KINEMATIC ANALYSIS OF THE KNEE WHEN CLIMBING UP/DOWN STAIRS IN PATELLOFEMORAL INSTABILITY

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ABSTRACT

Objective: To analyze and to identify possible gait adaptations by individuals with objective patellofemoral instability when climbing up/down stairs. *Methods*: A control group (group A) composed by nine women with mean age = 25 years (±1.87), height = 1.62 m (±0.05) and weight = 56.20 kg (±7.34), and; nine women with objective patellofemoral instability (group B) with mean age = 24 years (±6.02), height = 1.62 m (±0.06) and weight = 60.33 kg (±10.31) were analyzed. The groups underwent kinematic analysis while climbing up/down stairs, in a previously determined area. Images were obtained by six cameras (*Qualysis*) and data analysis utilized the *Q gait* software program. *Results*: Group B presented, in the support phase, less knee flexion when climbing up (p = 0.0268), and lower speed (p = 0.0076/ p =0.0243) and pace (p = 0.0027/ p = 0.0165) when climbing up and down stairs, respectively. *Conclusion*: It is suggested that group B used functional changes such as reduced knee flexion, speed and pace when climbing up and down stairs.

Keywords: *Knee. Joint instability. Biomechanics.*

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INTRODUCTION

Patellofemoral pain syndrome (PFPS) is one of the most common disorders of the knee, accounting for one fourth of the diagnoses found in orthopaedic practice.[1,2]

An abnormal or misaligned patellar position is a frequent morphologic finding in this condition.[3] Mid-lateral patellar malpositioning, occurring in cases of lateral patellar dislocation, lateral retinacular tension, or retinacular and medial muscular structures failure, may result in a higher concentration of the load on lateral facette. Increased load associated to a small contact area enhances stress as compared to a normal situation.[4]

According to Witvrouw et al.[5] and Thomeé et al[6], patellofemoral pain (PFP) is also a symptom presented by most of the individuals. This is located at medial or lateral regions of the patellofemoral joint (PFJ), and may be caused or enhanced by flexing and extending the knee under load, occurring in daily life activities such as climbing up stairs, squatting, and riding a bicycle. Remaining for prolonged time with knees flexed, in severe cases, can produce discomfort and become unbearable.

Clinically, individuals with PFP complain of gait restrictions, particularly in slopes and when climbing up and down stairs. The discomfort present in these activities results in gait changes in an attempt to reduce pain and the forces on PFJ.[7]

For Magee[8], a musculoskeletal dysfunction tends to cause changes on gait as a result of pain, muscle weakness and/ or modifications on the range of motion. Many individuals, provided they have normal sensitivity and are able to develop a selective control, are able to immediately adjust to these changes, offsetting the deficits caused by the muscles involved.

In a study conducted by Salsich et al.[9], the authors investigated kinetic and kinematic parameters of individuals with PFP when climbing up/ down stairs. They concluded that the same trend was noticed for climbing up and down stairs in both studied groups, only differing for knee extension timing, where the group with the disease achieved a lower value, as compared to the control group. Crossley et al.[10] found a changed kinematics, where individuals with PFP showed lower knee flexion angle both when climbing up and down stairs.

Therefore, the present study was designed to assess and identify potential adaptations of individuals diagnosed with objective patellofemoral instability, when climbing up and down stairs.

MATERIALS AND METHODS

Subjects

Two groups of female subjects submitted to gait analysis at free speed have been assessed. One group was composed by 9 individuals with objective patellofemoral instability, with injuries duration

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between 1 and 6 years, selected by the Orthopaedics Service of a University Hospital. The mean age of the subjects was 24.00 (±6.02) years, mean height 1.62 (±0.06) m and mean weight of 60.33 (±10.31) kg. The other group was constituted of 9 individuals with no joint change, with mean age of 25.00 (±1.87) years, mean height 1.62 (±0.05) m, and mean weight of 56.20 (±7.34) kg.

The exclusion criteria were the following: presence or apparent evidence of locomotive disorder, such as spine displacements, differences on lower limbs' length, or prosthesis use. This study was approved and authorized by the Committee of Ethics in Research of UNICAMP Medical Sciences School. For this, all subjects signed a "Free and Informed Consent Term", stating their willingness to take part of the research.

