P01-15 ID50

THE KINETIC ANALYSIS OF THE LOWER EXTREMITY OF NORMAL WEIGHT, OVERWEIGHT & OBESE INDIVIDUALS DURING STAIR ASCENT & DESCENT

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The purpose of this study was to examine whether there is a difference in the joint moment of force between normal weight, overweight and obese participants during stair climbing. In all, 19 normal weight participants, 18 overweight participants, and 8 obese participants were recruited to perform a series of stair ascent and descent. The 3-D kinetic data were collected using 10 cameras and 4 force plates. The peak knee extensor moment was significantly higher (p=0.026) in the overweight than in the normal weight participants during descent. The obese participants also had a higher ankle abductor moment than the normal (p=0.031) and overweight participants (p=0.002) during descent. The findings from the study confirm stair climbing results in higher loading at the knee in obese/overweight individuals, which could be a potential mechanism of osteoarthritis.

KEYWORDS: stair ascent, stair descent, joint moment of force, obesity

INTRODUCTION: Obesity is a growing epidemic not only in United States, but also in other developed countries such as Canada. According to Statistic Canada, 2 out of every 3 adults in Canada are overweight or obese (Statistics Canada, 2006). Individuals with a high BMI may be at risk of developing osteoarthritis due to joint loading, which accelerate the 'wear and tear' of the joints (Griffin & Guilak, 2005). Little, however, is known about the effects that obesity has on the musculoskeletal system during walking and stair-climbing (Wearing et al., 2006; Hills et al., 2002). To the author's knowledge, only one study (Strutzenberger et al., 2011) has examined the joint loading pattern of children during stair ascent and descent. The aged population has a higher risk in developing joint degeneration compared with other subgroups in the normal population. Hence, the purpose of this study was to determine whether there is a difference in the joint moment of force between the normal weight, overweight, and obese participants during stair ascent and descent. Based on the results from Strutzenberger et al. (2011), it is hypothesized that the knee extensor and hip adductor joint moment for the overweight/obese participants will be higher than the non-obese participants when ascending stairs, while their ankle moments in the sagittal and frontal plane will be similar to the normal weight participants.

METHOD: 19 normal weight (BMI: 22.1 kg/m^2), 18 overweight (BMI: 27.4 kg/m^2), and 8 obese participants (BMI: 33.3 kg/m^2) were recruited to perform a series of stair ascent and descent. Those with a BMI of BMI of 18.5 to 24.9 were classified as normal weight, while individuals with a BMI of 25.0 to 29.9 were classified as overweight. And those with a BMI of 30.0-34.9 were classified as obese class I (CDC, 2000). The staircase was comprised of three steps 17.8 cm high and 28 cm deep, with the first and second steps built with portable force plates (Model 9286AA, Kistler Instruments Corp, Winterhur, and Swtz). The participants were free from neuromuscular disorders, musculoskeletal injuries, cardiorespiratory problems, and weight fluctuations. The participants in the study were asked to ascend and descend the staircase for 5 trials. A motion capturing system (Vicon MX-13, Oxford Metrics, Oxford, UK) was used to record the participant's movement at 200 Hz as they performed each trial. There were 10 infrared cameras that captured the 3D trajectories of 43 reflective markers that were placed on the participant's body based on the University of Ottawa Motion Analysis Model (UOMAM). The anatomical landmark for the markers included: the heel, the lateral and medial side of the ankle, the tibia, the lateral and medial side of the knee, the thigh, the anterior iliac spine, the posterior iliac spine, C7 and T10 vertebras, the wrist, the second metacarpal of the

hand, the radius, the elbow, upper arm, shoulder, the posterior side of the head, and the anterior side of the head.
Four Kisler force plates, two were built in the stair case and two were built on the ground, were used to record the ground reaction force. The hip, knee, and ankle joint moments were computed using Polygon and normalized. The stride period were normalized by gait cycle (%). The joint moment for the right hip, knee, and ankle were based on the sagittal plane (x-direction) and frontal plane (y-direction). The ensemble averages of the moment were calculated over a total of 5 trials, and normalized by body mass (kg). Hence, the units for moment were N•m/kg.
A two-way MANOVA analysis was used to determine whether there was a significant interaction between "sex" and "body mass" on the dependent variables. When no significant interaction and main effect of sex were found, the data was pooled for the males and females so a one-way ANOVA analysis and Tukey's Post-hoc test could be performed to further investigate whether there were differences in the masses.

