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Hip, knee, ankle kinematics and kinetics during stair ascent and descent in healthy young individuals

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Abstract

Background. Few studies have reported the biomechanical aspects of stair climbing for this ergonomically demanding task. The purpose of this ethically approved study was to identify normal functional parameters of the lower limb during stair climbing and to compare the actions of stair ascent and descent in young healthy individuals.

Methods. Thirty-three young healthy subjects, (16 M, 17 F, range 18–39 years) participated in the study. The laboratory staircase consisted of four steps (rise height 18 cm, tread length 28.5 cm). Kinematic data were recorded using 3D motion analysis system. Temporal gait cycle data and ground reaction forces were recorded using a force platform. Kinetic data were standardized to body mass and height.

Findings. Paired-samples t tests showed significantly greater hip and knee angles (mean difference standard deviation (SD): hip 28.10° (SD 4.08), knee 3.39° (SD 7.20)) and hip and knee moments (hip 0.25 N m/kg (SD 0.18), knee 0.17 N m/kg (SD 0.15)) during stair ascent compared to descent. Significantly greater ankle dorsiflexion angles (9.90° (SD 3.80)) and plantarflexion angles (8.78° (SD 4.80)) were found during stair descent compared to ascent. Coefficient of variation (mean (SD)) in percentage between repeated tests varied for joint angles and moments, respectively (2.35% (SD 1.83)–17.53% (SD 13.62)) and (4.65% (SD 2.99)–40.73% (SD 24.77)).

Interpretation. Stair ascent was shown to be the more demanding biomechanical task when compared to stair descent for healthy young subjects. The findings from the current study provide baseline measures for pathological studies, theoretical joint modelling, and for mechanical joint simulators.

Keywords: Stair climbing; Motion analysis; Kinematics; Kinetics

1. Introduction

Stair climbing is a common activity of daily life. Kinematic and kinetic studies have shown that, in comparison to level walking, larger ranges of knee flexion angle and knee flexion moment are required during stair climbing (Andriacchi et al., 1980; Jevsevar et al., 1993). Andriacchi et al. (1980) found the maximum external knee flexion moment during stair ascent to be three times greater than level walking and maximum hip flexion moments during stair descent to be a maximum of 1.5 times greater than level walking. Jevsevar et al. (1993) found an average of 98.6° (SD 6.5°) of knee flexion was required to ascend stairs, 90.3° (SD 4.9°) of knee flexion to descend stairs and 64.6° (SD 6.7°) of knee flexion to walk on level ground. Analysis of the biomechanical requirements involved in stair climbing can add to our understanding of the diverse demands of this common activity in human locomotion.

In comparison to level walking, only a small number of studies have investigated normal human stair ascent and

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descent (Andriacchi et al., 1980; Costigan et al., 2002; Kowalk et al., 1996; Livingston et al., 1991; McFadyen and Winter, 1988; Riener et al., 2002). Researchers have also used stair climbing to describe changes in a patient's functional performance following knee arthroplasty (Andriacchi et al., 1982; Andriacchi and Galante, 1988), anterior cruciate ligament deficiency (Berchuck et al., 1990; Andriacchi and Birac, 1993) transtibial amputations (Powers et al., 1997) and patellofemoral pain (Salsich et al., 2001; Brechter and Powers, 2002). Understanding the biomechanics and pathomechanics of the lower limb during stair climbing is important for therapists attempting to integrate scientific findings into clinical examination and management of patients with lower extremity dysfunction.

Andriacchi et al. (1980) investigating hip, knee, ankle joint angles and moments in ten young healthy male subjects during stair climbing found maximum external knee flexion moments during stair descent to be 2.7 times greater than during ascent. They used the ground reaction method for the calculation of joint moments. This method involves calculation of joint moment by calculating the product of the ground reaction force vector and the perpendicular distance from the joint center to that vector (Winter, 1991). Wells (1981) found that the ground reaction method is a good predictor of net joint moments for slow gait, but increasing the velocity of gait results in increased errors, especially at the hip. Therefore for healthy populations, the linked segment method is preferable to calculate joint moments; the linked segment method takes into consideration the mass-acceleration products of the foot, leg and thigh, that the ground reaction method neglects (Winter, 1991). McFadyen and Winter (1988) used the linked segment method for the calculation of joint moments during stair climbing. However, the small sample size ($n = 3$) in their study limits the power and usefulness of the results. Kowalk et al. (1996) reported external abduction–adduction moments at the knee joint in young adults ($n = 10$) ranging in age from 22 to 40 years, while Costigan et al. (2002) reported only external hip, knee moments ($n = 35$, mean age = 24.6). Further studies that include larger numbers of subjects and more developed analysis of joint moments are required before definitive conclusions can be made.

