Gender Differences in Lower Limb Kinematics During Stair Descent

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The purpose of this study was to compare lower limb kinematics between genders during stair descent. Fifteen females and fifteen males who were healthy and active were included in this study. The lower limb kinematics (pelvis, femur and knee) in the coronal and transversal planes were assessed during stair descent at 30°, 40°, 50° and 60° of knee flexion. The study found that females showed greater knee medial rotation for all the knee flexion angles (P = .02–.001), greater femoral adduction (P = .01 for all variables), with exception for 30° (P = .13), and greater femoral lateral rotation at 60° (P = .04). Females also showed a trend to have greater knee valgus at all the knee flexion angles (P = .06–.11) as well as less contralateral pelvis elevation at 50° and 60° (P = .10 and .12, respectively). This study showed that females carry out the stair descent with a lower limb alignment that might predispose them to develop overuse knee injuries, such as the iliotibial band syndrome and patellofemoral pain syndrome. Further prospective investigations should be carried out to verify whether these variables are factors that could predict these knee injuries.

Keywords: stair descent, hip, iliotibial band syndrome, knee, patellofemoral pain syndrome

It has been reported that females are more likely to sustain overuse knee injuries such as the iliotibial band syndrome (ITBS) and patellofemoral pain syndrome (PFPS) than their male counterparts.1 Some factors (anatomical, hormonal and biomechanical) have been investigated in an attempt to clarify why females are more prone to such injuries. Recently, studies have focused on gender differences in lower limb biomechanics during functional activities in the belief that females could show unique movement characteristics that might play an important role in the greater incidence of knee injuries.2

In general, it has been observed that females carry out functional activities with greater hip adduction3,4 and medial rotation,5,6 as well as greater knee valgus and medial rotation than males. This typical lower limb alignment has been related to weakness of the hip abductor and lateral rotator muscles,3,10 and it has been argued that such a lower limb alignment would increase iliotibial band and patellofemoral joint stress.2 Thus it is critical for clinicians engaged in preventing and treating overuse knee injuries to quickly and easily identify this lower limb movement pattern that should be corrected to minimize stress on the knee joint.

The lower limb movement pattern cited above has been observed in females during several weight-bearing tasks such as the single-leg squat,3,4 drop landing,9,11 side-cutting maneuvers12 and running.5,6 However, there are no data regarding gender differences in the lower limb biomechanics during the stair descent. Only one study compared the genders with respect to lower extremity movement during a similar functional task.13 It was verified that females showed greater hip adduction and knee valgus than males during the step-down task.

The stair descent is a weight-bearing activity carried out daily by people in general. During the single-leg stance of this activity, the hip abductor and lateral rotator muscles are challenged to stabilize the pelvis and hip joint in the coronal and transversal planes.14 Since this activity is not very complex, almost all healthy people are able to perform it, whereas landing and cutting maneuvers are carried out mainly by athletes. In addition, clinicians may prefer to choose this task because it is slower and occurs in a more controlled fashion than other functional tasks. Finally, this task seems to be clinically useful due to the common complaint of pain during stair walking reported by patients with PFPS.15–17

Knowledge of the lower limb biomechanical features of both genders during the stair descent would provide benchmark data for males and females to identify the spectrum of what is “normal” as defined by symptom-free subjects. Therefore, the purpose of this study was to compare lower limb kinematics between genders during the stair descent. It was hypothesized that females, when compared with males, would exhibit greater femoral adduction and medial rotation, contralateral pelvic depression, and knee valgus and...
medial rotation during the stance phase of the stair descent.

**Methods**

This cross-sectional study included 15 females (mean ± SD: age, 20.7 ± 1.7 y; height, 1.6 ± 0.1 m; body mass, 57.7 ± 10.6 kg) and 15 males (mean ± SD: age, 21.8 ± 2.9 years; height, 1.8 ± 0.1 m; body mass, 75.5 ± 9.3 kg) who were active (anyone carrying out aerobic or athletic activities at least 3 times per week) but not athletes. Anyone with a current injury or previous surgery to the lower limb, or who had cardiovascular, pulmonary, neurological or systemic conditions that limited physical activity, were excluded from the study. Before participation, all subjects signed an informed consent form approved by the Institutional Review Board of the University.

