

EFFECT OF EXCESSIVE ADIPOSITY ON RISK OF SLIPPING AND POSTURAL STABILITY

Jian Liu, Ph.D.

*Center for Neuromotor and Biomechanics Research
Department of Health and Human Performance
University of Houston, Houston, TX, 77204, USA*

Obesity in the workplace is a growing concern. Epidemiological evidence indicates the connection between obesity and traumatic workplace injuries, such as fall accidents. However, relevant studies are limited, with mixed findings. Therefore, the objective of the current study was to evaluate the effect of excessive adiposity on postural stability during standing and risk of slip initiation during walking. Twelve young adults (18-30 years old) were involved in a laboratory study. Based on BMI measures, seven participants were categorized into normal-weight group and five into overweight group. Postural stability was quantified using standard Sensory Organization Tests by computerized posturography system. Risk of slip initiation, as quantified by friction demand, was measured by having participants walk on an instrumented treadmill with embedded 3D force plates. **The overweight group was found to require significantly higher friction (17.5% more, $p = 0.004$) than their normal weight counterparts. It was concluded that it is necessary to implement more rigorous environmental control measures for overweight and obese workers in order to prevent slip-induced fall accidents.**

Introduction

Obesity in the workplace is a growing concern. Recent statistics indicates that approximately 85% percent hourly manufacturing employees are either overweight or obese (Pollack, et al., 2007). Obesity is associated with a variety of health problems including increased risk of falling. Middle-aged and older obese adults fall almost twice as frequently (27%) as their normal-weight counterparts (15%) each year (Fjeldstad, Fjeldstad, Acree, Nickel, & Gardner, 2008). And once they fall, those who are overweight or obese are 15% to 79% more likely to sustain a fall-related injury requiring medical treatment (Finkelstein, Chen, Prabhu, Trogon, & Corso, 2007).

However, our understanding of the biomechanical mechanism of obesity-related falls has been very limited and largely inconclusive. For example, there has been conflicting evidence regarding the impaired postural stability associated with obesity. Studies (Hue, et al., 2007) have indicated that postural instability increased with body weight and Body Mass Index (BMI). Nevertheless, the measures of postural balance were not different between obese and non-obese adults (Fjeldstad, et al., 2008). This may suggest that the increased falling risk associated with obesity may be more related to their impaired ability to maintain their balance during the dynamic process of fall accidents, such as the initiation, detection and recovery paradigm in slip-induced falls (Lockhart, Smith, & Woldstad, 2005).

Therefore, the objective of the current study is to investigate the effect of excessive adiposity on postural stability during standing and risk of slip initiation during walking. It is hypothesized that the risk of slip initiation, instead of postural stability, may differentiate overweight and normal-weight adults.

Method

Twelve healthy young adults were involved in a laboratory study. Their anthropometric information is summarized in Table 1. According to CDC guideline (Center for Disease Control and Prevention, 2009), seven participants were categorized as normal weight (N, $20 < \text{BMI} < 25$) while five as overweight (O, $25 < \text{BMI} < 30$). Informed consent has been approved by the Committee for Protection of Human Subjects at University of Houston and obtained from each participant prior to data collection.

Group	Age (yrs)	Height (m)	Weight (kg)	BMI
N	19 ~ 26	1.63 ± 0.11	61.8 ± 8.4	23.1 ± 0.6
O	18 ~ 23	1.66 ± 0.12	103.4 ± 64.1	28.1 ± 2.7

Table 1 – Summary of participant anthropometric information

During the postural stability session, each participant went through the standard Sensory Organization Tests (SOT) using computerized posturography system (NeuroCOM Balance Manager, NeuroCOM Int'l, OR). SOT involves 6 test conditions: (1) eyes open, fixed visual reference, fixed support; (2) eyes open, sway visual reference, fixed support; (3) eyes close, fixed support; (4) eyes open, fixed visual reference, sway support; (5) eyes open, sway visual reference, sway support; (6) eyes close, sway support.

During the walking session, each participant was instructed to walk on an instrumented split-belt treadmill (TO-08-B, Bertec Co., OH) at their normal speed for approximately 5 minutes. Three trials of ground reaction force under the dominant foot were obtained from the embedded 3D force-plate at a sampling rate of 1000Hz. Friction demand (i.e., required coefficient of friction) was calculated as the peak negative ratio between anterior-posterior force and vertical force (Perkins, 1978).