Livingston et al. (1991) investigated stair climbing kinematics of the hip, knee, and ankle joints on stairs of differing dimensions. Fifteen young healthy women were divided into short, medium, and tall subject groups with five subjects in each group ranging in age from 19 to 26 years. Subject height appeared to influence knee motion during stair climbing. Short subjects used greater maximum knee flexion angles than taller subjects during stair ascent and descent. Riener et al. (2002) investigating how stair inclination affects the kinematic and kinetic patterns of stair climbing ($n = 10$, mean age = 28.8 years) found joint ranges and maximum flexion angles to increase with increasing inclination of the staircase.

So far, few if any studies have provided a comprehensive set of data on biomechanics of the hip, knee and ankle joint in healthy young subjects during stair-climbing; either the subject populations were small or a limited number of parameters were reported. The purpose of the present study was to identify normal functional parameters in the hip, knee and ankle joints during stair climbing in healthy individuals.

2. Methods

2.1. Subjects

Thirty-three healthy subjects, 16 men and 17 women, ranging in age from 18 to 39 (mean age 28.09 years; standard deviation 6.08) mean height 1.69 m (SD 0.08) and mean mass 67.48 kg (SD 12.12), recruited from the staff and student population of the University of East London participated in this study. Subjects were excluded from the study if they presented with: history of injury to the lower limbs in the previous 6 months, any type of lower extremity surgery, pathology of the back and pelvis, systematic disease, neuromuscular disease, or balance problems. Eleven subjects from the above population, seven men and four women, (range 19–36 years), mean age 27 years (SD 6.62), mean height 1.72 m (SD 0.07) and mean mass 70 kg (SD 10.66) were tested on two separate occasions to test variability of the data recorded. This study was approved by the University of East London Research Ethics Committee and all subjects gave their written informed consent to participate.

2.2. Equipment

The experimental staircase consisted of four steps (step height 18 cm, tread length 28.5 cm). Kinematic and kinetic recordings were collected from an 8-camera, three-dimensional motion analysis system (Vicon M3 camera system, Oxford Metrics Ltd, UK) and force platform (Bertec Model 4020 H, MIE Ltd, Leeds, UK) positioned in the second stair step. Kinematic data were collected at a sampling rate of 120 Hz and ground reaction forces were collected at a rate of 1080 Hz. Both kinematic and kinetic data were recorded simultaneously on a personal computer.

2.3. Subject preparation and procedure

All subjects were barefoot and wore shorts to allow attachment of reflective markers on the skin of the lower limbs. Reflective markers (14 mm spheres) were placed on: second metatarsal head, lateral malleolus, posterior calcaneus at the same level as the second metatarsal marker, lateral surface of tibia, lateral aspects of the knee joint, lateral surface of the thigh below hand swing, and over both anterior and posterior superior iliac spines. To enable calculation of hip, knee, and ankle joint angles and external joint moments, anthropometric measures were obtained including bilateral leg length, knee width, ankle width, height, and body mass. All participants were instructed to ascend and descend the stairs at a self-selected pace, placing only one foot on each step (step-over-step). For each subject, stair climbing testing consisted of one static posture trial, and three ascending and descending trials for both right and left leg, respectively.

2.4. Data management

All stride events were expressed as a percentage of the stride cycle. During stair ascent, a stride cycle was defined as first foot contact on the second step and ended at the same foot contact on the fourth step. During stair descent, the selected stride cycle started with foot contact (of the same foot) on the second step and ended with foot contact (of the same foot) on the floor. Joint moments were calculated using the link-segment method. The moments were normalized to subject body mass and height and were expressed as external moments.

