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Original article

Trunk biomechanics and its association with hip and knee kinematics in patients with and without patellofemoral pain

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A B S T R A C T

Patellofemoral pain (PFP) is a common lower extremity condition observed in sports clinics. Recently, it has been suggested that trunk motion could affect hip and knee biomechanics in the frontal plane. Thus, the purpose of the study was compare trunk kinematics, strength and muscle activation between people with PFP and healthy participants. In addition, the associations among trunk biomechanics, hip and knee kinematics were analysed. Thirty people with PFP and thirty pain-free individuals participated. The peak ipsilateral trunk lean, hip adduction, and knee abduction were evaluated with an electromagnetic tracking system, and the surface electromyographic signals of the iliocostalis and external oblique muscle were recorded during single-leg squats. Trunk extension and trunk flexion with rotation isometric strength and side bridge tests were quantified using a handheld dynamometer. Compared with the control group, the PFP group demonstrated increased ipsilateral trunk lean, hip adduction and knee abduction ($p = 0.02–0.04$) during single-leg squat accompanied with decreased trunk isometric strength ($p = < 0.001–0.009$). There was no between-group difference in trunk muscle activation. Only in the control group, ipsilateral trunk lean was significantly correlated with hip adduction ($r = -0.66$) and knee abduction ($r = 0.49$); also, the side bridge test correlated with knee abduction ($r = -0.51$). Differences in trunk, hip and knee biomechanics were found in people with PFP. No relationship among trunk, hip and knee biomechanics was found in the PFP group, suggesting that people with PFP show different movement patterns compared to the control group.

1. Introduction

Patellofemoral pain (PFP) is one of the most common lower extremity conditions observed in sports medicine clinics (Baquie and Brukner, 1997). PFP is particularly prevalent in physically active young adults (Taunton et al., 2002). It has been suggested that the patellofemoral joint may be influenced by other lower extremity joints (Powers et al., 2003). Excessive knee valgus, resulting from hip adduction and knee abduction, is believed to increase the dynamic quadriceps angle, which reflects the frontal plane forces acting on the patella (Powers, 2010). The abnormal motion of the femur and the tibia in the frontal plane would be expected to adversely affect the patellofemoral joint mechanics by increasing the laterally directed force acting on the patella (Powers, 2003).

In people with PFP, increased ipsilateral trunk lean has been hypothesised to compensate for hip abductor muscle weakness to control hip adduction by elevating the contralateral pelvis during functional activities (Dierks et al., 2008). However, it has also been suggested that ipsilateral trunk lean could affect knee kinetics in the frontal plane (Hunt et al., 2008). In fact, it has been shown that when performing increased ipsilateral trunk lean during gait, healthy volunteers have demonstrated increased hip and knee abduction moments (Mundermann et al., 2008). Note that previous results have suggested that increased knee abduction moment during landing contributes to an increased incidence of PFP (Myer et al., 2010). A higher knee abduction moment might increase the dynamic quadriceps angle and consequently increase the lateral vector force acting on the patella, which would result in greater stress on the lateral compartment of the patellofemoral joint (Powers, 2003, 2010). Although there is evidence of increased trunk movement in the frontal plane in people with PFP during gait, the relation among

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the trunk, hip and knee kinematics in the frontal plane has not been investigated in people with PFP.

It has recently been demonstrated that persons with PFP performed greater ipsilateral trunk lean during weight-bearing activities (Nakagawa et al., 2012; Noehren et al., 2012). Trunk muscle strength and muscle activation could influence trunk kinematics in people with PFP; thus, it is important to investigate whether trunk muscle strength and activation are altered during functional activities and how those potential differences in trunk muscle strength and activation may influence trunk, hip and knee kinematics in people with and without PFP. Also, the associations among trunk biomechanics, hip adduction and knee abduction should be analysed in both groups.

The purpose of this study was to compare trunk extension, flexion with rotation and lateral flexion isometric strength; iliocostalis and external oblique muscle activation and ipsilateral trunk lean, hip adduction, knee abduction during a single-leg squat between people with PFP and healthy participants. In addition, the associations among trunk biomechanics, hip adduction and knee abduction were analysed in both groups. It was hypothesised that the participants with PFP would present lower isometric trunk muscle strength and diminished activation of the iliocostalis and external oblique muscles when compared with the control participants. It was expected given previous findings that people with PFP would present increased trunk, hip, and knee frontal plane motion. It was also hypothesised that lower trunk muscle strength, lower trunk muscle activation and greater ipsilateral trunk lean would be associated with lower hip adduction and greater knee abduction in both groups.

2. Methods

Sixty participants between the ages of 18–35 participated in this study. The PFP group consisted of 20 females and 10 males (mean ± SD age, 22.7 ± 3.4 years, height, 171.3 ± 9.2 cm, and body mass, 65.3 ± 10.3 kg). The control group also consisted of 20 females and 10 males (age, 22.3 ± 3.0 years, height, 168.6 ± 8.6 cm, and body mass, 63.3 ± 9.8 kg). The groups were matched for age, height and body mass ($p > 0.05$).