One-way between-subject ANOVA was performed in JMP 8 (SAS Institute, USA), with the weight group (N or O) as the independent variable, and the equilibrium scores under 6 test conditions and the friction demand as the dependent variables. A significant level of $\alpha = 0.05$ was adopted.

Results

As illustrated in Figure 1, there was a significant group effect ($p = 0.004$) on friction demand. In average, the overweight group was found to require 17.5% higher friction than their normal weight counterparts. In other words, the overweight group was more likely to initiate a slip on a slippery surface.

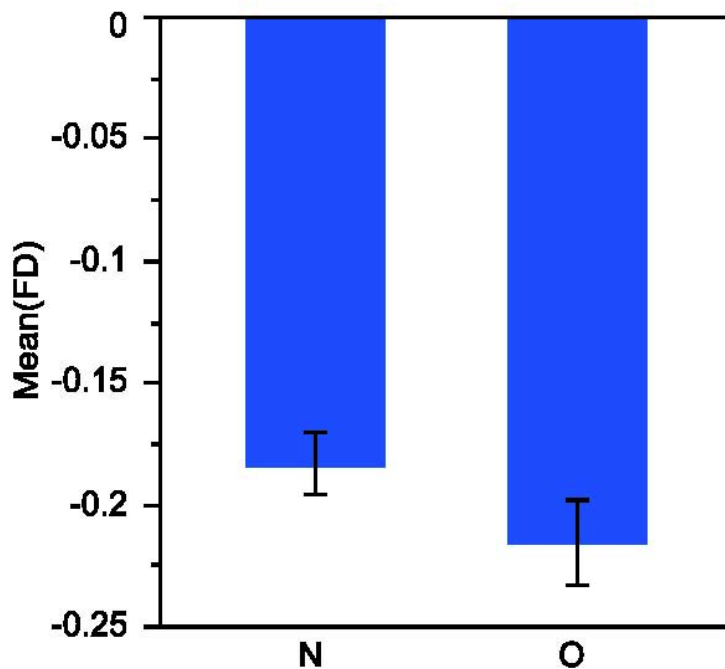


Figure 1 – Friction demand (mean \pm 1SD) by group

Contrary to friction demand, no significant group effect was found on the equilibrium scores in any of the 6 test conditions (Figure 2). In other words, there is no evidence showing the overweight group had impaired postural stability during upright posture than their normal weight counterparts.

Discussions and Conclusions

A better understanding of the effect of increased level of body adiposity on individuals' ability to maintain balance under upright posture as well as dynamic conditions (e.g., walking) would afford a greater opportunity to develop new fall prevention strategies and guidelines specifically for obese populations in the workplace. The objective of this study was to investigate the risk of slip initiation between overweight and normal-weight adults.