The results were displayed in Vicon polygon software as graphs and visual data. The results were saved in ASCII format and transferred to Excel and SPSS 10.1 for statistical analysis. Key variables included for analysis were: cycle duration, stance phase, velocity, hip/knee/ankle angles, and external hip/knee/ankle moments, during stair ascent and stair descent. Data were expressed as mean and standard deviation (SD) for angles, moments and temporal stride cycle parameters. Three trials were averaged for each subject individually and the mean maximum flexion/extension angles and the mean maximum flexion/extension moments were calculated. These were then averaged to provide the group mean maximum value and SD for angles and moments. Paired-samples t test showed no significant difference ($P = 0.45$) between left and right legs; therefore, right and left leg trials were combined for further analysis. Paired-samples t tests were performed to determine possible significant differences between stair ascent and descent. Statistical significance was defined as $P < 0.05$. Variability of the data for angles and moments in hip knee and ankle joints were tested performing intrasubject coefficients of variation (CV), expressed as a percentage. The average of three trials from the right leg from eleven subjects were analysed during stair ascent and descent. The intrasubject CV was calculated individually; these were then averaged and SD calculated to provide an average CV for angles and moments.

3. Results

3.1. Temporal stride cycle parameters during stair ascent and descent

Cycle duration was greater ($P < 0.0001$) during stair ascent (mean 1.45 s (SD 0.14)) compared to descent (mean 1.32 s (SD 0.13)). Subjects demonstrated minimal differences in stance phase during stair ascent (mean 60.74% of stride cycle (SD 1.72)) compared to descent (mean 60.45% of stride cycle (SD 1.43)). Velocity was less ($P < 0.0001$) during stair ascent (mean 0.49 m/s (SD 0.05)) compared to descent (mean 0.56 m/s (SD 0.06)).

3.2. Angles during stair ascent and descent

Mean (SD) sagittal plane movements of the hip, knee, and ankle joint during stair ascent and descent are illustrated in Fig. 1. During stair ascent in stance phase (from 0% to 60.74% of stride cycle) the hip and knee joints move forwards extension and the ankle joint into plantarflexion while during stair descent in stance phase (from 0% to 60.45% of stride cycle) the hip and knee joints move into flexion and the ankle joint into dorsiflexion (Fig. 1). During stair ascent and descent the maximum hip flexion, knee flexion, and ankle dorsi/plantar flexion angles occurred during swing phase (from 60.74% to 100% of stride cycle for stair ascent and from 60.45% to 100% of stride cycle for stair descent) (Fig. 1).

Table 1 summarises mean maximum angles observed at the hip, knee and ankle joint during stair ascent and descent. Subjects required greater flexion at the hip ($P < 0.0001$), and knee ($P < 0.05$) joint during stair ascent compared to descent but subjects used less dorsiflexion ($P < 0.0001$) and plantar flexion ($P < 0.0001$) at the ankle joint to ascend the stairs compared to descent. Eleven subjects were tested on a second occasion and Table 2 shows the CV of hip, knee and ankle joint angles during stair ascent and descent. Greatest variability was seen in ankle plantar flexion angles during stair ascent.

3.3. Ground reaction forces during stair ascent and descent

Mean (SD) of vertical ground reaction forces during stair ascent and descent are illustrated in Fig. 2. The vertical ground reaction forces produced at the beginning of the stance phase were higher during stair descent than during stair ascent while the ground reaction forces produced at the end of the stance phase were less during stair descent than stair ascent.

3.4. Moments during stair ascent and descent

Mean (SD) sagittal plane moments of the hip, knee, and ankle joint during stair ascent and descent are illustrated in Fig. 3. Table 3 shows mean maximum external moments observed at the hip knee and ankle joint during stair ascent and descent. Subjects demonstrated greater external hip flexion ($P < 0.0001$) and knee extension ($P < 0.0001$) moments during stair ascent compared to descent. Subjects demonstrated minimal differences in external knee flexion moments and external dorsiflexion moments at the ankle joint during stair ascent compared to descent.

