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Lower extremity mechanics of females with and without patellofemoral pain across activities with progressively greater task demands

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Abstract

Background. Patellofemoral pain is commonly associated with lower extremity joint rotations that decrease retropatellar contact area and subsequently increase retropatellar stress during weightbearing activities. People with patellofemoral pain are thought to be capable of avoiding such harmful mechanics during activities with low external demands. However, this may not be possible during more demanding activities. The purpose of this study was to analyze lower extremity mechanics in females with and without patellofemoral pain during three different activities. Specifically, we sought to determine if differences between groups increase with increasingly demanding activities.

Methods. 20 females with patellofemoral pain and 20 healthy female controls performed single leg squats, running, and repetitive single leg jumps as their three-dimensional lower extremity mechanics were recorded. Transverse and frontal plane hip and knee kinematics were compared between groups for all activities.

Findings. Differences in the variables of interest between groups did not generally depend on the nature of the activity. The patellofemoral pain group performed all three activities with 4.3° greater knee external rotation ($P = 0.06$), 3.5° greater hip adduction ($P = 0.012$), and 3.9° decreased hip internal rotation with respect to the control group ($P = 0.01$).

Interpretation. These results suggest that females with patellofemoral pain do not employ different mechanics as demand of the activity increases. Rather, females with patellofemoral pain seem to demonstrate similar abnormal lower extremity mechanics across a variety of activities.

Keywords: Anterior knee pain; Kinematics; Kinetics; Running; Jump; Squat

1. Introduction

Patellofemoral pain syndrome (PFPS) is the most common orthopedic knee complaint with respect among active young adults, especially females (Devereaux and Lachmann, 1984; Sanchis-Alfonso et al., 1999; Taunton et al., 2002). A review of running-related injuries revealed that individuals who presented to a sports medicine clinic were approximately twice as likely to present with PFPS as any other single orthopedic condition (Taunton et al., 2002). Recent military studies suggest that 37% of recruits developed PFPS over six weeks of basic military training (Van Tiggelen et al., 2004). Finally, prospective studies of university students engaged in physical education classes reveal that nearly 10% of the students develop PFPS during a single course (Witvrouw et al., 2000). The consequences of PFPS may include pain during functional activities, a reduction in activity level, and an increased risk of developing patellofemoral osteoarthritis later in life (Utting et al., 2005).

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The etiology and progression of PFPS are frequently associated with excessive patellofemoral joint stress. As the largest sesamoid bone in the body, the patella serves to increase the moment arm of the quadriceps. This improves the capacity of this muscle to generate knee extension torque. As such, the inert articular cartilage is subject to joint reaction forces between seven to 20 times body weight during running and squatting, respectively (Lee et al., 2003). Repetitive exposure to such high stress is alleged to damage retropatellar cartilage, facilitating greater force transmission to innervated subchondral bone (Ateshian and Hung, 2005; Huang et al., 2003; Zimmerman et al., 1988). These initial articular insults hasten development of further cartilage structural damage (Foster et al., 1999; Kerin et al., 1998). Indeed, the location of patellofemoral osteoarticular lesions are most frequently identified at retropatellar surface areas associated with the greatest loads (Seedhom, 1979).

Considering the documented in-vitro evidence, several authors have attempted to compare patellofemoral joint loading conditions in subjects with and without PFPS. Unfortunately, in-vivo measurement of patellofemoral joint stress is not practical at this time. Therefore, results of lower extremity modeling and surrogate measures of patellofemoral joint stress (knee extension moment, principally) during weightbearing activities have been reported. Heino Brechter and Powers (2002) reported no change in estimated patellofemoral joint reaction forces between groups of subjects with and without PFPS during walking. However, using MRI, they determined that contact area was reduced in the PFPS group. This led their model to predict increased patellofemoral joint stress among subjects with PFPS.

If PFPS is truly a consequence of increased retropatellar stress, then it is critical to evaluate factors that may affect retropatellar contact area. The quadriceps angle (Q angle) approximates the resultant force orientation of the four muscles of the quadriceps group acting on the patella (Mizuno et al., 2001). Q angle is the angle between a line drawn from the tibial tubercle to the center of the patella and a second line drawn from the anterior superior iliac spine to the center of the patella. A typical value for this angle is 15° As this value increases, the lateral component of the resultant force acting on the patella also increases (Mizuno et al., 2001). Females typically have a larger quadriceps angle than males. As such, Q angle has been hypothesized to be a factor in the gender bias for PFPS (Arendt, 1994). However, females with PFPS do not consistently exhibit high Q angles (Thomee et al., 1995).

Transverse and frontal plane rotations of the hip and knee can change the Q angle and significantly affect retropatellar stress. For example, in a cadaveric study, Lee et al. (2001) increased the Q angle by external rotating the tibiofemoral joint by 30°. This significantly increased retropatellar stress during physiological loading of the quadriceps muscles. More recently, Li et al. (2004) demonstrated that 3.6° of tibiofemoral external rotation increased patellofemoral joint stress 10–24% at every 30° interval of knee flexion. Finally, increasing the Q angle in the frontal plane has been reported to consistently increase retropatellar stress from 20° to 90° knee flexion (Huberti and Hayes, 1984). Participation in repetitive weightbearing activities with such alignment may lead to patellar cartilage damage and PFPS. Indeed, Harilainen et al. (2005) reported that the location of the patella with respect to the femur predicted the location of patellar cartilage lesions among subjects with PFPS.

Decreased hip external rotation and abduction strength may increase the tendency for females with PFPS to experience these transverse and frontal plane rotations which increase retropatellar stress. Ireland et al. (2003) reported that a group of females with PFPS exhibited significantly less hip abduction and external rotation strength than a healthy female control group. Depending on the magnitude of the external load, this decreased strength may limit the ability of these individuals to resist hip adduction and internal rotation forces which increase the quadriceps angle. During activities with low external demands such as walking, subjects with PFPS may possess sufficient strength to maintain normal lower extremity kinematics. During more demanding activities, however, females with PFPS may be particularly prone to hip adduction and internal rotation. Powers et al. (2002) reported greater hip external rotation among individuals with PFPS compared to a healthy control group during walking at self-selected speeds. They suggested this hip external rotation may be a compensatory mechanism to decrease the Q angle. In addition, they believed that it would be difficult to maintain these compensations during more dynamic activities. This appears to be true among some subjects with PFPS. Dierks (2006) reported that 7 of 20 subjects with PFPS demonstrated significantly greater hip internal rotation than a healthy control group. An activity with even greater external loads, such as repetitive jumping, may reveal even greater kinematic differences among subjects with PFPS. However, there are no studies to date examining jumping in subjects with PFPS.

The purpose of this study was to compare lower extremity kinematics in females with and without PFPS during the progressively demanding activities of single leg squats, running, and repetitive single leg jumps. Based on the available literature, we hypothesized that females with PFPS would demonstrate greater knee external rotation, hip internal rotation, and hip adduction peaks and excursions during activities with progressively greater loading compared to healthy controls.

2. Methods

A sample size calculation was performed to ensure reasonable protection from type II error. The variable with the largest standard deviation noted during pilot studies (hip transverse plane rotation) was chosen for the power analysis. Using a within group standard deviation of 5.5°, and an