

The Effects of Age on Gait Parameters During Adjustment

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Further understanding causes and characteristics of slip and fall accidents may aid in prevention of severe injuries and fatalities that result from these accidents. Moreover, understanding mechanisms associated with gait adjustment across a known slippery surface may help in proactively avoiding slips and falls. This study involved examination gait parameter characteristics of the lower extremities during different walking conditions. This study consisted of exposing 14 younger and 14 older participants to controlled slippery conditions safely, while studying normal and adjusted gait characteristics (friction requirement, heel contact velocity, and step length). First, a baseline measure was done to study normal gait prior to any exposure to slipping. A second measure was done following a slip from a contaminated floor surface, but before the initiation of a second slip. The results indicate that there are significant gait parameter differences between younger and older individuals. Findings suggest that older individuals require an additional step to properly adjust gait for a contaminated walking surface.

INTRODUCTION

Slips and trips often lead to, or are the cause of, fall related accidents (Cohen and Compton 1982). One half of reported falls are resultants of slips occurring most frequently on floor surfaces (Cohen and Compton, 1982). Thus, slips and falls are a severe problem in industry. Currently, there are approximately 35 million elderly individuals in the United States; this number is projected to double to more than 70 million by the year 2030 (Administration on Aging, 2000). Furthermore, the workforce in the United States is aging. One could infer that the problem with slips and falls for older adults will become more severe since the population of people over 65 years of age is increasing.

As people age physical ability decreases. This may be due to the decrease of muscle strength, loss of motor neurons, loss of muscle fibers, and decline of aerobic capacity (Prince, Corriveau et al., 1997; Winter, 1991). There exists an adaptation of gait (decreased stride length and a decrease in toe clearance) and a decrease in walking velocity in senior individuals (aged 65 and

older). This gait adaptation may be due to physical ability degradation.

Gait parameters (such as step length, friction requirement, and heel velocity) could be very important for influencing the ultimate outcomes of slip induced falls. There may exist age related changes to gait parameters suggesting that older individuals may be more susceptible to slip induced falls. For the present study, gait parameters consisted of ground reaction forces and three dimensional position data.

Ground reaction forces are the vertical and horizontal forces that are measured by a force plate. These forces consist of a total representation of all body forces acting as the foot comes into contact with the force plate. These forces occur in three directions. The vertical component of the force is acceleration due to gravity combined with vertical forces (F_v) applied by the body (body weight and downward momentum of the leg). Additionally, there are horizontal forces (F_H) (in the direction of body motion) and transverse forces (F_T) (perpendicular to the direction of body motion) (Perkins, 1978).

The coefficient of friction is the horizontal force created by the body divided by the

vertical force created by the body (Chaffin, Woldstad, and Trujillo, 1992). The required coefficient of friction (RCOF) is the lowest coefficient of friction required to keep the foot from sliding at the time of heel contact. If the RCOF exceeds the available COF at any point, a slip will result. Measurement of RCOF (FH/Fv) resulted in six peaks. Peaks 3 and 4 represent the part of the heel strike phase which is, most likely to result in a slip (Perkins 1978).

METHOD

Fourteen older (65 and older) persons and fourteen younger (18 – 35 years of age) persons participated in the experiment (Table 1). Both groups consisted of seven females and seven males.

Table 1: Participant characteristics (Age, Weight, & Height)

	Young (19-35 years old) Mean (S.D.)	Old (67-79 years old) Mean (S.D.)
Age (yr)	23.21 (4.41)	72.64 (4.36)
Weight (kg)	71.74 (11.97)	72.59 (16.31)
Height (cm)	172.41 (10.94)	168.49 (9.1)

A linear walking track was used to conduct the walking trials. An overhead track supporting a fall-arresting support system was utilized to protect individuals from fall related injury. Vinyl flooring materials (Armstrong) were used in this experiment to simulate a realistic environment. The area of contaminated flooring was located on a sliding track and operated by the experimenter to alternate contaminated and non-contaminated surfaces without the participant's knowledge. Two workstations were placed at each end of the track to direct the attention of the participant away from the floor surface. The function of this system was to control the experiment such that the floor surface could be changed from not slippery to slippery without the participants' awareness.

An infrared passive marker system (ProReflex Qualysis) utilizing six cameras was used to collect three dimensional posture data (sampled and recorded at a rate of 120 Hz) of the participants walking

through the test area. Two Bertec force plates at a sampling rate of 1200 Hz measured ground reaction forces exerted by the participants as they walked over the test surface.