The external hip moment was positive during stair ascent and descent for the most of the stance phase (Fig. 3), indicating that the line of action of the ground reaction force was aligned anterior to the hip joint, creating an external hip flexion moment. There was a small period

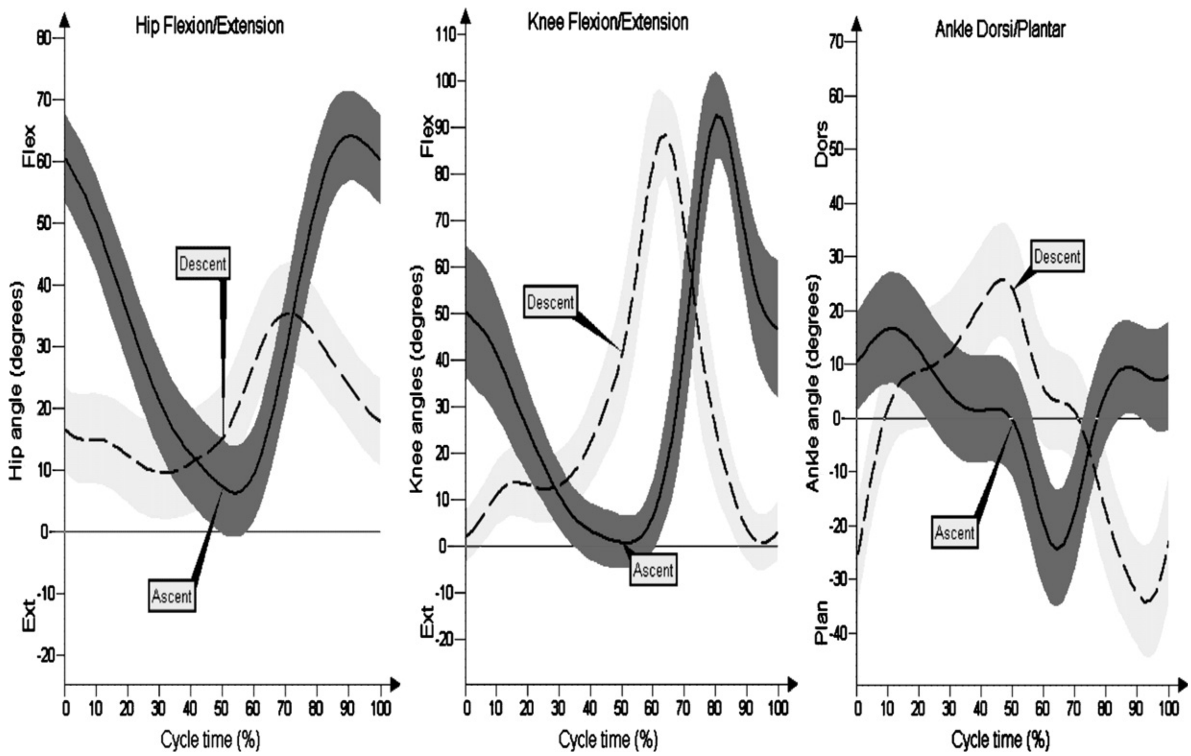

Fig. 1. Mean sagittal plane angles of the hip, knee, and ankle joint during stair ascent and stair descent ($n = 33$). The continued and dashed lines represent the mean during stair ascent and descent, respectively. The dark and pale grey shades represent the SD during stair ascent and descent, respectively.

Table 1
Mean (SD) of maximum hip, knee and ankle angles during stair ascent and descent ($n = 33$)

	Stair ascent	Stair descent
	Joint angles (°)	Joint angles (°)
Hip flexion	65.06 (7.16)	39.96 (7.81)***
Knee flexion	93.92 (7.40)	90.52 (7.11)*
Ankle dorsiflexion	11.21 (3.83)	21.11 (4.47)***
Ankle plantar flexion	31.31 (5.12)	40.08 (5.96)***

* $P < 0.05$.
*** $P < 0.0001$.

Table 2
Coefficients of variation (mean (SD)) in percentage of hip, knee and ankle angles and moments during stair ascent and descent ($n = 11$)

	Stair ascent	Stair descent
	CV	CV
Joint angles		
Hip flexion	2.99 (1.76)	4.30 (3.34)
Knee flexion	2.35 (1.83)	2.90 (2.69)
Ankle dorsiflexion	3.31 (3.53)	4.94 (3.42)
Ankle plantar flexion	17.53 (13.62)	5.77 (4.18)
Joint Moments		
Hip flexion	6.41 (5.01)	23.45 (18.14)
Hip extension	–	40.73 (24.27)
Knee flexion	21.34 (19.64)	13.22 (9.21)
Knee extension	11.51 (9.68)	21.84 (16.73)
Ankle dorsiflexion	4.65 (2.99)	8.65 (7.42)

– indicates no data.