Equipment and procedures

Seven reflexive markers were unilaterally fixated at anatomical sites such as: trochanter, 1 cm above the patella, knee interline, anterior tibial tuberosity, lateral malleolum, calcaneus and between the II and III metatarsal. (Figure 1) After the markers were fixated, the individuals were asked to climb up and down, foot after foot, a staircase composed by three steps, 19 cm high each. (Figure 2) Two positive attempts (those in which the subject stepped on the platform without increasing or reducing the length of the step) were selected and assessed. Collected data concerned the affected limb on group I and the right limb on group II.

For collecting kinematic data (knee angle) and the space-time data, the movement capture system (Qualysis) with six cameras operating at a frequency of 240 Hz was used.

Figure 1 – *Reflexive markers' positions*

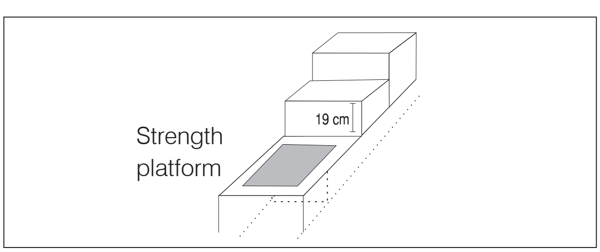

Figure 2 – *Schematic illustration of the staircase and the location of the strength platform*

Data analysis

Following data collection, these were analyzed with the *Q gait* software, thus obtaining the peak knee flexion on support, as well as values for speed and pace, both when climbing up and down stairs.

Statistical analysis

In order to identify differences on analyzed data between both groups, the Student's t-test was used, and the significance level adopted was $p < 0.05$.

RESULTS

Group B subjects showed lower knee flexion during the support period when compared to group A. However, a significant difference was found only when climbing up (group B peak = 53.52°±4.06 vs. group A peak=58.43°±5.80, p=0.0268). When climbing down, group B also presented a lower knee flexion degree as compared to group A, but the difference was not significant (group B peak = 25.33°±6.14 vs. group B peak= 28.36°±2.72, p=0.1011). (Figures 3 and 4)

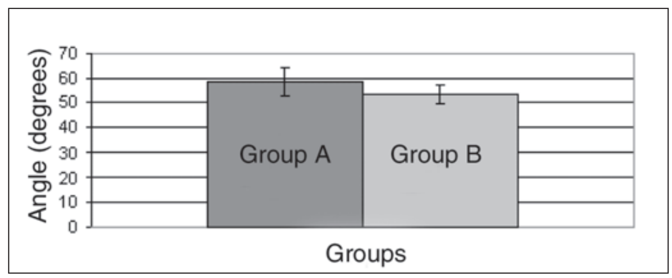

Figure 3 – *Knee flexion angles when climbing up stairs*

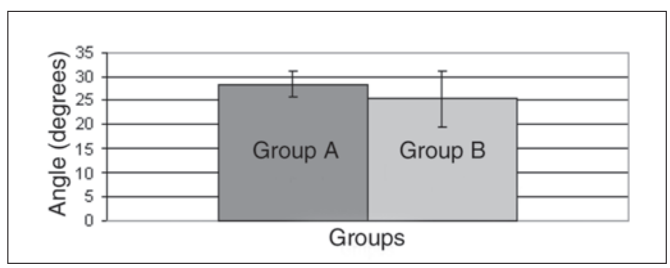

Figure 4 – *Knee flexion angles when climbing down stairs*

In parallel, a significant reduction was identified for speed (climbing up: 0.56m/s±0.08 vs. 0.65m/s±0.05, p=0.0076; climbing down: 0.61m/s±0.12 vs. 0.71m/s±0.08, p=0.0243) and for pace (up: 62.11steps/min±9.80 vs. 74.44steps/min±6.00, p=0.0027; down: 67.94steps/min±12.78 vs. 80.22 steps/min±9.27, p=0.0165) in group B when compared to control group. (Figures 5 and 6)