All of the participants with PFP reported an insidious onset of symptoms (>3 months). Furthermore, the participants reported readily reproducible peripatellar or retropatellar pain while performing at least 2 of the following activities: stair ascent or descent, running, kneeling, squatting, prolonged sitting, jumping, or isometric quadriceps contraction. Participants with no history of knee injury or pain were selected for the control group. The exclusion criteria for all groups included a previous history of knee surgery; a history of back, hip or ankle joint injury or pain; patellar instability; signs or symptoms of meniscal or knee ligament involvement, and any neurological condition that would affect movement. Prior to the data collection, all participants provided written informed consent and the experimental protocol was approved by the Institutional Review Board of the xxxxxxx. In the participants with PFP who reported bilateral symptoms, the lower extremity reported to be most affected was tested. The corresponding limb of each gender- and age-matched control participant was tested.

The electromyographic signals (EMG) of the trunk muscles were sampled at 2000 Hz using surface electrode DE-3.1 sensors (Delsys Inc., Boston, MA, USA) and interfaced with an amplifier Bagnoli™ 8-channel system (Delsys Inc., Boston, MA, USA). The EMG activity was recorded unilaterally between a frequency band from 20 to 500 Hz. Before the electrode placement, the skin was shaved, abraded and cleaned with isopropyl alcohol. For the iliocostalis muscle, the electrode was placed 1 finger width medially from the line from the posterior spinal iliac superior to the lowest point of the lower rib, at the L2 level (Hermens et al., 1999). For the external oblique abdominis muscle, the electrode was placed midway between the anterior superior iliac spine and the rib cage (Ekstrom et al., 2007).

The EMG data obtained during the single-leg squat were normalised to the maximal voluntary isometric contraction (MVIC). The participants performed one practice trial prior to the collection of three 5-s MVICs for the iliocostalis muscle and the external oblique abdominis muscle and rested for 30 s between the trials (Bolgla et al., 2010). The handheld dynamometer (Lafayette Instruments, Lafayette, IN, USA) was used to simultaneously measure the trunk extension (Fig. 1A) and trunk flexion with rotation strength (Fig. 1B) generated during each MVIC (Bolgla et al., 2010). The participants were required to obtain three measurements with a variability of ± 10%; otherwise, another trial was performed (Bolgla et al., 2010). For the iliocostalis muscle (Fig. 1A), the participants were in the prone position with their hands folded behind their necks (Muller et al., 2010). The handheld dynamometer was positioned between the scapulae, under a nylon strap secured around the upper trunk and the examination table, which was used to resist trunk extension. A second adjustable nylon strap, which was placed on the distal thighs and secured firmly around the underside of the table, was used to stabilise the participant on the examination table. For the external oblique abdominis muscle (Fig. 1B), the participant performed an oblique curl-up, attempting to move the shoulder toward the opposite knee (Ekstrom et al., 2007). The handheld dynamometer was positioned on the sternum, under a nylon strap secured around the upper trunk and the examination table, which was used to resist trunk flexion with rotation. A second adjustable nylon strap was placed on the distal

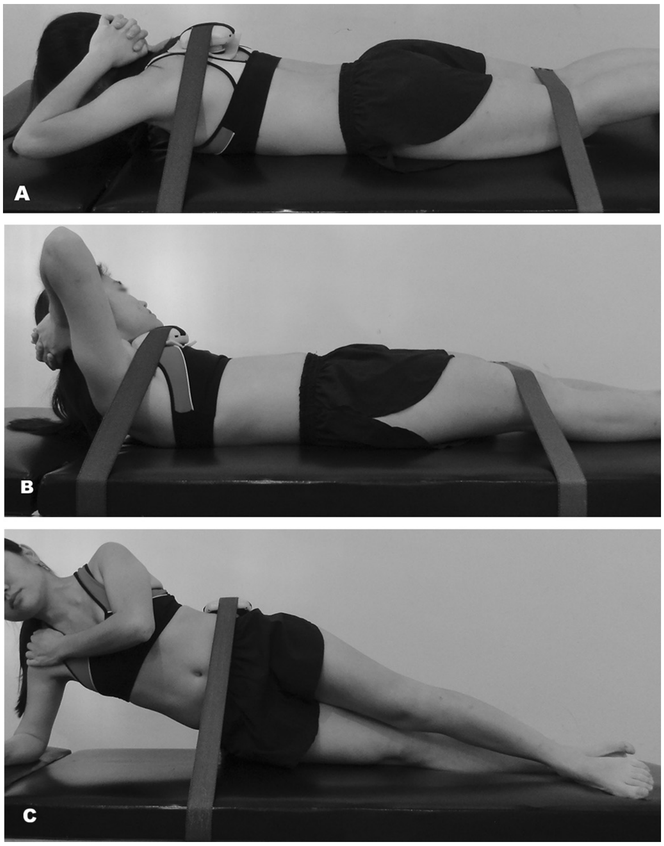

Fig. 1. (A) Trunk extension isometric strength test position. (B) Trunk flexion with rotation isometric strength test position. (C) Side bridge test position.