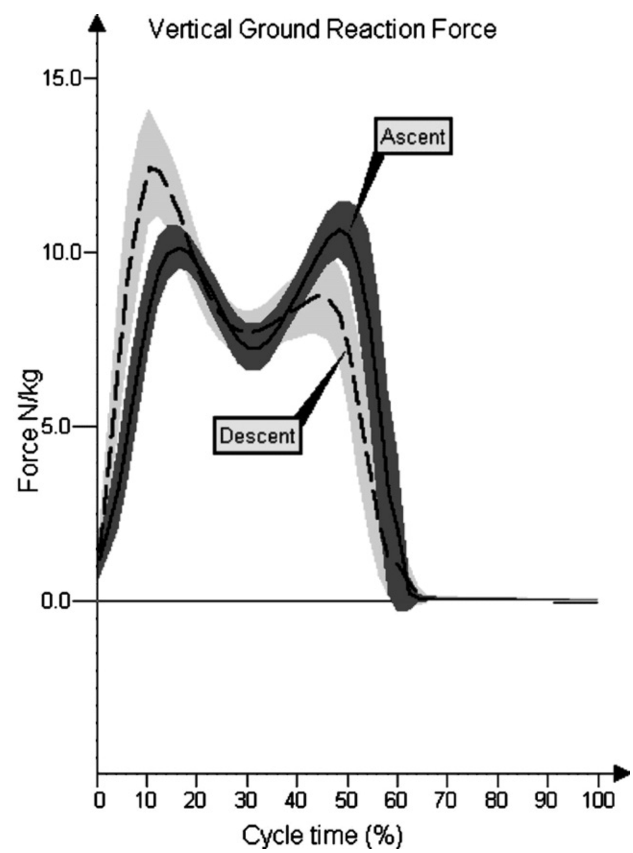

Fig. 2. Mean vertical ground reaction forces during stair ascent and stair descent ($n = 29$). The continued and dashed lines represent the mean during stair ascent and descent, respectively. The dark and pale grey shades represent the SD during stair ascent and descent, respectively.

