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Reliability and differentiation capability of dynamic and static kinematic measurements of rearfoot eversion in patellofemoral pain

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ABSTRACT

Background: Excessive rearfoot eversion is thought to be a risk factor for patellofemoral pain development, due to the kinesiological relationship with ascendant adaptations. Individuals with patellofemoral pain are often diagnosed through static clinical tests, in scientific studies and clinical practice. However, the adaptations seem to appear in dynamic conditions. Performing static vs. dynamic evaluations of widely used measures would add to the knowledge in this area. Thus, the aim of this study was to determine the reliability and differentiation capability of three rearfoot eversion measures: rearfoot range of motion, static clinical test and static measurement using a three-dimensional system.
Method: A total of 29 individuals with patellofemoral pain and 25 control individuals (18–30 years) participated in this study. Each subject underwent three-dimensional motion analysis during stair climbing and static clinical tests. Intraclass correlation coefficient and standard error measurements were performed to verify the reliability of the variables and receiver operating characteristic curves to show the diagnostic accuracy of each variable. In addition, analyses of variance were performed to identify differences between groups.
Findings: Rearfoot range of motion demonstrated higher diagnostic accuracy (an area under the curve score of 0.72) than static measures and was able to differentiate the groups. Only the static clinical test presented poor and moderate reliability. Other variables presented high to very high values.
Interpretation: Rearfoot range of motion was the variable that presented the best results in terms of reliability and differentiation capability. Static variables do not seem to be related to patellofemoral pain and have low accuracy values.

1. Introduction

One of the most common knee disorders affecting young individuals is patellofemoral pain (PFP) (Barton et al., 2012). Studies have suggested that females have a greater risk of developing this condition (Baldon et al., 2014). The percentage of young females who initiate physical activity programs and risk being diagnosed with PFP is up to 10% (Baldon et al., 2014). Furthermore, PFP affects 1 in 4 subjects in the general population (Ferrari et al., 2014). It has been shown that PFP can limit participation in sports and daily activities, such as stair climbing, squatting or remaining seated, as these activities intensify the pain (Ferrari et al., 2014). Despite its high incidence, the multifactorial etiology of PFP remains unclear (Nunes et al., 2013).

Rearfoot eversion has been reported as a PFP risk factor due to its kinesiological relationship with ascendant adaptations in runners and non-runners (Collado and Fredericson, 2010; Levinger and Gilleard, 2007; Nunes et al., 2013). During the stance phase of gait or stair climbing, an everted rearfoot could lead to excessive internal rotation of the tibia which can induce a compensatory internal rotation of the femur, increasing patellofemoral joint stress (Aliberti et al., 2011). Despite rearfoot alterations having been used in assessments of subjects with PFP through static clinical tests (Powers et al., 1995, 1999), the adaptations generally appear in dynamic conditions (Barton et al., 2009). Moreover, knowing whether these static measures are correlated with dynamic measures is necessary, due to the fact that foot orthoses utilized to treat rearfoot eversion are manufactured in a static position, yet their main function occurs during dynamic tasks (Barton et al., 2011a).

Although there is a reasonable theoretical explanation for treating PFP with foot orthoses (Tiberio, 1987), the results of high-quality studies have been inconsistent. Barton and colleagues found that only 28% of participants reported a markedly better condition after 12 weeks of wearing foot orthoses (Barton et al., 2011a). Similarly, Vicenzino and colleagues found an improvement of 40% in participants and

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consequently, non-successful orthotic treatment in 60% (Vicenzino et al., 2010). Evaluating the same subject, a study (Collins et al., 2009) reported reduced pain in young women after being treated with foot orthoses, although no significant differences were found between foot orthoses and conventional physiotherapy, even when treated with a combination of foot orthoses and conventional physiotherapy (Collins et al., 2009). All the above studies classified the subjects as having greater rearfoot eversion through static tests. The inconsistencies in results between these studies could be due to inappropriate use of foot orthoses in some individuals with PFP.

Although it is quite important to have a good understanding of the precise relationship between static and dynamic rearfoot measures in PFP, what appears mandatory in this context is to provide some clarifications as to why these alterations seem to be evident in theoretical models and biomechanical assessments and yet there are satisfactory treatment results. To answer this important question, it is necessary to evaluate reliability, precision, sensitivity and specificity measures. Therefore, a study that analyzes three different measures (two static and one dynamic), regarding their reliability and capability to differentiate individuals with PFP versus pain-free individuals would add greatly to the knowledge in this area. To the best of our knowledge, this is the first study to approach this problem from such a perspective.

In this context, the aim of this study was to determine the reliability, precision and differentiation capability of three rearfoot eversion measures: a static clinical test, rearfoot range of motion during stair climbing and a static measurement using a 3D system.

