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A BOOTSTRAPPING METHOD TO ASSESS THE INFLUENCE OF AGE, OBESITY, AND GENDER ON PROBABLITY OF TRIPPING AS A FUNCTION OF OBSTACLE HEIGHT

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INTRODUCTION

Tripping accounts for an estimated 53% of falls among older adults [1]. The most common measure for characterizing the probability of tripping while walking is the minimum foot clearance (MFC) during swing. A decrease in the central tendency (i.e. mean/median) of MFC, or an increase in MFC variability, are both associated with an increased probability of tripping [2-4]. These indirect measures of probability of tripping can lead to ambiguous results, though, when both increase or decrease simultaneously. Moreover, median MFC and MFC IQR are positively correlated [3], indicating concurrent increases or decreases in both are to be expected.

The purpose of this study was to develop a method that can determine the probability of tripping and to compare this probability between groups of interest while avoiding the noted ambiguous situations (i.e., wherein median MFC and MFC IQR concurrently increase or decrease). This method was applied to a experimental dataset to estimate differences in the probability of tripping with respect to obesity, age, and gender. These specific factors were investigated based upon reports of elevated risks of falling and sustaining a fall-related injury among obese adults [5], older adults [6] and females [7].

METHODS

Eighty participants completed the study including four gender-balanced groups comprised of 20 participants each (Table 1). Participants completed 16 trials walking along a 10 m walkway at two speeds: a self-selected gait speed and a hurried speed of 1.9 m/s. All participants wore the same brand of athletic shoes, to which were attached three reflective markers. A Vicon MX T10 motion analysis system (Vicon Motion Systems Inc., LA, CA) was used to sample marker positions at 100 Hz. MFC was determined using a method adopted from Startzell et al [2].

Table 1: Participant information (mean ± SD),

Group	Age (y)	BMI (kg/m^2))
Young Normal-Weight	24±3.3	22.3± 2.2
Young Obese	23.1±3.0	33.4±3.3
Older Normal-Weight	60.7±5.9	24.5±1.5
Older Obese	59.1±5.6	33.1±3.2

MFC values were used to create trip probability curves that indicated how the probability of tripping varied as a function of the height of a potential tripping obstacle (Figure 1). For potential tripping obstacle heights ranging from 0 - 7 cm, in increments of 2 mm, each experimental MFC value was dichotomized as either a trip (if the potential obstacle height was greater than MFC) or a non-trip (if the potential obstacle height was equal to or less than MFC). The percentages of trips at each obstacle height were then computed, serving as an estimate of the probability of tripping versus obstacle height.

A statistical bootstrapping technique was used at each potential obstacle height to determine whether the probability of tripping differed by obesity, age, or gender. The first step in this technique was to randomly reassign participant group labels (e.g., obese or normal weight when investigating obesity effects) to each participant's 16 MFC values. A probability curve was then created for each group, and the difference in trip probability between groups was calculated at each potential obstacle height. This process was repeated a large number of times (100,000 in our analysis) to obtain a distribution of differences at each potential obstacle height that would occur if group assignment was random. The distribution of these resampled differences acted as the sampling distribution of the difference under the null hypothesis that the groups had equal trip probabilities.

The second step in this technique was to examine the position, within the distribution of group differences, of the actual observed difference in probability of tripping between groups. This was done to determine if this difference was statistically significant at a level of α=0.05. A multiplicity correction was used to avoid inflation of type I errors. As such, if the difference was positioned in the outer 0.14% of the distribution, then the difference in trip probability between groups was considered statistically significant (α=0.0014). The percentage of the distribution of differences outside of the actual observed difference yielded a bootstrap *p*-value. This second step was performed for the complete set of potential obstacle heights, and between all participant groups of interest, to determine the specific heights at which the probability of tripping differed significantly between groups.

Group differences identified from this statistical bootstrapping technique were compared with group differences identified using the traditional measures of median MFC and MFC IQR. Group differences in median MFC and MFC IQR were determined using separate three-way, mixed-factor analyses of covariance (ANCOVA) with planned contrasts. Independent variables in the ANCOVAs were age, obesity, and gender, and gait speed was the covariate. Analyses were performed using JMP v7 (Cary, North Carolina, USA).