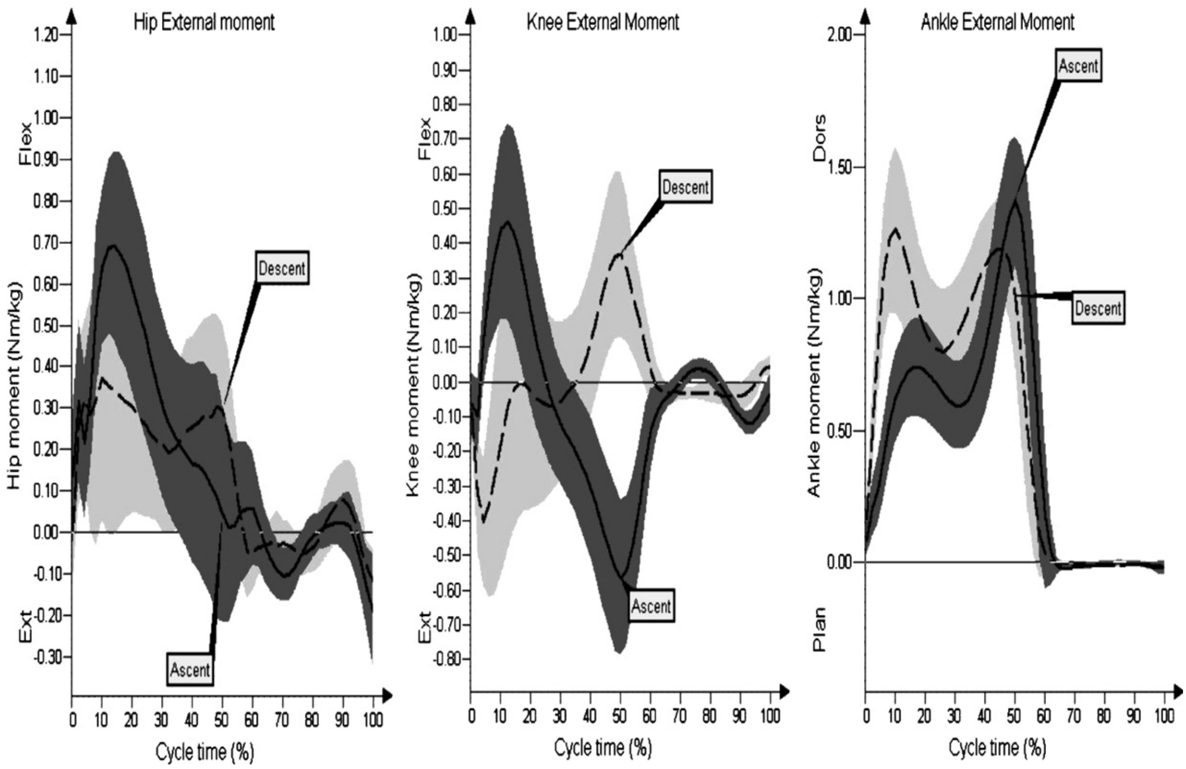

Fig. 3. Mean sagittal plane moments of the hip, knee, and ankle joint during stair ascent and stair descent ($n = 29$). The continued and dashed lines represent the mean during stair ascent and descent, respectively. The dark and pale grey shades represent the SD during stair ascent and descent, respectively.

Table 3
Mean (SD) of maximum external hip, knee and ankle moments during stair ascent and descent ($n = 25$)

	Stair ascent	Stair descent
	Joint moments (N m/kg)	Joint moments (N m/kg)
Hip flexion	0.76 (0.19)	0.52 (0.19)***
Hip extension	–	0.13 (0.11)
Knee flexion	0.51 (0.23)	0.46 (0.22)
Knee extension	0.58 (0.19)	0.40 (0.18)***
Ankle dorsiflexion	1.45 (0.15)	1.38 (0.16)

– indicates no data.
*** $P < 0.0001$.

in stance phase during stair descent (from 58% to 60.45% (toe-off) of stride cycle) that the external hip moment was negative, creating an external hip extension moment.

During stair ascent there was an external knee extension moment from foot contact on the 2nd stair step (0% of stride cycle) to 4% of stride cycle (Fig. 3), an external knee flexion moment from 4% to 26% of stride cycle and an external knee extension moment from 26% to 60.74% (toe-off) of stride cycle. During stair descent there was an external knee extension moment from foot contact on the 2nd stair step (0% of stride cycle) to 36% of stride cycle, (Fig. 3) and an external knee flexion moment from 36% of stride cycle to 60.45% (toe-off) of stride cycle.

The external ankle moment was positive in stance phase during stair ascent and descent (Fig. 3), creating an external dorsiflexion moment.

Eleven subjects were tested on a second occasion and Table 2 shows the CV% of hip, knee, and ankle joint moments during stair ascent and descent. Greatest variability was seen in hip extension moments during stair descent.

4. Discussion

4.1. Temporal stride cycle parameters during stair ascent and descent

In the present study, as in previous stair climbing investigations (Livingston et al., 1991; Riener et al., 2002), cycle duration was lower during stair descent compared to ascent. The mean cycle duration during stair ascent was 1.45 s (SD 0.14) while during descent was 1.32 s (SD 0.13). In the current study, the mean velocity during stair ascent was less (0.49 m/s (SD 0.05)) compared to descent (0.56 m/s (SD 0.06)), which is consistent with an increased cycle duration during stair ascent compared to stair descent. Livingston et al. (1991) also found velocity on an optimal staircase (see Table 4) during stair ascent (mean 0.7 m/s (SD 0.1)) to be less compared with during stair descent (mean 0.8 m/s (SD 0.1)).

Livingston et al. (1991) reported that shorter subjects (mean height 155.9 cm (SD 2.1)) ascended and descended stairs at faster velocities than taller subjects (mean height 171.6 cm (SD 2.1)). Both groups in the Livingston et al. (1991) study moved faster as the step height increased.

Table 4
Staircase dimensions and subject height

		Step height (cm)	Tread depth (cm)	Mean subject height (cm)
Andriacchi et al. (1980)		21	25.5	179
McFadyen and Winter (1988)		22	28	Not reported
Livingston et al. (1991)	Optimal staircase	20.3	30.5	163.5
Livingston et al. (1991)	Steep staircase	20.3	21	163.5
Livingston et al. (1991)	Shallow staircase	12.7	41.9	163.5
Kowalk et al. (1996)		20.3	25.4	174
Costigan et al. (2002)		20	30	170
Riener et al. (2002)	Normal staircase	17	29	179
Riener et al. (2002)	Max staircase	22.5	25	179
Riener et al. (2002)	Min staircase	13.8	31	179
Current Study, (2005)		18	28	168.5

Mean height of subjects in our study was greater than that of the Livingston et al. (1991) study but our step height was lower. These factors may account for the differences in velocity of stair ascent and stair descent reported in this study and other published studies.