2. Methods

2.1. Participants

Twenty-nine females with PFP and twenty-five pain-free females (control group) were recruited via advertisements placed at the University of Sao Paulo State, Presidente Prudente, SP, in the city center and in gyms around the city. The mean (SD) age, height and mass were 21.9 (2.72) years, 1.65 (0.05) m and 65.72 (10.76) kg, respectively, for the PFP group and 22.07 (3.67) years, 1.65 (0.04) m and 62.3 (7.3) kg for the control group (CG). For this sample size, to evaluate rearfoot eversion, observing a minimum difference of 2.83° between means and a standard deviation of 4.61°, with two groups and a significance level of 5%, a statistical power of 80% was expected. The study was approved by the University of Sao Paulo State Human Ethics Committee, and each participant gave written informed consent prior to participation. Diagnosis of PFP was based on definitions used in a previous high-quality PFP diagnostic study (Ferrari et al., 2014). The inclusion criteria were: (1) anterior knee pain during at least 2 of the following activities: remaining seated, squatting, kneeling, running, climbing stairs and jumping; (2) pain during patellar palpation; (3) symptoms for at least 1 month with an insidious beginning; (4) pain level in the previous month of up to 3 cm on a 10 cm visual analog scale (VAS); and (5) 3 or more positive clinical signs in the following tests: Clarke's sign (Nijs et al., 2006), McConnell test (Watson et al., 1999), Noble compression (Magee, 2008), Waldron test (Nijs et al., 2006) and patella in the medial or lateral position (Halabchi et al., 2013). The participants needed to fulfill all 5 requirements to be allocated to the PFP group and could not present any signs or symptoms of PFP or other diseases to be allocated to the control group (pain-free). Having any of the following conditions was considered an exclusion criterion: events of patellar subluxation or dislocation, lower limb inflammatory process, osteoarthritis, patellar tendon or meniscus tears, bursitis, ligament tears or the presence of neurological diseases. Those who had undergone knee surgery or knee treatments such as arthroscopy, steroid injections, oral steroids, opiate treatment, acupuncture or physiotherapy during the preceding 6 months were excluded from this study.

All the participants were evaluated according to the exclusion and inclusion criteria by two investigators with five years of clinical practice and were only allocated into the PFP group or control group if these two investigators were in agreement about the criteria.

2.2. Procedure

Static rearfoot measurements were performed by two investigators during the sample evaluation (inclusion and exclusion criteria) using the technique described by Powers et al. (1995). Subjects were placed in a prone position with the ankle resting and the calcaneus parallel to the floor. The subtalar position was determined by palpating the head of the talus at the medial and lateral borders of the talonavicular joint, and when the talus could not be palpated or felt equally prominently on both sites, the neutral position was considered. After subtalar joint neutrality had been obtained, the angle formed by the bisection of the calcaneus and the lower one-third of the leg was measured with a goniometer. The bisection of the lower leg, determined by palpating the leg's medial and lateral borders, was independent of the Achilles tendon orientation. The longitudinal midline of the posterior calcaneous was also estimated by palpating the medial and lateral borders. Vertical lines were drawn with a straight edge to assist the goniometer alignment. The angle formed by these two lines represented the rearfoot position in relation to the subtalar joint neutral. The evaluators were isolated in a separate room at the moment of assessment, thereby avoiding potential bias which could influence the reliability of the measurement.

2.3. Kinematic analysis

Data collection included lower limb kinematic evaluation of each participant's symptomatic limb (those with unilateral symptoms) or most symptomatic limb (in those with bilateral symptoms) during stair climbing. Motion analysis was collected using a three-dimensional motion analysis system (VICON MX, Vicon Motion Systems Inc.; Denver EUA) combined with 4 cameras (type Bonita®B10) operating at a sampling frequency of 100 Hz with a resolution of 1 megapixel. Ground reaction forces were collected using a force plate (AMTI, OR6, Watertown, MA, USA) at a sampling frequency of 2000 Hz.

To perform kinematic evaluation of each participant during stair climbing, the Oxford Foot Model (OFM) (Barton et al., 2011a; Stebbins et al., 2006) was used associated with a plug-in gait model (PIG-SACR) to perform static calibration (Kadaba et al., 1990). Each participant's height, mass, inter-anterior superior iliac spine distance (ASIS), ASIS to lateral malleolus distance, knee width and ankle width were recorded. Retroreflective markers (9.5 mm) were placed in accordance with the models by the same investigator on specific anatomical landmarks (outlined below) to form rearfoot, tibial, femoral and pelvic segments, on both members: markers were placed on the right and left ASIS, top of the sacrum (L4–L5), lateral aspect of the femur, estimated average axis of rotation of the knee joint, lateral aspect of tibia, lateral malleolus, heel posterior face, base of first metatarsal, head of first metatarsal, head of fifth metatarsal and base of fifth metatarsal. The rearfoot segment was formed by three markers bisecting the heel (distal, medium and proximal), and markers placed on the lateral calcaneus and sustentaculum tali. The tibial segment was formed by markers placed on the head of the fibula, tibial tuberosity, anterior border of tibia, lateral aspect of tibia and medial malleolus.

A relaxed standing calibration trial was then captured, after which the participants performed practice stair climbing trials to allow familiarization with the instrumentation and environment. Evaluation of motor tasks that are more challenging in terms of mechanical and muscular demands, such as managing stairs, may further contribute to the understanding of compensatory mechanisms generated by subjects with PFP, which are not observed during walking (Aliberti et al., 2010). Because of this, the experimental design included a seven-step staircase, each step being 18 cm high and 28 cm deep, with a 2 m walkway in front of and behind the staircase. Once participants felt they were comfortable,