INTRODUCTION
Obesity is a major health concern that afflicts more than one-third of all adults in the United States [1]. Older adults, aged 60 and over, are also more likely to be obese compared to younger adults [1]. One of the many negative consequences associated with obesity is an increased risk of falling and subsequent disability in older adults [2]. It is possible that this increased risk of falling may be due to an increased risk of slipping. To our knowledge, only one study has directly examined the effects of obesity on risk of slipping, and this study was limited to young adults and a small sample size (n=5 per group) [3]. Therefore, the effects of obesity on the risk of slipping, and the influence of age on this relationship, remains unclear. The goal of the current study was to investigate the effects of obesity, age, and their interaction on the risk of slipping during level walking. We hypothesized that obese adults would have an increased risk of slipping, and that age would exacerbate this difference.

METHODS
Seventy-eight participants completed this study including 21 healthy-weight (HW) young adults (age = 25.0±4.3 yrs, BMI = 22.3±2.2 kg/m²), 20 obese (OB) young adults (age = 23.6±3.3 yrs, BMI = 33.6±3.3 kg/m²), 23 HW older adults (age = 64.1±8.4 yrs, BMI = 24.2±1.8 kg/m²), and 20 OB older adults (age = 63.5±9.5 yrs, BMI = 32.9±3.1 kg/m²). All participants were required to pass a screening designed to exclude those with self-reported medical conditions, such as musculoskeletal, neurological, or balance disorders, that could impact the validity of the results, and all participants provided informed consent.

Participants walked at a self-selected speed along a 10m level walkway. During each of four trials, the positions of selected anatomical landmarks on the feet were sampled at 100 Hz using a Vicon MX motion analysis system with T10 cameras (Vicon Motion Systems Inc., Los Angeles, CA), and ground reaction forces were sampled at 1000 Hz using a force platform (Bertec Corporation, Columbus, OH). Risk of slipping was quantified using resultant heel velocity at heel contact, and the peak resultant required coefficient of friction (RCOF) during the weight acceptance portion of stance time, which was calculated as the ratio of total shear force to normal force during stance.

A three-way mixed-model analysis of covariance (ANCOVA) was used to investigate the effects of obesity (HW or OB), age (young or older adults), foot (dominant or nondominant), and obesity x age interaction on risk of slipping measures. Gait speed and step length were also included as covariates due to their effect on peak RCOF [4]. Effect sizes (ES) for significant main effects were calculated as the difference in the means divided by the standard deviation [5]. A two-way ANOVA was also used to investigate the effects of obesity, age, and their interaction on gait speed and step length. Statistical analyses were performed using JMP Pro 10 (SAS Institute, Inc., Cary, NC).

RESULTS AND DISCUSSION
At heel contact, older adults exhibited a 12.6% higher heel contact velocity compared to younger adults (p=0.013, ES=0.444). The non-dominant foot also exhibited a 2.2% higher heel contact velocity compared to the dominant foot (p=0.005, ES=0.078).

During weight acceptance in early stance, older adults exhibited a 2.5% lower peak resultant RCOF compared to young adults (p=0.031, ES=0.217), and OB adults exhibited a 2.8% higher peak resultant RCOF compared to HW adults (p=0.031, ES=0.203, Figure 1). The non-dominant foot also exhibited a 2.0% higher peak resultant RCOF compared to the dominant foot (p<0.001, ES=0.155).
During push-off in late stance, OB adults exhibited a 10.7% higher peak resultant RCOF ($p<0.001$, ES=0.790, Figure 1) compared to HW adults. The dominant foot also exhibited a 2.9% higher peak resultant RCOF compared to the non-dominant foot ($p=0.006$, ES=0.198).

Gait speed was 7.4% lower ($p=0.008$, ES=0.575) and step length was 4.2% shorter ($p=0.019$, ES=0.483) in obese adults (Table 1), but neither gait parameter differed with age.

Table 1. Gait Parameters (mean±s.d.)

<table>
<thead>
<tr>
<th></th>
<th>HW</th>
<th>OB</th>
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<tbody>
<tr>
<td>Gait Speed (m/s)</td>
<td>1.34±0.17</td>
<td>1.24±0.15</td>
</tr>
<tr>
<td>Step Length (m)</td>
<td>0.69±0.06</td>
<td>0.67±0.06</td>
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*ob denotes a significant obesity effect ($p<0.05$)

Figure 1. Least square means and standard errors for peak resultant RCOF.

Obesity was associated with an increased risk of slipping during the weight acceptance and push-off phases of stance. The small effect size during weight acceptance suggests that obese adults are only at a slightly greater risk of slipping during weight acceptance compared to their healthy-weight counterparts. The larger effect size observed during push-off suggests a larger risk of slipping during push-off. A prior study found no difference in resultant RCOF, gait speed, nor step length between young obese and healthy-weight adults [3].

We found no evidence that obesity increases the risk of slipping at heel contact. Additionally, we did not find evidence that age exacerbated the effects of obesity on risk of slipping.

Older adults exhibited a higher resultant heel velocity at heel contact and smaller resultant RCOF at weight acceptance compared to young adults. Effect sizes indicate that age moderately increases the risk of slipping at heel contact, but that age only minimally decreases the risk of slipping at weight acceptance. Similarly, previous research has shown older adults to have a significantly higher heel contact velocity, indicating a greater risk of slipping, though no significant differences were found in RCOF values between young and older adults [6]. Changes in gait associated with aging have been thought to produce a “safer” gait pattern, resulting in reduce RCOF values in older adults. However, in cases where the available coefficient of friction is below typical RCOF values for both young and older adults, the increased heel contact velocity could put older adults at a higher risk of slipping [6].

CONCLUSIONS

Obesity was associated with an increased risk of slipping during weight acceptance and push-off phases of stance, but age did not exacerbate these effects of obesity. Other effects of age were found that were similar to prior research.

REFERENCES


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