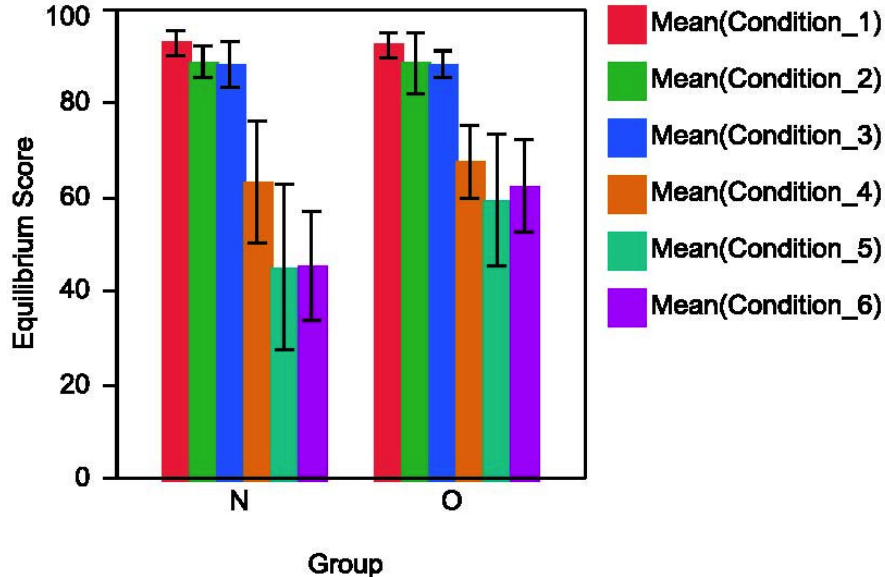


Figure 2 – Postural stability (equilibrium score: mean \pm 1SD) by group

As expected, the overweight group requires significantly higher friction during walking, even though there is no evidence showing they have impaired postural stability during upright posture. This finding supported the postulation in the literature that the fall accidents in obese individuals are more related to dynamic measures of stability (Fjeldstad, et al., 2008). Friction demand has been widely studied for general population and it is agreed that maintaining an adequate level of floor coefficient of friction (COF) is important in preventing slip-induced fall accidents (Gronqvist, et al., 2001). Although the scientific community has yet to reach a consensus on the safe level of floor COF (Gronqvist, et al., 2001), it can be reasonably concluded that based on the current findings, higher standard on floor COF has to be implemented in places where overweight and obese workers are prevalent.

Over the years, researchers have proposed several mechanisms to explain the obesity-related fall accidents. Through computer simulation, it has been demonstrated there is an exponential increase in ankle torque requirements as the body fat increases (Corbeil, Simoneau, & Rancourt, 2001). In addition, increased body mass leads to increased moment of inertia about the ankle joint (Corbeil, et al., 2001), which may present as a disadvantage in the reactive-recovery phase of a typical slip-induced falls. The current study contributes to the mechanism of obesity-related falls by showing that the biomechanical disadvantage starts as early as the slip initiation phase for the obese individuals.

As a preliminary investigation, the current study is limited in several aspects which need to be addressed in future studies. Besides limited sample size, the current study also lacked the representation of more severe obese status (i.e., BMI > 30). In addition, the BMI measurement only provides a gross categorization of one's weight status. More precise knowledge of one's body fat percentage and distribution will certainly aid our understanding of the influence of excessive adiposity on the biomechanics of falls. Lastly, by inducing slip/trip types of perturbation, future studies are needed to investigate the effect of obesity on the detection phase and the reactive-recovery phase of slip-induced falls.

In summary, the current study concluded that the risk of slip initiation during walking, rather than postural stability during upright posture, may better explain the obesity-related fall accidents. In addition, the fact that overweight adults require significantly higher friction during walking makes it necessary to implement more rigorous environmental control for workplaces where overweight and obese workers are prevalent.

Acknowledgement

The author gratefully acknowledges the financial support from UH COE Faculty Research Award and the assistance in data collection from Qurrat-ul-ain Ainy Aziz, Roopa Deepti, and Karyna Ramirez.

References

- Center for Disease Control and Prevention. (2009). Defining Overweight and Obesity. Retrieved 5/4/2009, 2009, from <http://www.cdc.gov/nccdphp/dnpa/obesity/defining.htm>
- Corbeil, P., Simoneau, M., & Rancourt, D. (2001). Increased risk for falling associated with obesity: mathematical modeling of postural control. *IEEE trans neural Syst Rehabil Eng*, 9, 126 - 136.
- Finkelstein, E. A., Chen, H., Prabhu, M., Trogon, J. G., & Corso, P. S. (2007). The relationship between obesity and injuries among US adults. [Article]. *American Journal of Health Promotion*, 21(5), 460-468.
- Fjeldstad, C., Fjeldstad, A., Acree, L., Nickel, K., & Gardner, A. (2008). The influence of obesity on falls and quality of life. *Dynamic Medicine*, 7(1), 4.
- Gronqvist, R., Chang, W. R., Courtney, T. K., Leamon, T. B., Redfern, M. S., & Strandberg, L. (2001). Measurement of slipperiness: Fundamental concepts and definitions. *Ergonomics*, 44(13), 1102-1117.
- Hue, O., Simoneau, M., Marcotte, J., Berrigan, F., Dore, J., Marceau, P., et al. (2007). Body weight is a strong predictor of postural stability. [Article]. *Gait & Posture*, 26(1), 32-38.
- Lockhart, T. E., Smith, J. L., & Woldstad, J. C. (2005). Effects of aging on the biomechanics of slips and falls. *Human Factors*, 47(4), 708-729.
- Perkins, P. J. (1978). Measurement of slip between the shoe and ground during walking. *American Society of Testing and Materials: Special Technical Publication*, 649, 71-87.
- Pollack, K. M., Sorock, G. S., Slade, M. D., Cantley, L., Sircar, K., Taiwo, O., et al. (2007). Association between body mass index and acute traumatic workplace injury in hourly manufacturing employees. [Article]. *American Journal of Epidemiology*, 166(2), 204-211.