THE EFFECT OF LOWER LIMB INSTRUMENTATION ON KINETICS AND KINEMATICS DURING STAIR CLIMBING

Andrew S. Beath, Jennifer L. Durkin
Department of Kinesiology, University of Waterloo, Waterloo, ON
Email: abeath@uwaterloo.ca

INTRODUCTION

The level of instrumentation applied to the lower limb may influence 3D joint kinetics and kinematics during stair ambulation. The purpose of this study was to determine these effects by manipulating the number of active motion capture markers applied to the thigh, lower leg and foot during a stair climbing task. A secondary purpose was to determine whether these effects were related to movement speed.

METHODS

Nine healthy subjects completed 3 stair ambulation trials at 2 speeds (self selected and 1Hz timed) while motion capture (Northern Digital, Waterloo, ON) and ground reaction force (AMTI, Watertown, MA) data were collected at 64 Hz and 1024 Hz, respectively. The force platform was mounted in the second step of a custom staircase. Three motion capture marker setups were collected in a randomized order. These included a setup with skin markers over bony landmarks, a setup with only rigid marker clusters attached to the lower limbs, and a third setup combining the first two. Lower limb kinetics and kinematics were determined using Visual3D (C-motion, Kingston ON). Moments of force were normalized to body mass, all trials were normalized to 100% of contact time and ensemble averaged. Key variables that were included in the analysis were: contact time, ankle and knee minimum, maximum angles and range of motion, and ankle and knee minimum and maximum moments of force, during stair ascent and descent. Two-way repeated measures ANOVAs (α=0.05) followed by Tukey HSD post hoc analyses were run on the data.

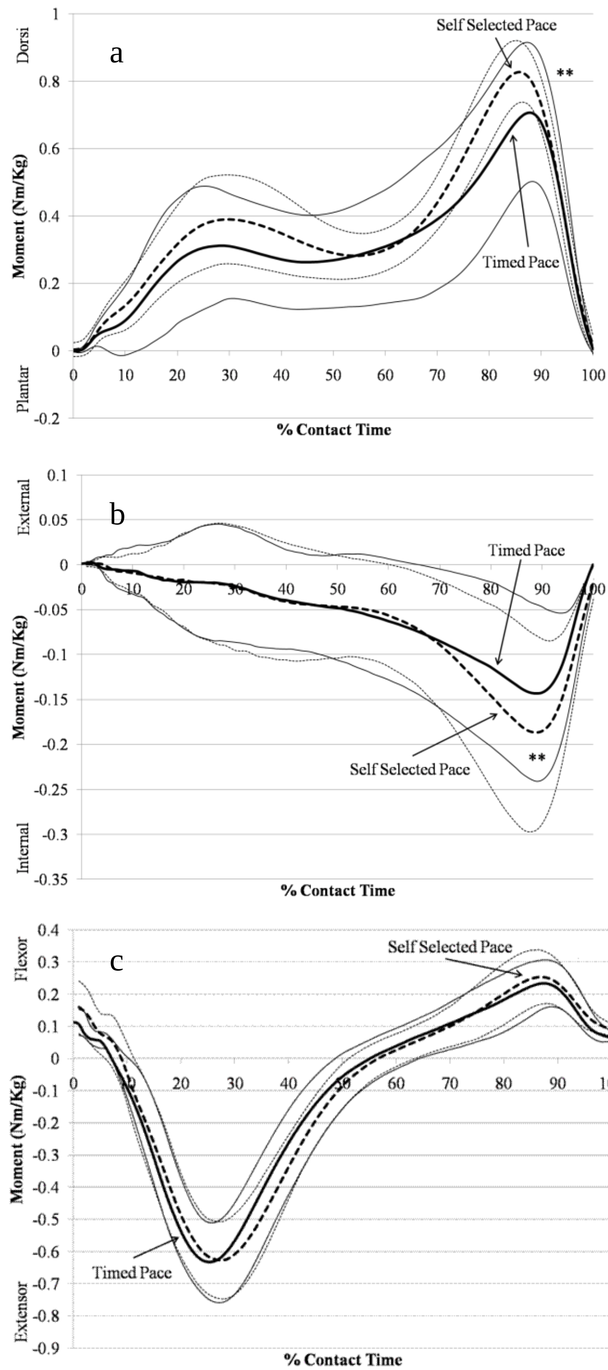

Figure 1: a) Ankle F/E moment b) Ankle I/E moment c) Knee F/E moment. ** indicates where significance occurred.