RESULTS: Table 1 provides the participants' physical characteristics information and the significant peak values of the hip, knee, and ankle joint moments during stair climbing. While figure 1 and 2 illustrate the joint moment profiles of the hip and knee in the sagittal plane and the ankle joint moment in the frontal plane that showed significant differences. The MANOVA analysis did not find any significant interaction between mass and sex ($F(34) = 0.594$, $p=0.943$). The MANOVA also indicated body mass had a significant influence on the joint moments ($F(34) = 1.836$, $p=0.026$), irrespective of sex ($F(17)=1.730$, $p=0.110$). During ascent, the obese participants had a significantly larger peak hip flexor moment than the overweight group ($p=0.031$) (Table 1). The peak knee extensor moments were quite similar when all three groups were ascending the stairs (Table 1). The only difference that was noted between the groups was that the peak knee extensor moment was significantly higher in the overweight participants ($p=0.026$) than in the normal weight participant when descending the stairs (Table 1). During descent, the peak ankle abductor moment was significantly larger in the obese participant compared to the normal weight ($p=0.031$) and overweight ($p=0.002$) participants (Table 1).

Table 1 Physical characteristics of the participants and peak values (mean) of the hip, knee, and ankle joint moment of force (N•m/kg)

Participant	Age (year)	BM (kg)	BH (cm)	BMI	Hip Flexor		Knee Extensor		Ankle Abductor	
					Up	Down	Up	Down	Up	Down
Normal M:8; F:11	61.4	59.5	163.8	22.1	0.26	0.26	-0.94	-0.70[a]	-0.14	-0.12
Overweight M:14; F:4	59.7	81.3	172.1	27.4	0.22	0.22	-1.05	-0.98	-0.16	-0.09
Obese M:3; F:5	60.3	93.3	167.6	33.3	0.42[b]	0.27	-0.99	-0.86	-0.20	-0.21[ab]

BM, body mass; BH, body height; M, males; F, females;
[a] $p<0.05$: indicates a significant difference between the normal weight vs. obese group
[b] $p<0.05$: indicates a significant difference between the overweight vs. obese group

DISCUSSION: The hip extensor and flexor moments during stair climbing for this study were consistent with the results from past studies on normal weight individuals. As seen in studies by Riener et al., (2002) and Lin et al., (2002), the hip produced an extensor moment during stance phase in order to lift the body during stair ascent, which later changed to a peak flexor moment during the rest of swing phase. Contrary to this, the hip produced a flexor moment during descent rather than an extensor moment, which is similar to findings by Riener et al., (2002). Both the overweight and normal weight participants in this study had similar peak hip extensor moments during ascent (figure 1) and peak hip flexor moments during descent (figure 2).