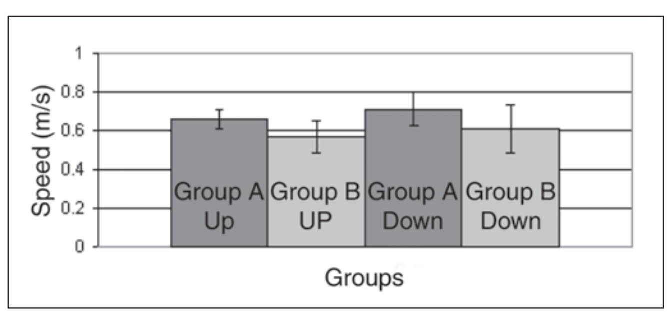

Figure 5 – *Speed when climbing up and down stairs*

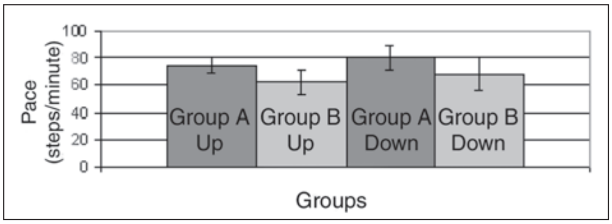

Figure 6 – *Pace when climbing up and down stairs*

DISCUSSION

Patellofemoral instability (PFI) is a disease whose clinical onset course with pain, muscle weakness, and, consequently, gait function loss.[11] One of the most common activities of daily life is to climb up/ down stairs. There are several ways to carry this task out, but the most used method is the "foot after foot" one, where the limbs move in a cyclic pattern, similar to plain gait.[12]

The analysis of gait pattern by means of phases better identifies the functional importance of the various movements occurring on individual joints. In addition, gait phases provide a mean to correlate simultaneous actions of the individual joints with total limb function. By this approach, the functional effects of inability can be interpreted.[13]

According to Crossley et al.[10] although there are some studies examining knee joint movement when climbing up/ down stairs, these are not conclusive, with the assumption that a restrained knee flexion during the support phase can be a consistent adaptation for individuals with patellofemoral pain remaining obscure.

In the present study, we found a reduced knee flexion during the support phase in the group with objective patellofemoral instability, both climbing up and down stairs. However, the difference was statistically significant just when climbing up, consistently with the study by Protopapadaki et al.[14] where the authors concluded that the task of climbing up stairs for healthy individuals is more biomechanically demanding than climbing down. Similar findings were reported on the study conducted by Crossley et al.[10], although they have found significant changes at the knee flexion angle at initial contact and at the mid support (support phase) when climbing up and down stairs.

Oppositely, Salsich et al.[9] didn't find significant changes on lower limbs' kinematics (hip, knee and ankle) of individuals with PFP, while climbing up/down stairs. Bretcher and Powers[15] did not find significant changes on angle displacements measured on knee joint when climbing up/ down stairs, as well, between individuals with PFP and control group. The difference on findings may have occurred especially due to the fact that the subjects in this study have a more severe clinical picture, with the presence of at least one episode of dislocation in all cases.

Additionally to knee flexion angle, space-time parameters were assessed, such as speed and pace, where a significant reduction in both variables was found (on group B), both when climbing up and down. Consistently with these findings, Bretcher and Powers[15] have also found significant differences in terms of pace, where the group with PFP presented a lower value when compared to control group. Salsich et al.[9] found slower pace in individuals with PFP, but with a statistically significant difference only when climbing down, while Crossley et al.[10] did not find differences on space-time parameters. Some authors[9,15] hypothesized that the trend to a slow speed and pace influenced the knee joint motion, in addition to the PFJ response strength, suggesting that these offsetting strategies were employed with the objective of keeping normal levels of joint stress when climbing up and down stairs.

In the current study, the reduced speed and pace in individuals with patellofemoral instability was probably not a sufficient adaptation to reduce pain and tension on their PFJs, thus inducing them to reduce knee flexion angle as well.

Individuals with PFP can use a number of strategies, such as kinematic modifications on the hip and ankle[16], reduced gait speed[7] and changed neuromotor control[9], in order to minimize response strengths and pain on the PFJ. For Rose and Gamble[17] gait speed influences muscular demand, i.e., the higher the speed, the higher the demand of decelerating muscles. Conversely, with a slower gait, within a limited range, the required muscle activity intensity can be reduced.

Although the present study has detected significant changes on knee kinematics of individuals with patellofemoral instability, maybe the use of a larger group of individuals is necessary in order to better characterize their gait pattern and extend it to the population with the same disease characteristics and features.

CONCLUSION

Gait analysis of individuals with objective patellofemoral instability when climbing up and down stairs evidenced kinematic changes on the knee. Group B featured a lower knee flexion angle during the support phase when climbing up stairs. In parallel, this group showed a reduced speed and pace when climbing up and down stairs. These findings suggest the use of adjusting strategies by the group with patellofemoral instability when climbing up and down stairs. From a biomechanical point of view, the reduced knee flexion, pace and speed can enable a reduced stress on patellofemoral joint and of pain, as a result.

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