RESULTS

Statistically significant differences between marker setup and speed are displayed in Tables 1-2. Participant contact time with the force plate was shorter for the self selected pace compared to the timed pace ($p<0.0005$). There was no difference in pace between the marker setups ($p>0.05$). No significant differences were found for stair descent ($p>0.05$). During stair ascent, pace affected peak ankle dorsiflexor moment ($p<0.01$), peak ankle eversion moment ($p<0.05$), peak knee flexor moment ($p<0.05$), and peak knee abductor moment ($p<0.05$). Figure 1 shows the peaks occurred at the same instance for both ankle moments but a significant difference in time to peak moment was found for the knee moments. During stair ascent, marker setup affected peak knee abduction angle ($p<0.01$), and the range of knee motion in the frontal plane ($p<0.01$).

DISCUSSION

Movement speed significantly affected ankle and knee joint peak moments during stair ascent. This is a well-known effect [1], however instrumentation did not affect self-selected walking speed as interaction effects were not found. The number of markers applied to the lower limb affected ankle and knee joint angles during stair climbing. This could be due to the number of markers applied to the lower limb, soft tissue artifact [2], or due to the methods of securing the plates to the leg segments using tensor bandages. The results show that the skin-mounted marker setup was significantly different from both the rigid plates and the combination setups. Since the rigid plates and combination setups both involved the use of an underwrapping method to secure the rigid plates, this likely caused the differences in kinematics seen. Similar methods of securing rigid plates to the lower limbs is common and should be carefully considered in future research [3]. Further, the effect of active motion capture markers in addition to other data recording devices such as EMG on natural motion should considered whenever possible [4].

REFERENCES

1. Lelas, J.L. et al. (2003). *Gait and Posture* **17(2)**; p. 106-112.
2. Cappozzo, A. et al (1996) *Clinical Biomechanics* **11(2)**; p. 90-100
3. Manal, K. et al (2000) *Gait and Posture* **11;** p. 38-45
4. Frigo, C. and Crenna, P. (2008). *Clinical Biomechanics*, In Press.

ACKNOWLEDGEMENTS

The authors wish to thank the Natural Sciences and Engineering Research Council for financial support of this study.

Table 1. Main effects for marker setup. Values with dissimilar letters (A,B) are statistically different.

Stair Ascent	Skin-Mounted	Rigid Plates	Both
Ankle Range of Motion (^{o})	33.2 (3.2)^A	35.3 (3.5)^B	34.4 (3.7)^{AB}
Knee Abduction Angle (^{o})	-2.3 (4.2)^A	2.2 (5.2)^B	2.2 (5.5)^B
Knee Abd/Add ROM (^{o})	6.4 (2.8)^A	10.3 (2.6)^B	9.7 (2.3)^B
Stair Descent			
Ankle Inversion Angle (^{o})	16.1 (7.1)^A	13.9 (6.6)^B	14.4 (6.7)^B

Table 2. Main effects for movement speed. Peak moments are compared.

Stair Ascent	Self-Selected	Timed
Contact Time (s)	0.99 (0.14)	1.24 (0.07)
Ankle Dorsiflexion Moment (Nm/kg)	0.84 (0.09)	0.76 (0.07)
Ankle Eversion Moment (Nm/kg)	0.16 (0.05)	0.14 (0.05)
Knee Extension Moment (Nm/kg)	0.29 (0.06)	0.25 (0.07)
Knee Abduction Moment (Nm/kg)	0.03 (0.02)	0.02 (0.02)
Stair Descent		
Contact Time (s)	0.93 (0.14)	1.21 (0.07)