

INFLUENCE OF AGE AND GAIT SPEED ON REQUIRED COEFFICIENT OF FRICTION INDEPENDENT OF STEP LENGTH

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INTRODUCTION

Falls are a major cause of injury and death in both the elderly and occupational settings, and slips are a major cause of falls [1]. The required coefficient of friction (RCOF) has been used as an indicator of the risk of slips as it indicates the minimum friction necessary to prevent the foot from slipping [1]. RCOF increases with step length independent of gait speed [2]. RCOF may also depend on age: older adults show lower RCOF during stair descent when compared to younger adults [3], although in a study of gait on level surfaces no significant age differences were found [4]. However, this study used self-selected walking conditions, and the older adults in the study walked at significantly slower speeds and took significantly smaller steps than the younger adults. Thus, it is unknown if there are age differences in RCOF independent of speed and step length. The purpose of this study was to examine the effects of age and speed on RCOF during gait on level surfaces, and separate age and speed effects from the effects of step length.

METHODS

Forty healthy adults participated in gait testing including 20 young adults (mean age 23.9 ± 3.3 years) and 20 older adults (mean age 80.3 ± 4.0 years). Each age group included 10 males and 10 females. Informed consent was obtained prior to participation. Participants walked down a walkway under four gait conditions, and stepped on a six degree-of-freedom force platform (Advanced Mechanical Technology Inc., Watertown, MA) placed in the center of a walkway with their right foot. Ground reaction forces were collected at 1000 Hz for each trial. A VICON 460 motion analysis system (VICON Motion Systems Inc., Lake Forest, CA) was used to record the positions of reflective markers placed on the left and right heel and right ASIS at 100 Hz.

All four gait conditions involved controlled gait speed, and two conditions controlled step length as well (Table 1). Speed was controlled by having participants keep pace with a moving belt placed alongside the walkway. Step length was controlled by having participants step on markings on the walkway. Gait conditions were presented to each participant in a random order. Three trials were collected for each condition. For each trial, speed and step length were determined from marker data.

A single trial was selected for analysis for each participant and gait condition. The trials were selected such that there were no significant speed differences between gait conditions with the same target speed (e.g. SF and SS, FF and FS) nor between age groups within gait conditions. Similarly, trials were selected so there were no significant differences in step lengths between gait conditions SS and FS, nor between age groups within these conditions.

The RCOF was determined by dividing the anterior-posterior shear force by the normal force throughout stance phase (Figure 1). The peak (minimum)

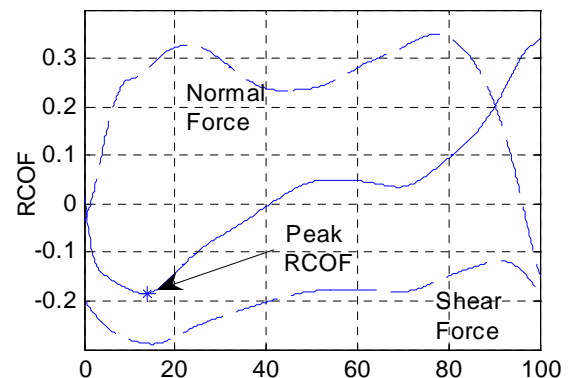


Figure 1: RCOF (solid line) is calculated throughout the stance phase as shear over normal ground reaction forces (dashed lines). Peak RCOF occurs in early stance phase.

RCOF during early stance phase was used for further analyses because it represents the minimum magnitude of coefficient of friction that will prevent the foot/heel from slipping forward.

Two-way repeated measures ANOVAs were used to investigate the effects of age and speed on RCOF within both controlled and uncontrolled step length conditions. A two-way repeated measures ANOVA was also used to investigate the effects of age and speed on step length within the uncontrolled step length conditions. All analyses were performed in JMP (SAS Institute Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

In gait conditions SF and FF, in which step length was not controlled, RCOF (Table 2) was lower in older adults ($p = 0.015$) and increased with increased speed ($p < 0.001$). However, older adults exhibited smaller step lengths ($p = 0.026$), and RCOF was affected by step length ($p < 0.001$). Therefore, these age differences in RCOF were confounded by differences in step length.

In gait conditions SS and FS, in which step length was controlled, RCOF (Table 2) was not significantly different between age groups ($p = 0.671$), and decreased with increased speed ($p = 0.049$). For these conditions, there were no age differences in speed ($p = 0.151$) or step length ($p = 0.133$).

The results show that when step length is controlled, there is no age difference in RCOF. In addition, increasing gait speed while not controlling step length increased RCOF (as in [2]), but increasing gait speed while controlling step length decreased RCOF. This speed effect may be due to

greater increases in normal force than shear force when walking at a higher speed with the same step length.

Table 2: Mean (SD) RCOF by age group for the four gait conditions tested.

| Gait Condition | RCOF | |
|----------------|---------------|---------------|
| | Older | Younger |
| SF* | 0.166 (0.025) | 0.201 (0.022) |
| FF* | 0.195 (0.040) | 0.227 (0.027) |
| SS | 0.188 (0.033) | 0.175 (0.025) |
| FS | 0.169 (0.041) | 0.170 (0.036) |

* Significant age group differences ($p < 0.05$).

CONCLUSIONS

- RCOF during level gait does not appear to depend on age independent of gait kinematics (speed and step length).
- RCOF during level gait decreases with increased speed when step length is held constant.

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ACKNOWLEDGEMENTS

This work was supported by Award Number F31AG030904 from the National Institute on Aging. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institute on Aging or the National Institutes of Health.

Table 1: The four gait conditions tested. Speed condition was either slow or fast, and step length condition was either freely chosen or controlled. Mean (SD) values obtained are presented.

| Gait Condition | Speed | | Step length | |
|----------------|-----------|-----------------------|-------------|-----------------------------------|
| | Condition | Mean (SD) Value (m/s) | Condition | Mean (SD) Value (m) |
| SF | Slow | 1.180 (0.026) | Free* | Y: 0.672 (0.028) O: 0.630 (0.043) |
| FF | Fast | 1.523 (0.031) | Free* | Y: 0.785 (0.044) O: 0.741 (0.048) |
| SS | Slow | 1.184 (0.034) | Set | 0.650 (0.005) |
| FS | Fast | 1.526 (0.045) | Set | 0.653 (0.010) |

*Significant age group differences in step length ($p < 0.05$).