**Procedures**

After the physical evaluation, a kinematic assessment of the dominant lower limb (determined by asking which leg was used to kick a ball as far as possible) was carried out during the stair descent task. The trials were recorded using four digital cameras (Panasonic NV–GS180, Matsushita Group, Japan) adjusted to the acquisition frequency of 60 Hz and positioned so they could capture all the passive markers. For the calibration procedure, an object with dimensions of 1 m × 1.8 m × 0.8 m was filmed in the area where the subjects would carry out the task. This object had 24 control points with known absolute positions in relation to the Cartesian coordinate system. The global reference system was then defined with this calibrated object, in which the Y axis was oriented upwards, the X axis was oriented anteriorly and the Z axis oriented to the right of the subjects.

In each evaluation, nine passive reflective markers (10 mm in diameter) were positioned by the same researcher at the following anatomical landmarks: both anterior superior iliac spines, first sacral vertebra, prominence of the greater trochanter of the femur, lateral and medial epicondyle of the femur, head of the fibula, and the lateral and medial malleolus. This marker distribution was necessary to determine the hip and knee alignment during the stair descent. The raw marker coordinates were tracked using the software Dvideow (Digital Video for Biomechanics for Windows 32 bits), which uses the direct linear transformation (DLT) method for 3D representation.

During the test, the subjects were instructed to go to the top of a 3-step wooden staircase (height, depth and width of each step = 20.5, 27.5 and 60 cm, respectively) and stand on it with their arms crossed in front of the thorax. This static standing trial was registered and used to determine the anatomical position of the dominant hip and knee in the coronal and transversal planes, with subsequent measurements referenced to this position. Standing in bipedal support on the top step, the subjects were asked to descend one step, initiating the movement with the non-dominant limb (dominant limb in support) and finishing the movement with the dominant limb. The execution time of the task was standardized at 3.0 ± 0.3 s, controlled by a progressive digital stopwatch (Timex marathon, Timex Group USA Inc, Middlebury, CT, USA).

A slow velocity was chosen to challenge the lower limb movement control. Each subject completed 3 attempts for familiarization and 5 acceptable trials for the data analysis. If any of the evaluation requirements was not completed, the attempt was invalidated and a new one carried out. The averages of the dominant limb kinematic values obtained during the stance phase (defined as the period where the body weight was only supported by the dominant lower limb) from the 5 acceptable trials were used in the statistical analyses. Only the stance phase of the task was considered because we were interested in challenging the main hip muscles responsible by stabilizing this joint in the coronal and transversal planes during stair descent.

After recording the 3D coordinates for each marker, the data were submitted to the software Matlab (Mathworks Inc., Natick, MA, USA) and analyzed using a low-pass 4th-order Butterworth filter with a 5 Hz cutoff frequency. The local coordinate systems of the pelvis, femur and leg were then defined and algorithms created to quantify the joint angles. The knee joint angles were calculated with the mathematical convention of Euler angles, using the coordinate system of the distal segment relative to the coordinate system of the proximal segment. Since the authors believe that isolated movements of the pelvis and femur are capable of altering the load on the patellofemoral joint and iliotibial band, the movement of these segments (femur and pelvis) were calculated relative to themselves. For this purpose, the local coordinate systems of the pelvis and femur were defined in the static standing trial, and the relative angles (in relation to the initial orientation) calculated for the subsequent time instants.

The kinematic variables studied were as follows: contralateral pelvis elevation/depression and posterior/ anterior rotation; femoral adduction/abduction and medial/lateral rotation; and knee varus/valgus and medial/lateral rotation. These variables represented the movements which were calculated by subtraction of the values acquired when the knee was at 30°, 40°, 50°, and 60° of flexion, from that recorded in the static standing position. By convention, positive kinematic values represented the contralateral pelvis elevation, contralateral pelvis posterior rotation, femoral adduction, femoral medial rotation, knee varus and knee medial rotation. The experimental error was verified using a specific test described elsewhere. In this study the experimental error was 2.8 mm.

