The Knee 23 (2016) 376–381

Contents lists available at ScienceDirect

The Knee

Contribution of altered hip, knee and foot kinematics to dynamic postural impairments in females with patellofemoral pain during stair ascent☆

Danilo de Oliveira Silva [a], Fernando Henrique Magalhães [b], Marcella Ferraz Pazzinatto [a], Ronaldo Valdir Briani [a], Amanda Schenatto Ferreira [a], Fernando Amâncio Aragão [c], Fábio Mícolis de Azevedo [a,*]

[a] Physical Therapy Department, School of Science and Technology, University of São Paulo State, Presidente Prudente, Brazil
[b] School of Arts, Sciences, and Humanities, University of Sao Paulo, Sao Paulo, Brazil
[c] Physical Therapy Department, State University of West Parana, Cascavel, Parana, Brazil

ARTICLE INFO

Article history:
Received 7 October 2015
Received in revised form 13 January 2016
Accepted 15 January 2016

Keywords:
Center of pressure
Patellofemoral joint
Knee injury
Regression analysis
Postural control

ABSTRACT

Background: Altered hip, knee and foot kinematics have been systematically observed in individuals with patellofemoral pain (PFP). However, less attention has been given to the altered dynamic postural control associated with PFP. Additionally, the relative contribution of kinematic impairments to the postural behavior of subjects with PFP remains an open question that warrants investigation. The aims of this study were: i) to investigate possible differences in hip adduction, rearfoot eversion, knee flexion and displacement area of the center of pressure (COP) in individuals with PFP in comparison to controls during stair ascent; and (ii) to determine which kinematic parameter is the best predictor of the displacement area of the COP measured during the stance phase of the stair ascent.
Methods: Twenty-nine females with PFP and 25 asymptomatic pain-free females underwent three-dimensional kinematic and COP analyses during stair ascent. Between-group comparisons were made using independent t-tests. Regression models were performed to identify the capability of each kinematic factor in predicting the displacement area of the COP.
Results: Reduced knee flexion and displacement area of the COP as well as increased peak hip adduction and peak rearfoot eversion were observed in individuals with PFP as compared to controls. Peak hip adduction was the best predictor of the displacement area of the COP ($r^2 = 23.4\%$).
Conclusions: The excessive hip adduction was the biggest predictor of the displacement area of the COP.
Clinical relevance: Based on our findings, proximally targeted interventions may be of major importance for the functional reestablishment of females with PFP.

1. Introduction

Patellofemoral pain (PFP) is a common and costly musculoskeletal disorder characterized by the presence of idiopathic anterior knee pain [1,2], which can severely affect quality of life by limiting the participation in functional activities [3]. PFP is usually observed in the physically active population [1] and accounts for 25 to 40% of all knee injuries observed in sports clinics [1]. Females are 2.23 times more likely to experience PFP than males [2], and the estimated prevalence of PFP among females aged 18 to 35 years is 13% [4].

A commonly cited hypothesis as to the cause of PFP is increased patellofemoral joint (PFJ) stress associated with abnormal lower extremity kinematics [5,6]. In this direction, studies have reported that stair ascent results in more challenging patellofemoral contact mechanics than walking [7,8], thereby being a useful experimental model to reproduce symptoms and abnormal movement patterns associated with PFP. Therefore, to investigate lower extremity mechanics during stair negotiation has been important to clarify the compensatory behavior shown by females with PFP [5].

It is generally agreed that the etiology of PFP is multifactorial and several factors have been proposed in an attempt to explain the pathomechanisms underlying PFP [9]. For instance, a large amount of biomechanical alterations have been observed in individuals with PFP [9], which have been grouped into three mechanistic categories: proximal factors, distal factors and local factors [1]. Studies approaching proximal factors have been focused on understanding how the hip, pelvis, and trunk may contribute to PFP. Local factors' studies have focused on the contribution of PFJ mechanics and surrounding tissues to PFP. Moreover, distal factors' studies are dedicated to the contribution of foot and ankle mechanics to PFP [1].

Currently, special attention has been given to the increased rearfoot eversion and hip adduction as well as reduced knee flexion that have

☆ This work was developed in the Laboratory of Biomechanics and Motor Control at the University of São Paulo State.

* Corresponding author at: Rua Roberto Simonsen, 305, Presidente Prudente, SP 19060-900, Brazil.
E-mail address: micolis@fct.unesp.br (F.M. de Azevedo).

http://dx.doi.org/10.1016/j.knee.2016.01.014
0968-0160/

been observed in females with PFP as compared to controls [1,8,10–13]. However, to the best of our knowledge, there is no previous investigation on the specific contribution of such alterations to the dynamic postural impairments observed in subjects with PFP. More specifically, evidences from studies with traditional measurements based on center of pressure (COP) analysis (e.g. 95% ellipse area) have indicated impaired postural control in individuals with PFP during stair negotiation [14,15]. For instance, in a prospective study in which 43% of the participants developed PFP, the alteration of dynamic COP displacement was considered one of the three most important gait-related intrinsic risk factors for PFP development [16]. As proximal, distal and local kinematic alterations previously reported in subjects with PFP during stair ambulation [8,10,17] may contribute to changes in dynamic COP displacement, the relative influence of each of these alterations to PFP-associated postural impairments remains an open question that warrants investigation.

Proximally, weakness or delayed onset of hip abductor and hip external rotator muscles are thought to contribute to excessive hip adduction during stair negotiation activities in individuals with PFP [17]. The importance of hip muscles to postural stability was demonstrated experimentally by Gribble and Hertel [18], who showed increased COP excursion velocity during single leg stance after fatigue of the hip muscles. Therefore, it is reasonable to suppose that biomechanical alterations at the hip level may account for the impaired postural performance observed in subjects with PFP.