Two measurement conditions were studied. First, a baseline measure was done to study normal gait prior to any exposure to slipping. This normal gait condition was referred to as condition 1. Second, a measure was done following a slip from a contaminated floor surface, but before the initiation of a second slip. Here participants were allowed to view the slippery floor surface before walking over it again while trying not to slip. This gait condition was referred to as the adjusted condition. The adjusted condition region was defined as the transitional step from the dry force plate to the contaminated force plate. Heel contact velocity (HCV) and required coefficient of friction (RCOF) were measured for the heel contact of the adjusted step onto the contaminated surface (later referred to as adjustment 2), as well as the step prior to stepping on the contaminated surface (later referred to as adjustment 1, or the preliminary adjustment).

Heel contact velocity (HCV) = $|X_{i+1} - X_{i-1}| / 2\Delta t$ cm/sec (where t = time, and X = horizontal displacement component). This was calculated for 10 frames preceding and one frame following heel contact. The heel velocity results for the 11 frames were averaged to obtain an average heel contact velocity. Heel contact velocity was measured for each force plate for both walking conditions.

Step length – length (in centimeters) from heel contact to heel contact of one foot to the other. This was measured for each participant through the motion capture system utilizing the distance formula $(\sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2})$ where (X1, Y1) represents the position of the first foot and (X2, Y2) is the position of the alternating foot. This was done by measuring the heel position during the final heel contact on the first force plate to the initial heel contact on the second force plate.

Friction requirement [the ratio of horizontal to vertical force (F_H/F_V) at peak 3] was measured for each participant through information gained by the force platforms for walking conditions 1 and 2.

Dependent measures of gait parameters (friction demand, heel contact velocity, and step length) were analyzed using a 2 x 2 repeated measures (age x condition) analysis of variance (ANOVA) design. Tukey-Kramer post hoc analysis was performed on measures with more than 2 repetitions for significance. Furthermore, bivariate correlation analysis was performed to describe possible relationships among dependant variables.

RESULTS

Gait parameters (such as step length, RCOF, heel velocity) could be very important for influencing the ultimate outcomes of slip induced falls. Results indicate several significant differences in gait parameters found between younger and older participants. Overall, older participants required a lower coefficient of friction (RCOF) than younger individuals ($F_{1,26} = 12.3356$, $P = 0.0016$), exerted a lower heel contact velocity than younger individuals ($F_{1,26} = 10.6733$, $P = 0.0030$), and had a shorter step length (in centimeters) than younger participants ($F_{1,26} = 4.7245$, $P = 0.0390$).

Bivariate correlation analysis indicated that as RCOF for the normal gait condition increased, HCV on the second force plate increased ($F_{1,26} = 4.5937$, $P = 0.0416$) where $R^2 = 0.150$. Additionally, as RCOF values for a normal gait condition increased, total slip distance increased ($F_{1,26} = 10.2004$, $P = 0.0037$) where $R^2 = 0.282$.

Overall, a higher required coefficient of friction (RCOF) was found for a normal walking condition versus both adjustment conditions ($F_{2,25} = 125.2063$, $P < 0.0001$).

Younger participants RCOF was statistically significantly higher than older participants for a normal gait condition ($F_{1,26} = 11.2843$, $P = 0.0024$). A higher RCOF value was found for the preliminary adjustment (1)

than for the adjustment onto the contaminated surface (2). Younger participants RCOF was statistically significantly higher than older participants for the adjusted gait condition (1) on a dry surface ($F_{1,26} = 9.2350$, $P = 0.0054$). No statistically significant difference was reported for the age effect of RCOF on the adjustment (2) condition on a contaminated surface ($F_{1,26} = 0.9230$, $P = 0.3455$) (Table 2 and Figure 1).

Younger participants HCV was statistically significantly higher than older participants for the normal gait condition ($F_{1,26} = 7.6377$, $P = 0.0104$). Younger participants HCV was statistically significantly higher than older participants for the adjusted gait condition for the heel contact upon the dry force plate ($F_{1,26} = 12.7816$, $P = 0.0014$). However, there was no statistically significant difference for age for the adjusted 2 condition upon the contaminated force plate ($F_{1,26} = 1.7738$, $P = 0.1945$) (Table 2 and Figure 2).