4.2. Joint angles during stair ascent and descent

In agreement with results reported by Andriacchi et al. (1980) and Livingston et al. (1991), our subjects required significantly greater hip and knee flexion angles to ascend stairs compared to descent. Similar to findings reported by Andriacchi et al. (1980), the current study showed significantly greater ($P < 0.0001$) dorsiflexion angles during stair ascent compared to descent. However, the plantarflexion angles showed in the current study were much greater than that reported by Andriacchi et al. (1980) and Livingston et al. (1991). Andriacchi et al. (1980) and Livingston et al. (1991) reported mean maximum plantar flexion angles of 25.6° (SD 5.3) and 30° (SD 1.8), respectively, while the present study reported mean maximum plantar flexion angles of 40.08° (SD 5.96). Livingston et al. (1991) reported that during stair ascent short subjects (mean height 155.9 cm (SD 2.1)) used greater mean maximum knee flexion angles (92°–105° than taller subjects (mean height 171.6 cm SD 2.1)) whose angles ranged from 83° to 96°. Different subject height, step dimension, marker placement, and motion analysis devices may be factors for different results among studies.

In the current study, the mean CV of hip, knee, and ankle joint dorsiflexion angles varied from 2.35% (SD 1.83) to 5.77% (SD 4.18) during stair ascent and descent indicating good reliability. The ankle plantar flexion angle during stair ascent was 17.53% (SD 13.62) (Table 2). Three of the eleven subjects who were tested on two separate occasions to test variability of the data recorded showed large variability in ankle plantar flexion angles during stair ascent that ranged from 27.9% to 43% but during stair descent these subjects showed a small amount of variability, under 10%. There is no satisfactory explanation for these differences, although the results indicate that the subjects may have changed the pattern of movement during stair ascent on the second session. Variation in foot contact, that is forefoot contact only or full foot contact, during stair ascent or descent may lead to variability in ankle joint ankles.

4.3. Ground reaction forces during stair ascent and descent

In agreement with the graphs reported by Riener et al. (2002) the vertical ground reaction forces during stair descent were higher than stair ascent (Fig. 2). The magnitude of the vertical ground reaction force changes with variation in gait speed (Nilsson and Thorstensson, 1989). Nilsson and Thorstensson (1989) reported that increased speed was accompanied by higher peak vertical ground reaction forces. The peak amplitude of the vertical ground reaction force in walking and running increased with speed from approximately 1.0–1.5 body weight and 2–2.9 body weight, respectively (Nilsson and Thorstensson, 1989). Greater velocity during stair descent in our study was accompanied with higher vertical ground reaction force in early stance phase compared to stair ascent.

4.4. Joint moments during stair ascent and descent

The external joint moments recorded in our study indicated that action of the hip extensor muscles was required to counter the external hip flexion moment during stair ascent and descent. In knee joint, an interchange in the action of the knee flexor and extensor muscles occurred during stair ascent and descent. In the ankle joint the action of the ankle plantar flexor muscles was required to counter the external ankle dorsiflexion moment during stair ascent and descent.