Locally, reduced knee flexion during stair negotiation is a common finding in individuals with PFP [10,19]. Recently, this mechanism was shown to alter vertical ground reaction forces [10], which is directly related to postural stability [20]. Therefore, altered knee kinematics may be associated with impaired postural stability in individuals with PFP.

Distally, excessive rearfoot eversion has been reported during stair ascent and walking [8,21] in subjects with PFP, which is suggested to lead to greater PFJ stress due to the coupling between subtalar motion and tibia rotation [22]. A prospective study [16] showed that individuals who developed PFP (as compared to subjects that did not) had greater rearfoot pronation associated with greater pressure on the medial portions of the plantar surface during walking. A similar pattern was reported for subjects with PFP (as compared to healthy controls) during stair negotiation [23]. It is reasonable to speculate that individuals with PFP may demonstrate poorer postural control during dynamic activities due to altered foot motion.

Assessment of postural control is of frequent interest to researchers and clinicians as postural steadiness is considered an important factor in functional reestablishment [24,25]. Identifying the kinematic alterations that most closely predict dynamic postural impairments would help clinicians to develop more specific and successful interventions.

In this context, the aims of this study were (i) to investigate possible differences in hip adduction, rearfoot eversion, knee flexion and displacement area of the COP in individuals with PFP as compared to controls during stair ascent; and (ii) to determine which one of these kinematic parameters is the best predictor of the displacement area of the COP. Due to the previous literature mentioned above, it was hypothesized greater rearfoot eversion and hip adduction as well as decreased knee flexion in subjects with PFP in comparison to controls. The relative contribution of hip, knee and foot kinematics to dynamic postural behavior cannot be predicted beforehand due to contradictory results that have been reported with regard to the dynamic postural alterations observed in subjects with PFP.

2. Methods

2.1. Participants

Fifty-four females aged 18 to 30 years were recruited and divided into two groups: PFP group (PFPG; n = 29) and control group (CG; n = 25). Only females were included due to high prevalence of PFP in this population [2]. In addition, we assumed that including both sexes could be seen as a confounder because females are reported to exhibit different movement patterns than males [26]. Mean (SD) age, height, mass and physical activity level are presented in Table 1. Physical activity level was evaluated with the self-administered International Physical Activity Questionnaire long form [27]. Participants were recruited via advertisements in gyms, parks and Universities, between June and November 2014. The study was approved by the Local Ethics Committee and each participant gave written informed consent prior to participation.

Diagnosis of PFP was completed following consensus from two experienced clinicians (>5 years of experience) and based on definitions used in previous studies [28–30]. The inclusion criteria were: (1) anterior knee pain during at least two of the following activities: prolonged sitting, squatting, kneeling, running, climbing stairs, and jumping; (2) pain during patellar palpation; (3) symptoms of insidious onset and duration of at least one month; and (4) worst pain level in the previous month at least three centimeters on a 10 cm visual analogue scale (VAS). Participants were required to fulfill all four requirements to be included in the PFPG. Subjects allocated in the CG could not present any signs or symptoms of PFP or other musculoskeletal impairments as well as no previous history of lower limb injuries. The presence of the following conditions were carefully screened: events of patellar subluxation, lower limb inflammatory process, patellar tendon tears, meniscus tears, bursitis, ligament tears or the presence of neurological diseases. Those who had undergone knee surgery, received oral steroids, acupuncture or physiotherapy during the preceding six months were excluded from this study.

2.2. Kinematic analysis

Data collection included lower limb kinematic evaluation of each participant's symptomatic limb (unilateral symptoms) or most symptomatic limb (bilateral symptoms) during stair ascent. The dominant leg was evaluated in the CG. Motion analysis was collected using a three-dimensional motion analysis system (Vicon Motion Systems Inc.; Denver EUA) combined with four cameras (type Bonita®B10). Data were recorded with a sampling rate of 100 Hz and a resolution of one megapixel. Kinematic analysis was performed using the Oxford Foot Model (OFM) combined with plug-in gait (PIG-SACR), which was previously reported as a valid and reliable method [8,21,31]. Retroreflective markers (9.5 mm) were placed on specific anatomical landmarks by the same investigator, in accordance with the models specifications. The anatomical landmarks are described in detail in Appendix A.

2.3. Dynamic postural stability analysis

Center of pressure data were obtained using a force plate (AMTI, OR6, Watertown, MA, USA). The COP signals were sampled at 2000 Hz. According to Rhea et al. [32], the inherent instability of upright posture requires anterior–posterior (AP) and medial-lateral (ML) sway

Table 1
Characteristics of the participants included in both groups.

Variable	Control group	PFP	p-Value
	Mean (SD)	Mean (SD)	
Age	22.27 (3.52)	21.81 (2.69)	0.487
Mass (kg)	63.45 (6.31)	65.02 (9.06)	0.158
Height (m)	1.65 (0.04)	1.65 (0.06)	0.789
Cadence (steps/min)	81.03(6.27)	76.89(6.02)	0.191
Physical activity (MET min·week^{-1})	4029.53 (595.32)	4432.71 (437.02)	0.742
Worst pain level in the previous month (VAS)	0.00 (0.00)	5.78 (1.99)	0.000*
Pain level during stair ascent task (VAS)	0.00 (0.00)	2.02 (1.46)	0.000*

* Statistically significant ($p < 0.05$) values.