RESULTS

Obesity-related differences in the probability of tripping were not consistent between the bootstrapping technique and the ANCOVA analysis. Among older adults, the probability of tripping was higher among obese adults across a range of obstacle heights (2.4-4.2 cm), while there were no obesity effects on median MFC or MFC IQR. Among young adults there were no significant effects of obesity on the probability of tripping, nor on median MFC or MFC IQR.

Age-related differences in the probability of tripping were also not consistent between the bootstrapping technique and the ANCOVA analysis. Among normal-weight adults the probability of tripping was lower among older adults across a range of obstacle heights (2.0-4.6 cm), while age effects were not significant for either median MFC or MFC IQR. Among obese adults the probability of tripping was also lower among older adults, but across a smaller range of obstacle heights (1.2-2.4 cm), while again there were no age effects on either median MFC or MFC IQR.

With respect to gender (Figure 1), the probability of tripping was higher among females across a range of obstacle heights (0.8-4.4 cm), while both median MFC and MFC IQR were lower among females.

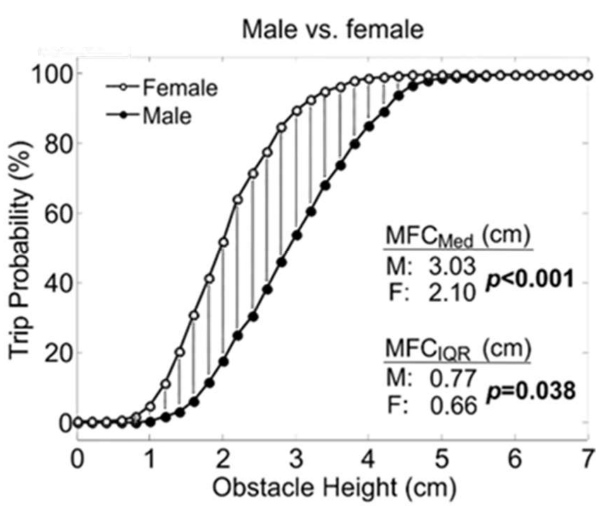

FIGURE 1: REPRESENTATIVE TRIP PROBABILITY CURVES AND MEDIAN/IQR MFC. DIFFERENCES IN TRIP PROBABILITY BETWEEN GROUPS ARE INDICATED BY A SOLID VERTICAL LINE, AND DIFFERENCES IN MEDIAN/IQR MFC ARE INDICATED BY BOLD. NOTE: M=MALE, AND F=FEMALE

With respect to gender (Figure 1), the probability of tripping was higher among females across a range of obstacle heights (0.8-4.4 cm), while both median MFC and MFC IQR were lower among females.

DISCUSSION

The technique presented here revealed differences related to obesity and age that were not identified from the more traditional approach using median MFC and MFC IQR. This technique also identified clear gender differences in the probability of tripping versus obstacle height despite ambiguous results from the ANCOVA analysis.

Furthermore, characterizing the probability of tripping as a function of obstacle height provides additional information on how individual factors may affect the probability of tripping. For example, results summarized in Figure 1a suggest that trip probability does not differ between normal-weight and obese older adults unless obstacle heights are greater than 2.4 cm. Such information may be helpful in establishing safety guidelines or standards that are more inclusive and protective for diverse populations.

Two limitations to the method presented here warrant mentioning. First, and similar to median/mean MFC and MFC IQR as commonly used to characterize probability of tripping, this method emphasizes foot clearance only at the instant that MFC occurs, even though a trip could occur at other instances during the swing phase. Second, unlike an ANOVA based upon median/mean MFC and/or MFC IQR, the current method cannot incorporate measures of covariance, or statistically control for the effects of other variables, when evaluating an independent variable of interest.

In conclusion, a pragmatic method is reported to characterize the probability of tripping as a function of obstacle height, and which can identify effects of factors not identifiable by the commonly used ANOVA analysis using MFC central tendency and variability.

