OBESITY IS ASSOCIATED WITH INCREASED JOINT TORQUES AND RELATIVE EFFORT DURING GAIT: PRELIMINARY FINDINGS

[1]Hoda Koushyar, [2]Dennis E. Anderson, [1]Maury A. Nussbaum, and [3]Michael L. Madigan

[1]Virginia Tech, Blacksburg, VA, USA
[2]Harvard Medical School, Boston, MA, USA
[3]Texas A&M, College Station, TX, USA

email: koushyar@vt.edu, web: http://www.biomechanics.esm.vt.edu/

INTRODUCTION

Obesity has been linked to altered gait kinematics and kinetics. For example, individuals who are obese walk with less hip and knee flexion and more ankle plantar flexion during stance [1]. They also exhibit higher hip and knee extensor torques [2], and higher ankle plantar flexor torque [1, 2]. Increased joint loading with obesity may increase the risk of musculoskeletal pathology.

Altered lower extremity strength may explain the differences in gait kinematics and kinetics between obese and healthy-weight individuals [2]. To better understand the importance of lower extremity strength during gait, earlier work investigated relative effort, or joint torques expressed as a percentage of maximum available joint torque [3]. Higher relative effort among obese individuals may help explain their altered gait.

To better understand the obesity-related changes in joint load during gait, and to assess the importance of muscle strength, the purpose of this study was to investigate whether and to what extent lower extremity joint torques and relative effort during gait differ with obesity.

METHODS

Participants included seven healthy-weight (HW, age: 22.3 ± 3.4 years, BMI: 22 ± 2 kg/m^2) and seven obese (OB, age: 23.6 ± 3.8 years, BMI: 31.7 ± 3.8 kg/m^2) females. Participants with any self-reported history of neurological, cardiac, or musculoskeletal disorders were excluded from the study.

Gait trials were performed at a self-selected speed on a 10-meter walkway. Ground reaction forces were sampled at 1000 Hz from a force platform (Bertec Corporation, Columbus, OH) embedded in the middle of the walkway, and kinematics were sampled at 100 Hz using a six-camera motion analysis system (MX-T10, Vicon Motion Systems Inc., L.A, CA).

Strength measures included isometric and isokinetic (concentric and eccentric) maximum voluntary contractions (MVCs) of the right lower extremity. Torques were sampled at 200 Hz using a Biodex System 3 dynamometer (Biodex Medical Systems, Inc., Shirley, NY), in plantar flexion (PF), dorsiflexion (DF), knee extension (KE), knee flexion (KF), hip extension (HE), and hip flexion (HF).

A sagittal plane, rigid-link model was created, and inverse dynamics analysis was used to estimate resultant joint torques at the ankle, knee, and hip during the stance phase of gait. Relative effort was determined using the method reported by Anderson and Madigan (2014) [3]. At the instants of peak torques, relative effort was calculated as:

$$Relative\ Effort = \frac{T}{A+P} \times 100$$

where T is the peak resultant joint torque, and A and P are the respective active and passive components of available strength determined using a model relating joint torque, angle, and angular velocity [4, 5]. Peak absolute torques and relative effort were compared between groups using unpaired t tests. Statistical analyses was performed using JMP Pro 10 (SAS Institute, Inc., Cary, NC).

RESULTS AND DISCUSSION

Joint torques (Figure 1) and relative effort (Table 1) during gait differed with obesity. Peak torques were higher for the OB group in HF (30%; p=0.011), KE (101%; p=0.006), and PF (53%; p<0.001). Relative effort during gait was 70% higher in KE (p=0.033; Table 1). The mean gait speed was 1.33 m/s, and did not differ between groups (p=0.071).

