occurs due to muscular delayed activation or pre vious muscle fatigue, instead of actual ankle muscle weakness, thus subjects with PFPS may not present with weakness of the inverters and dorsiflexors.[5,9,18,42] Other factors that could be related would be the difference between available ankle range of motion (ROM) and pronation velocity during closed chain activities in subjects with and without PFPS, however these two constructs were not studied in the current research.[43]

Another contributor to PFPS may be excessive hip adduction and internal rotation. Fukuda et al[35] and Mascal et al[34] observed that after a hip abductor and external rotator strengthening program, subjects with PFPS showed significant clinical improvement in terms of function and pain relief. Corroborating these data, some authors demonstrated that an associated 6-week strengthening program focusing on hip abductor and external rotator strengthening, can control the dynamic tibial internal rotation during jogging, thus decreasing the eversion amplitude and the inversion rearfoot moment.[42]

Some limitations of this study include the method of muscle strength evaluation, due to lack of other evidence regarding ankle muscle isometric dynamometry. Also, handheld dynamometry testing is both examiner- and test-position dependent. However, a pilot study was previously performed by the authors in order to establish reliability, and demonstrated satisfactory to excellent reliability. It is important to highlight that other options for assessment methods of rearfoot eversion could have been used, such as plain film radiographs or motion analysis during a dynamic gait task. However, we chose the NDT and eversion range of motion measures because they are widely used methods in the clinical practice with good to excellent interrater and intrarater reliability for patients with patellofemoral pain syndrome.[24] To the authors' knowledge, this is the first study focusing on the measurement of isometric ankle muscle strength of the PFPS population. Therefore, future studies are needed to better understand the relationship between such variables as ankle muscle strength and patellofemoral contact area, as well as the possible influence of the timing of muscle activation using electromyography and kinematic assessments of changes during functional activities. Finally, the main clinical implication of this study is that there were no statistical differences in the ankle muscle strength measurements, and measures of foot pronation and rearfoot eversion between PFPS and control groups.

CONCLUSION

The results of this study indicate that there is no difference in nomalized isometric ankle strength in women with PFPS and those without. When compared to a matched control group, neither the NDT nor the rearfoot eversion measurements were statistically significantly different.

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