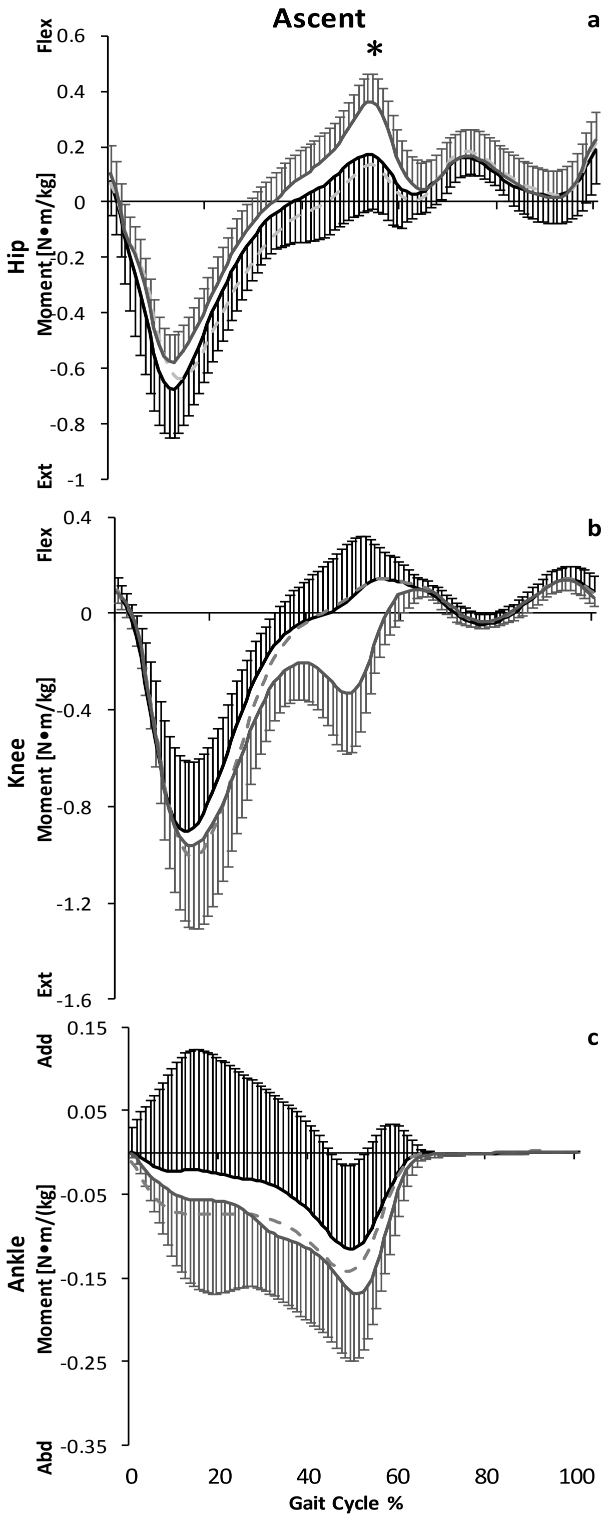

Fig 1: Mean and standard deviation of hip, knee, and ankle joint moments in sagittal and frontal plane during stair ascent for normal (black), overweight (open line),and obese (grey) subjects in a gait cycle. (a) Hip flex-ext moments (b) knee flex-ext moments, &(c) ankle abd-add moments