The present study showed significantly decreased mean maximum external hip flexion moment during stair descent (0.52 N m/kg (SD 0.19)) compared to ascent (0.76 N m/kg (SD 0.19)). We also observed mean maximum external hip extension moment of 0.13 N m/kg (SD 0.11) during stair descent only from 58% to 60.45% (toe-off) of stride cycle. Variability in the hip moment patterns during stair ascent and descent is reported in the literature (Andriacchi et al., 1980; Costigan et al., 2002; McFadyen and Winter, 1988; Riener et al., 2002; Salsich et al., 2001). Similar to our study, Andriacchi et al. (1980) and Costigan et al. (2002) observed external flexor moments during stair ascent and Costigan et al. (2002) reported external hip flexion moment of 0.8 N m/kg (SD 0.12). McFadyen and Winter (1988) and Riener et al. (2002) reported internal hip extensor moment during stair ascent but observed internal hip flexor moment at the end of the stance phase. In contrast, Salsich et al. (2001) reported a short period of internal hip flexor moment at the beginning of stance phase followed by internal hip extensor moment during stair ascent. During stair descent, Riener et al. (2002) reported internal hip flexor moment only during the activity whereas McFadyen and Winter (1988) and Salsich et al. (2001) reported internal hip flexor moment at the beginning of the stance phase, internal hip extensor moment during mid-stance and internal hip flexor moment at the end of the stance phase. Similar to our study, Andriacchi et al. (1980) reported external hip flexor moment during stair descent with a short period of external hip extensor moment at end of the stance phase. The possible reason for the observed variability in hip moment patterns during stair climbing may be the position of the trunk. Subjects may adopt different patterns ascending or descending stairs. Different positions of the trunk may bring the line of the ground reaction force anterior to or behind the hip joint affecting the hip joint moments.

The mean maximum external knee extension moment was significantly decreased during stair descent (0.40 N m/kg (SD 0.18)) compared to ascent (0.58 N m/kg (SD 0.19)). No significant difference was observed in mean maximum external knee flexion moment during stair ascent (0.51 N m/kg (SD 0.23)) compared to descent (0.46 N m/kg (SD 0.22)). For ten subjects with a mean body mass 71 kg Andriacchi et al. (1980) reported a mean knee flexion moment of 146 Nm (SD 48) during stair descent and 54.2 Nm (SD 17.2) during stair ascent. McFadyen and Winter (1988) showed a mean knee flexion moment of 1.50 N m/kg during stair ascent and descent (estimated from their Fig. 1), and Costigan et al. (2002) reported a mean value of 1.16 N m/kg (SD 0.24). Riener et al. (2002) reported maximum external moment values increased with increasing inclination at the knee during both stair ascent and descent. This may be one reason why the present study found reduced peak external knee flexion moments when compared to aforementioned studies. Furthermore different subject height, marker placement, and method of calculation of joint moments may be factors for different results among studies. The current study calculated joint moments by using the linked-segment method. Wells (1981) found different values when comparing moment calculation using the linked-segment method and the ground reaction method. The poverty of other published literature in this area means there is little other evidence with which to compare these values, and emphasizes the need for documentation of normative values.

As in previous stair climbing investigations (McFadyen and Winter, 1988; Salsich et al., 2001) highest external knee moments occurred in the current study while ascending stairs. Conversely, Andriacchi et al. (1980) demonstrated the highest external knee moments occurring in normal subjects during stair descent. As moment is a product of force and its lever arm (Morrison, 1968), it is purported that knee angle will influence moments produced during stride cycle. The present study found mean maximum knee flexion angles (90.52° (SD 7.11)) during stair descent to be less ($P < 0.05$) than during ascent (93.92° (SD 7.40)). As reduced knee flexion angle reduces the lever arm for joint torque, this brings the body centre of mass closer to the knee joint centre (Ernst et al., 1999). This may be a further reason why the present study found subjects had decreased peak external knee flexion and extension moments during stair descent.

Wide intrasubject variability was seen during stair ascent and descent in hip, knee and ankle external moments (see SD in Fig. 3). The mean CV of hip knee, ankle joint moments varied from 4.65% (SD 2.99) to 21.34% (SD 19.64) for stair ascent and from 8.65% (SD 7.42) to 40.73% (SD 24.27) for stair descent (see Table 2). Joint moments produced are depended on position of body mass relative to the vertical axis. It is possible that trunk position may have influenced lower limb moments and will need to be considered in future analysis.

5. Conclusion

This study looked at temporal gait cycle parameters, kinematics, and kinetics of hip, knee, and ankle joints during stair climbing in young healthy individuals. The maximum angles and moments occurred while ascending stairs, a consideration when therapists rehabilitate patients on stairs. The findings of the present study generally agree with the published literature on healthy young individuals. The data of the current study provides important baseline information for physicians and therapists concerned with the surgical and functional rehabilitation of clients with physical limitations and for engineers and prosthetists engaged in establishing criteria for lower limb prosthetics. Further research is needed on a range of populations that include the elderly and pathological groups and consider trunk movement.

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