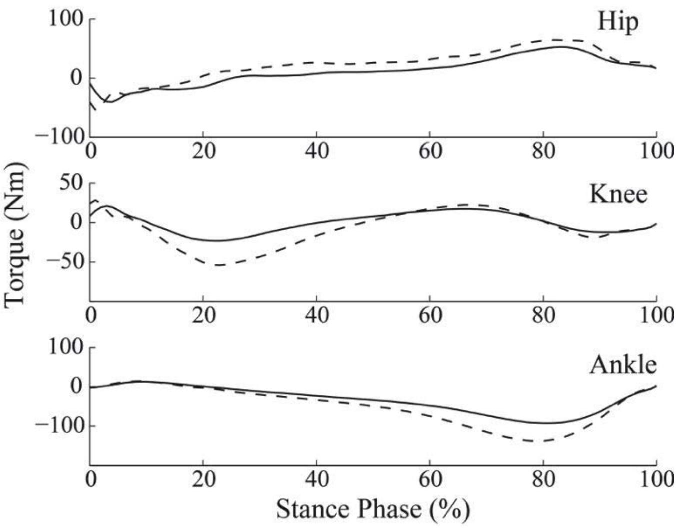

Figure 1: Ensemble averaged sagittal plane torques during stance for OB (dashed) and HW (solid) participants. Positive values are flexor/dorsiflexor torques and negative values are extensor/plantar flexor torques.

The higher HF torque among obese participants during gait has not been reported previously, though the higher knee extensor torque in this group is consistent with earlier evidence [2], as is the higher plantar flexor torque [1, 2]. In general, the current findings suggest that obese individuals walk with higher joint loads.

The higher KE relative effort among obese participants, despite them having higher KE absolute strength [6], suggests that obese individuals are more likely to be limited by knee extensor strength during gait. Furthermore, high muscle forces to produce large KE torques may increase knee loading beyond the increase due to higher weight. The large (>1) value for PF relative effort in both healthy-weight and obese groups suggests that both groups walk near the limits of their available PF strength during gait. This large PF relative effort, though, may have been influenced by participants not generating true maximum strength during strength measurements or to underestimation of maximum available torque using the torque model.

Table 1: Peak Torque (Nm) and Relative Effort (mean ± SD)

	Peak Torque during gait (Nm)		**Relative Effort**	
	HW	*OB*	*HW*	*OB*
HE	49.3±19.1	61.1±19.2	0.51±0.31	0.55±0.24
HF	53.4±9.5	69.8±10.9*	0.61±0.17	0.59±0.09
KE	27.1±14.8	54.6±15.9*	0.5±0.26	0.85±0.28*
KF	18.3±5.7	24.2±15.7	0.4±0.16	0.53±0.33
PF	92.9±14.2	142.3±18.5*	1.29±0.36	1.93±0.74
DF	13.5±6.3	14.1±5.3	0.45±0.17	0.4±0.18

* indicates a significant difference between HW and OB groups (p<0.05)

CONCLUSIONS

Obese individuals exhibited higher joint torque at HF, KE, and PF which suggests elevated joint loads in this group. Furthermore, higher KE relative effort among obese individuals may indicate greater likelihood of gait limitations due to KE strength, as well as excessive knee loading that can adversely affect the knee joint.

REFERENCES

1. DeVita, P., and Hortobagyi, T. *Journal of Biomechanics,* **36**:9, 1355-1362, 2003.
2. Browning, R. C., and Kram, R. *Medicine and Science in Sports and Exercise,* **39**:9, 1632, 2007.
3. Anderson, D. E., and Madigan, M. L. *Journal of Biomechanics,* **47**:5, 1104-1109, 2014.
4. Anderson, D. E., et al. *Journal of Biomechanics,* **40**:14, 3105-3113, 2007.
5. Anderson, D. E., et al. *Journal of Biomechanics,* **43**:6, 1220-1223, 2010.
6. Koushyar, H., et al. *Midwest ASB Regional Meeting*, March 4 -5, 2014 in Akron, OH.

ACKNOWLEDGEMENTS

This work was supported by grant R01OH009880.