**Data Analysis**

All statistical analyses were performed using the Statistica software (version 7.0, StatSoft Inc, Tulsa, OK, USA). Descriptive values (means, standard deviations) for each variable were first obtained. The data were analyzed as appropriate based on their statistical distribution and variance homogeneity according to the Shapiro–Wilk W and
Levene tests, respectively. With respect to the parametric data, the Student \( t \) test for independent samples was used to verify gender differences at each knee flexion angle. Nonparametric analyses were performed for knee varus/valgus at 50° of knee flexion, knee medial/lateral rotation at 40° of knee flexion, femoral adduction/abduction at 30° and 40° of knee flexion using the Mann-Whitney \( U \) test. Effect sizes (Cohen \( d \)) were calculated to determine the meaningfulness of any differences.

Results

Females showed greater knee medial rotation than males \((P = .02–.001; \text{Cohen } d = 0.89–1.32)\) and a trend for greater knee valgus \((P = .06–.11; \text{Cohen } d = 0.61–0.73)\) for all the knee flexion angles evaluated (Figure 1). Females also showed greater femoral adduction than males for all the knee flexion angles \((P = .01 \text{ for all variables}; \text{Cohen } d = 0.97–1)\), with exception for 30° \(P = \)

![Figure 1](https://example.com/figure1.png)

Figure 1 — Knee kinematics profiles of women (dashed line) and men (solid line) during the stair descent task. *Significant difference, \( P < .05 \).
.13; Cohen $d = 0.70$; Figure 2). Females also had greater femoral lateral rotation at 60° of knee flexion ($P = .04$; Cohen $d = 0.81$) and a trend for greater femoral lateral rotation in the other angles of knee flexion ($P = .06–.10$; Cohen $d = 0.61–0.73$; Figure 2). Finally, females showed a trend for smaller contralateral pelvis elevation at 50° and 60° of knee flexion ($P = .10$ and .12, respectively; Cohen $d = 0.64$ and 0.6, respectively; Figure 3). There were no differences between gender for contralateral pelvis posterior/anterior rotation ($P = .53–.99$; Cohen $d = 0–0.24$) and elevation/depression at 30° and 40° of knee flexion ($P = .33$ and .20, respectively; Cohen $d = 0.37$ and 0.49, respectively; Figure 3).

**Discussion**

It has been argued that gender differences in lower limb kinematics might play an important role in the greater incidence of overuse knee injuries in females.$^{3,4,6}$

*Figure 2* — Femur kinematics profiles of women (dashed line) and men (solid line) during the stair descent task. *Significant difference, $P < .05$. 
Therefore it is critical for the physiotherapist to recognize lower limb movement patterns that could predispose the subjects to knee disorders to plan efficient clinical strategies as quickly as possible. The stair descent is a fairly common activity carried out routinely by people in general. Although the slow stair descent cadence chosen in the current article is not typical of people in general and may not reflect usual movement patterns, we believe that at this cadence the hip muscles responsible for stabilizing this joint are more challenged to control the movement of the femur. However, to the best of the authors’ knowledge, there are no data regarding the influence of gender on lower limb kinematics during this activity. Thus the aim of this study was to verify whether females showed different lower limb kinematics during the stair descent when compared with males. The current results supported the original hypothesis that females would show greater femoral adduction and knee medial rotation than males throughout a range of knee flexion angles. Moreover, greater knee valgus and femoral lateral rotation were

Figure 3 — Pelvis kinematics profiles of women (dashed line) and men (solid line) during the stair descent task.
also observed in females, although these differences were not significant (only for femoral lateral rotation at 60° of knee flexion).

