THE EFFECT OF OBESITY ON BALANCE RECOVERY USING AN ANKLE STRATEGY IS DEPENDENT ON PERTURBATION TYPE

Sara L. Matrangola and Michael L. Madigan

Virginia Polytechnic Institute and State University, Blacksburg, VA, USA
email: smatrang@vt.edu, web: http://www.biomechanics.esm.vt.edu/

INTRODUCTION

More than one-third of adults in the United States (> 72 million) are obese [1]. The prevalence of obesity is not only high, but it continues to increase. For example, the prevalence of obesity among adults more than doubled from 1980 to 2000 [2-3]. One of the concerns with the high and increasing prevalence of obesity is its association with an increased risk of falls. Obese individuals fall twice as often compared to non-obese individuals [4].

The ability to recover balance from a postural perturbation is thought to be related to risk of falls. Therefore, understanding the effects of obesity on balance recovery may improve our understanding as to how obesity contributes to falls. The effect of obesity on balance recovery is not intuitive. Limiting balance to an ankle strategy, obese individuals have increased body weight, which increases the gravitational moment about the ankles. This increased gravitational moment would require larger ankle plantar flexor torque to recover from a perturbation [5], making balance recovery more physically demanding. At the same time, obese individuals have an increased mass moment of inertia about the ankles. Inertia can be defined as the resistance to rate of change in velocity [6]. The increased inertia in the obese may be beneficial in resisting an increase in velocity from a perturbation, making balance recovery less physically demanding. Because of this ambiguity, the purpose of this study was to investigate the effects of obesity on balance recovery using an ankle strategy.

METHODS

Twenty subjects were recruited, including ten normal-weight (age: 21.3 ± 1.1 yrs, BMI: 22.7 ± 0.6 kg/m^2) and ten obese (age: 22.4 ± 3.6 years, BMI: 32.2 ± 2.2 kg/m^2). This study was approved by the Virginia Tech Institutional Review Board, and written consent was obtained from all participants.

Three types of perturbations were used because the effects of obesity may be perturbation dependent. The first type involved releasing subjects from a static forward lean (lean trials) to impose an initial angular displacement from vertical with no initial angular velocity. Body angle relative to vertical (θ) was increased until the subject could no longer recover (return to upright stance). The second type of perturbation involved applying a forward-directed force impulse to the upper back with a ballistic pendulum while subjects stood comfortably (free perturbation trials). This imposed an initial angular velocity at an unconstrained body angle. The third type of perturbation involved applying a forward-directed force impulse to the upper back with a ballistic pendulum, but while subjects leaned against a rigid stop (lean perturbation trials) to impose an initial angular velocity at a controlled body angle. Initial angular velocity was increased until the subject could no longer recover for both free perturbation and lean perturbation trials. During all trials, subjects were harnessed to a backboard to limit balance recovery to an ankle strategy for all trials (contraction of only the muscles spanning the ankle and returning to an upright posture while keeping the body straight and not stepping).

Balance recovery capability was quantified by maximum lean angle (θ_{max}) for lean trials. For free perturbation trials and lean perturbation trials, balance recovery capability was quantified by the maximum angular velocity ($\dot{\theta}_{\max}$) at the body angle at the end of the force perturbation (θ_0).

During all trials, body angle was sampled at 1000 Hz and measured using a linear potentiometer (Unimeasure, Corvallis, OR). Body angle was lowpass filtered at 20 Hz (eighth order zero-phase-shift Butterworth filter).

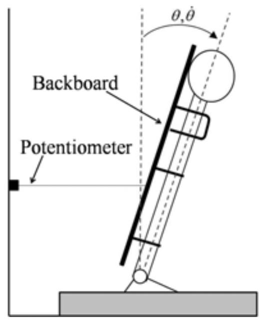

Figure 1. Experimental setup for the three types of perturbations.

A one-way ANOVA was used to investigate the effects of obesity on θ_{max} from lean trials, and $\dot{\theta}_{max}$ from free and lean perturbation trials. Body angle at the end of the perturbation (θ_0) was included as a covariate. Statistical analysis was performed using JMP v7 (Cary, North Carolina, USA) with a significance level of $p \leq 0.05$.

RESULTS AND DISCUSSION

Obesity impaired balance recovery, but only after certain types of perturbations (Table 1). For the lean trials, θ_{max} was not significantly different between normal-weight and obese subjects (p=0.497). In contrast, $\dot{\theta}_{max}$ was 29.9% (p=0.008) and 20.1% (p=0.035) lower in obese compared to normal-weight subjects for free and lean perturbations, respectively.

These results indicate that obese subjects had impaired balance recovery when perturbations involved an initial angular velocity, but not when perturbations involved only an initial angular displacement. The differences between perturbation types may be explained by a possible benefit of increased inertia. In particular, increased inertia may be beneficial for recovery after perturbations in which there is limited or no initial velocity because the increased inertia would resist changes in velocity, and therefore would accelerate slower. Theoretically, as initial velocity increases, increased inertia would become detrimental because that increased mass is already moving.

CONCLUSIONS

In conclusion, obese subjects were unable to recover balance using an ankle strategy as well as normal weight subjects when perturbations involved an initial angular velocity. No differences between obese and normal-weight subjects were found when perturbations only involved an initial angular displacement. Future studies should investigate less constrained tasks of balance recovery, such as slipping and tripping, to gain more insight on the source of the increased risk of falls in the obese.

REFERENCES

1. Ogden CL, et al. *NCHS Data Brief*, 1-8, 2007.
2. CDC. *Health, United States. Chartbook Table 75*. 2008.
3. Flegal KM, et al. *Jama*, **288**, 1723-7, 2002.
4. Fjeldstad C, et al. *Dyn Med*, **7**, 4, 2008.
5. Corbeil P, et al. *IEEE Trans Neural Syst Rehabil Eng*, **9**, 126-36, 2001.
6. Meriam JL and LG Kraige, *Engineering Mechanics Dynamics*. 5th ed. ed. Vol. 2. 2002, Hoboken, NJ: John Wiley & Sons.

ACKNOWLEDGEMENTS

SLM was supported by a National Defense Science and Engineering Graduate (NDSEG) Fellowship.

Table 1. Summary of Balance Recovery Measures (Mean ± S.D.)

Perturbation Type	Parameter	Normal-Weight	Obese	
Static Lean	θ_{max}	7.57 ± 1.14	7.18 ± 1.36	
Free Perturbations	θ_0	4.66 ± 0.91	4.83 ± 0.94	
	$\dot{\theta}_{max}$	16.53 ± 1.51	11.93 ± 2.72	*
Lean Perturbations	θ_0	2.70 ± 0.46	2.65 ± 0.63	
	$\dot{\theta}_{max}$	21.06 ± 2.44	17.54 ± 3.92	*

*indicates a significant difference between normal-weight and obese subjects ($p<0.05$)