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A BOOTSTRAPPING METHOD TO ACCESS THE INFLUENCE OF GENDER ON PROBABILITY 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 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 determine the probability of tripping using a method that avoids this ambiguous situation, and to demonstrate how this method can be used to compare this probability between groups of interest. This method was used to investigate differences in the probability of tripping between females and males, based upon reports of elevated risks of falling and sustaining a fall-related injury among females [5].

METHODS

Forty males and forty females completed 16 trials walking along a 10 m walkway at a self-selected speed. 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 [6].

MFC values from all trials 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 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 between females and males. The first step was to randomly reassign participant group labels (i.e., male or female) 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 second step was to examine the position, within the distribution of 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 at each potential obstacle height to determine the specific heights at which the probability of tripping differed between females and males.

Group differences identified from this statistical bootstrapping technique were compared with group differences identified using the traditional measures of median MFC and MFC IQR and mixed-factor analyses of covariance (ANCOVA). Analyses were performed using JMP v7 (Cary, North Carolina, USA).

RESULTS AND DISCUSSION

The probability of tripping was higher among females across a range of obstacle heights (1.2-4.4 cm), while both median MFC and MFC IQR were lower among females (Figure 1).

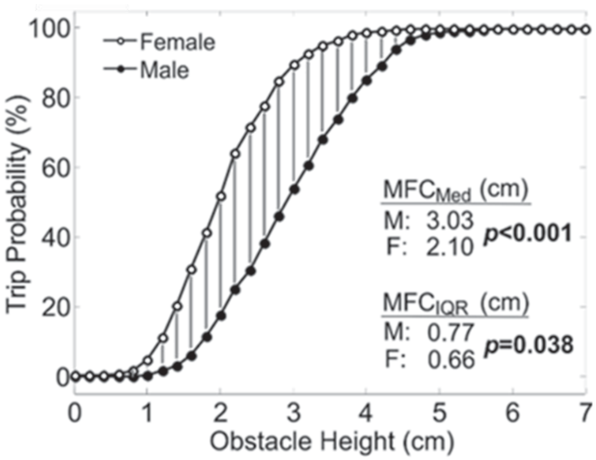

Figure 1: Trip probability curve and median/IQR MFC. Differences in trip probability between groups are indicated by a solid vertical line, and differences in median/IQR are indicated by bold. Note: m=male, and f=female

This technique identified clear gender differences in the probability of tripping versus obstacle height despite ambiguous results from the ANCOVA analysis in that both median MFC and MFC IQR were both lower among females. 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 suggest that trip probability does not differ between males and females unless obstacle heights are greater than 1.2 cm (Figure 1). Such information may be helpful in establishing safety guidelines.

Two limitations to the method presented here warrant mentioning. First, this method focuses on foot clearance 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

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