ACKNOWLEDGMENTS

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June 17-20, 2015
Snowbird Utah

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THURSDAY, JUNE 18	9:15am - 10:45am

Dynamics and Rehabilitation — Superior

Session Chair: Alan Eberhardt, *University of Alabama at Birmingham, Birmingham, AL, United States*
Session Co-Chair: Tammy Bush, *Michigan State University, East Lansing, MI, United States*

9:15AM **A Support Vector Machine Based On Vertical Ground Reaction Force To Supplement Observational Gait Evaluation** SB³C2015-568
Craig J. Simons[1], Cory L. Christiansen[2], Jennifer E. Stevens-Lapsley[2], Kevin B. Shelburne[1], Bradley S. Davidson[1], *[1]University of Denver, Denver, CO, United States,[2]University of Colorado Denver, Denver, CO, United States*

9:30AM **A Bootstrapping Method to Assess the Influence of Age, Obesity, and Gender on Probability of Tripping as a Function of Obstacle Height** SB³C2015-506
Christina M. R. Garman[1], Christopher T. Franck[1], Maury A. Nussbaum[1], Michael L. Madigan[2], *[1]Virginia Tech, Blacksburg, VA, United States,[2]Texas A & M University, College Station, TX, United States*

9:45AM **Metabolic Consumption Using Different Repetitive Lifting Strategies** SB³C2015-1039
Timothy D. Craig[1], Alice E. Riley[1], Sandra A. Billinger[2], Neena K. Sharma[2], **Sara E. Wilson**[1], *[1]University of Kansas, Lawrence, KS, United States,[2]University of Kansas, Kansas City, KS, United States*

10:00AM **Design, Calibration, and Validation of a Novel In Vitro Tibial Force Sensor** SB³C2015-29
Joshua D. Roth, Maury L. Hull, Stephen M. Howell, *University of California, Davis, Davis, CA, United States*

10:15AM **Oh Deer! Morphological and Biomechanical Evaluation of Cervine Femora** SB³C2015-415
Mark J. Hedgeland, Morgan A. Libruk, Nicole C. Corbiere, Mario J. Ciani, Laurel Kuxhaus, *Clarkson University, Potsdam, NY, United States*

10:30AM **The Effects of Low Intensity Vibration on Bone Mineral Density in the Intact Limb of Animals with a Percutaneously Attached Endoprosthesis.** SB³C2015-502
Kyle Bodnyk[1], Garrett Noble[1], Matthew Allen[2], Noel Fitzpatrick[3], Gabriel Pagnotti[4], Richard Hart[1], *[1]The Ohio State University, Columbus, OH, United States,[2]University of Cambridge, Cambridge, United Kingdom,[3]Fitzpatrick Referrals, Surrey, United Kingdom,[4]Stony Brook University, New York, NY, United States*

THURSDAY, JUNE 18	9:15am - 10:45am

Cerebral and Aortic Aneurysms — Wasatch

Session Chair: Ender A. Finol, *University of Texas at San Antonio, San Antonio, TX, United States*
Session Co-Chair: Naomi Chesler, *University of Wisconsin, Madison, WI, United States*

9:15AM **Effect of Branched and Fenestrated Stent-Grafts on Renal Blood Flow.** SB³C2015-107
Harkamaljot S. Kandail[1], Mohamad S. Hamady[2], Xiao Y. Xu[1], *[1]Imperial College London, London, United Kingdom,[2]Imperial College Healthcare NHS Trust, London, United Kingdom*

9:30AM **Hemodynamic Changes in Treated Cerebral Aneurysms and Correlations with Long-Term Outcomes** SB³C2015-557
Michael C. Barbour[1], Patrick M. McGah[1], Michael R. Levitt[2], Kurt Sansom[1], Ryan P. Morton[2], John D. Nevra[2], Pierre D. Mourad[2], Basavaraj V. Ghodke[3], Danial K. Hallam[3], Laligam N. Sekhar[2], Louis J. Kim[2], Alberto Aliseda[1], *[1]University of Washington, Seattle, WA, United States,[2]University of Washington, Neurological Surgery, Seattle, WA, United States,[3]Dept of Radiology, Harborview Medical Center, Seattle, WA, United States*

9:45AM **Anuerysm MRI Phantoms For Direct, Ex Vivo Fluid Dynamics** SB³C2015-283
Jeff R. Anderson[1], Orlando Diaz[2], Richard Klucznik[2], Yi J. Zhang[2], Gavin W. Britz[2], Robert G. Grossman[2], Christof Karmonik[1,2], *[1]Houston Methodist Research Institute, Houston, TX, United States,[2]Houston Methodist Hospital, Houston, TX, United States*

10:00AM **Endovascular Treatment of Intracranial Aneurysms: Finite Element Modeling of Various Intervention Strategies** SB³C2015-518
Robert Damiano, Ding Ma, Jianping Xiang, Adnan Siddiqui, Kenneth Snyder, Hui Meng, *University at Buffalo, State University of New York, Buffalo, NY, United States*