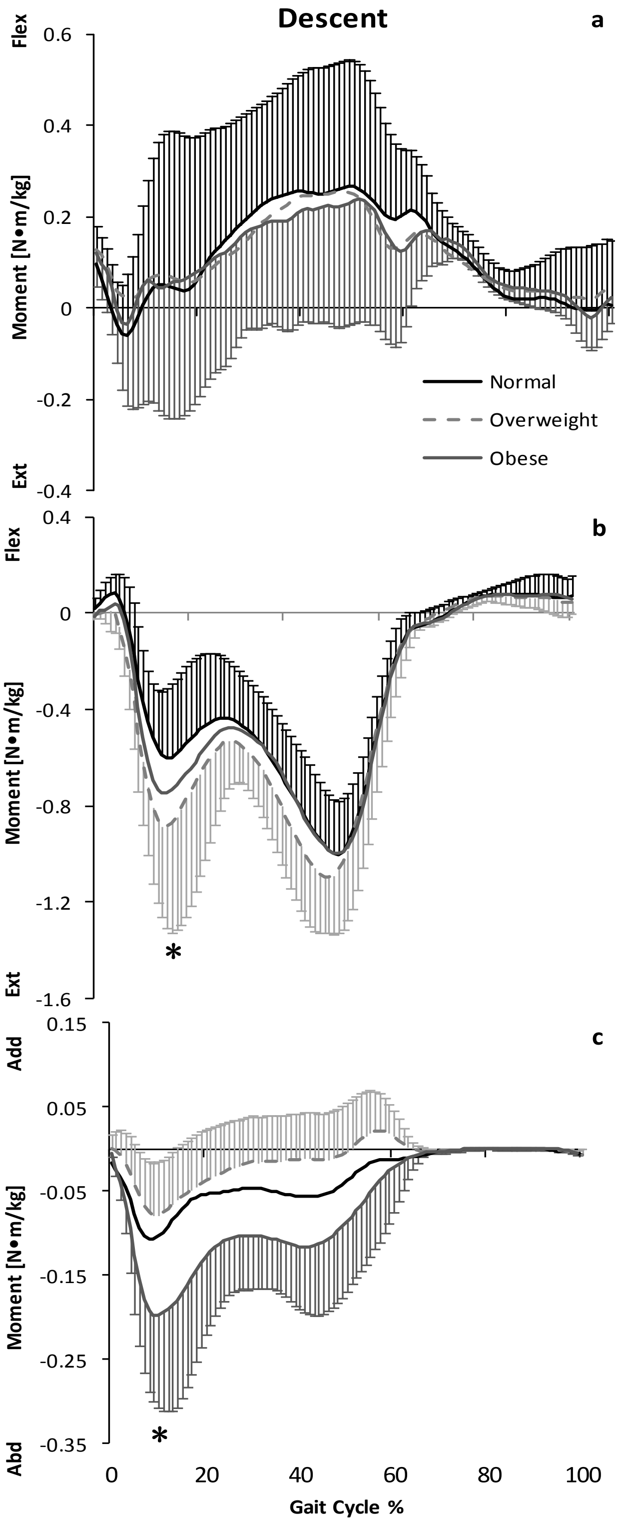

Fig 2: Mean and standard deviation of the hip, knee, and ankle joint moments in sagittal and frontal plane during stair descent normal (black), overweight (open line),and obese (grey) subjects in a gait cycle. (a) Hip flex-ext moments (b) knee flex-ext moments, and (c) ankle abd-add moments

Like the hip joint moments, the peak knee extensor and flexor moments for this study were also consistent with the results from past studies by Riener et al., (2002) and Lin et al., (2002). During ascent, the knee extensor moment gradually became smaller towards the end of swing phase. The joint moment curves for the knee, however, differed when it came to stair descent because there was a second peak that helped extend the knee. In terms of the difference between the curves for overweight/obese vs. normal weight participants, the results from the study *did support* the initial hypothesis. The overweight participant tended to have a significantly larger knee extensor moment than normal weight participant during stair descent as shown in figure 2 (overweight: -0.98 N•m/kg, normal: -0.70 N•m/kg). This finding was consistent with the study by Strutzenberger et al, (2011) who found a greater knee extensor moment during stair ascent and descent in obese children. The findings regarding the peak ankle joint moments, however, *did not support* the initial hypothesis. Based on the results from the study, the peak ankle abductor moment was significantly different during stair descent. As seen in (Table 1), the ankle abductor moment was significantly larger in the obese participant than in the normal weight and overweight participants during descent (obese: down: -0.21 N•m/kg; normal: down: -0.12 N•m/kg and overweight: down: -0.09). The larger abductor in the obese participants may reflect their need to compensate for the changes in their centre of mass (COM) by adducting or abducting their ankles when they were descending the stairs in order to maintain their balance and stability. This finding was again consistent with findings from past studies that have noted how excess movements of the foot-ankle complex in the frontal plane may reflect the changes in the individuals' centre of mass (COM) relative the person's base of support (Mian, Thom, Narici, & Baltzopoulos, 2007).

CONCLUSION: The knee and hip joint moment curves were consistent with the curves from past studies that examined the joint moments of normal weight individuals during stair ascent and descent. In terms of the difference between the peak joint moments, the findings from the present study confirm stair climbing results in higher joint loading at the knee, which could be a potential mechanism of knee osteoarthritis. In the future, the results from the study may serve as a basis for future studies on stair climbing in this segment of the population.

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