The present results regarding knee kinematics are in agreement with several studies which evaluated more complex functional activities. Greater knee medial rotation was observed in females during the flight phase of the vertical-stop jump9 and during the single limb drop landing.9 Moreover, greater knee valgus was shown in females during the single leg squat,3 drop landing11 and cutting maneuvers.12 It has been suggested that increasing knee medial rotation could increase the strain on the iliotibial band. Fairclough et al24 showed that the iliotibial band compresses into the lateral femoral condyle with landing.9 Moreover, greater knee valgus was shown in iliotibial band. Fairclough et al24 showed that the iliotibial band strain is supposed to increase with the higher incidence of ITBS and PFPS which has been observed in women.1

It was also verified that females carried out the stair descent with greater femoral adduction throughout a range of knee angles and with a trend toward smaller contralateral pelvis elevation at 60° and 50° of knee flexion. Greater femoral adduction in females was also verified in several studies during more complex functional activities.3,6,28 Iliotibial band strain is supposed to increase with hip adduction due to the proximal attachments at the pelvis and the distal attachments at the lateral femoral condyle.2 Thus, the knee movement pattern observed in females throughout a range of knee flexion angles of stair descent may be related with the higher incidence of ITBS and PFPS which has been observed in women.1

Although women only showed significantly greater femoral lateral rotation at 60° of knee flexion, they showed a trend for greater femoral lateral rotation at all knee flexion angles evaluated. Conflicting findings have been reported for the dynamic lower limb movement pattern in females in the transversal plane. Several studies have shown greater femoral medial rotation in females during more demanding activities such as running,3,6 landing from a jump,23 and cutting maneuvers.34 On the other hand, Baldon et al3 and Zeller et al4 verified greater femoral lateral rotation in females during the single leg squat. To minimize the effects caused by greater femoral adduction and knee valgus, it is possible that during slower activities females might carry out greater femoral lateral rotation as a compensation mechanism to avoid larger Q-angles.3 However, increased femoral lateral rotation associated with greater knee medial rotation has been seen in subjects with ITBS.26 As discussed above, this misalignment could increase strain on the iliotibial band and contribute to the development of ITBS.

Only one study comparing lower limb kinematics between genders in stair activities was found. Earl et al13 verified that females showed greater knee valgus and medial rotation as well as greater hip adduction during the step-down task. However, no difference between genders was observed in the hip transversal plane. It is important to emphasize that during the step-down task the subjects are oriented to stand on the lower limb under evaluation, and lower the contralateral foot to lightly touch the floor with the heel, before returning to the starting position. On the other hand, during the stair descent carried out in the current study, the subjects were oriented to stand in bipedal support on the top step of the stair, and then descend one step slowly, initiating the movement with the non-evaluated limb and finishing the movement with the dominant limb in the next step. Thus, the present results reveal that in comparison with the literature there are no apparent differences in the lower limb kinematics between the step-down task and the stair descent.

The authors recognize there were some limitations in this study. Firstly, the sample used in this study consisted only of healthy active subjects. Thus, the results cannot be extrapolated to people with knee disorders. Secondly, the small sample size may have contributed to the absence of significant differences in some variables, so the presence of type II error should not be ruled out. However, the moderate effect sizes indicated that the differences between genders for these variables were meaningful. Thirdly, the slow velocity of the task is not at all reflective of the natural descent condition and may have reflected a movement pattern that would not exist if the natural speed was adopted. Thus, caution is needed to generalize the current results for all descent stair cadencies. Finally, there is an inherent inaccuracy in carrying out motion measurements in the transversal plane with anatomical passive reflective markers, mainly due to the excessive movement of the skin. However, we believe this problem was minimized since most reflective markers were positioned at bone structures where skin movement was small. Thus, future studies should be addressed to an attempt to confirm the present results.

The main findings of the current study indicate that females carry out the stair descent with greater knee medial rotation and femoral adduction than males. Moreover, greater knee valgus and femoral lateral rotation as well as smaller contralateral pelvis elevation were also
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observed in females. The findings of this study identified gender differences that are reflective of patterns observed in women who experience ITBS and PFPS although a direct comparison is required to affirm the nature of the relationship.

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References