Step length was shorter for the adjustment condition than for the normal condition for all participants ($F_{1,26} = 36.7522$, $P < 0.0001$). Although young participants had a longer step length than older participants for both conditions, and both age groups had a shorter step length for the adjusted condition, there was not a significant age by condition effect (Table 2 and Figure 3).

Table 2: Age by Condition: RCOF, HCV, & Step Length

Measurement	Condition	Younger Mean (SD)	Older Mean (SD)
RCOF (F_H/F_V)	Normal	0.20 (0.02)	0.17 (0.02)
	Adjustment 1	0.16 (0.05)	0.11 (0.03)
	Adjustment 2	0.07 (0.02)	0.06 (0.03)
HCV (cm/sec)	Normal	228.30 (41.27)	172.24 (63.70)
	Adjustment 1	207.14 (91.45)	84.16 (90.58)
	Adjustment 2	148.22 (103.55)	97.44 (98.10)
Step Length (cm)	Normal	67.52 (6.31)	62.56 (7.02)
	Adjusted	55.52 (8.78)	46.96 (15.81)

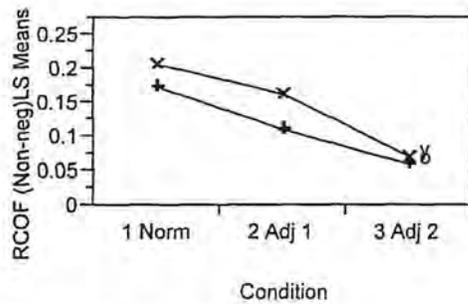


Figure 1: Age by condition: RCOF

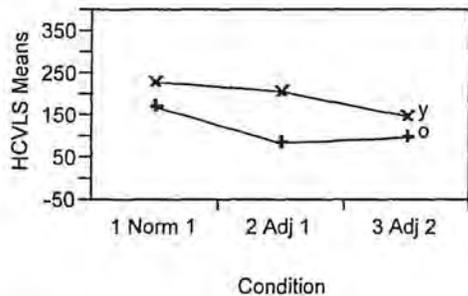


Figure 2: Age by condition: HCV

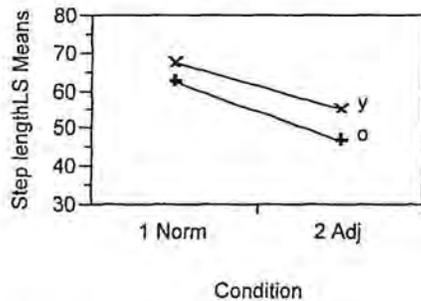


Figure 3: Age by condition: Step Length

DISCUSSION

To help avoid slip induced falls, gait parameters are adjusted to correct for contaminated or slippery conditions. Results from the present study support previous research by showing that gait parameters are adjusted for contaminated walking conditions for all participants. Persons who have a prior knowledge of a contaminated walkway adjust gait parameters by reducing RCOF, heel velocity and step length (Cham and Redfern, 2002; and Cham, Moyer, and Redfern, 2002; Do, Schneider, and Chong, 1999). Cham and Redfern, 2002, stated that individuals reduce

step length, RCOF and heel velocity to reduce likelihood of slipping. Resulting data from the present study supports findings from previous studies by showing significant differences from a normal condition to an adjusted condition for step length, friction requirement (RCOF), and heel contact velocity for all participants.

A primary goal of the present study was to examine age related differences to gait modifications. This study resulted in significant differences for younger and older participants for gait parameter measures for an adjusted condition versus a normal condition. Factors including heel velocity, RCOF, and step length are more susceptible to slip induced falls (Cham and Redfern, 2001; Lockhart 2000; Lockhart and Woldsted et al., 2000; Winter, 1991).

These findings reinforce previous research by showing both groups reduced step length, friction utilization, and heel contact velocity from normal gait to adjusted gait (the transitional step from a normal surface to a contaminated surface). However, the adjustment from the dry force plate to the contaminated force plate was similar for both age groups.

A very interesting finding for the adjustment condition lies not on the contaminated force plate as hypothesized, but on the dry force plate preceding it. These findings add to previous research by showing that for preliminary adjustment step (prior to stepping on the contaminated surface), heel contact velocity and friction utilization were considerably lower for older participants than for younger participants. Older individuals reduced both heel contact velocity (HCV) and required coefficient of friction (RCOF) well before traversing the contaminated surface than did younger individuals. Furthermore, as there was no age by condition interaction for normal versus adjusted step length, it may suggest that older individuals were adjusting gait parameters well before younger participants only to achieve similar adjustment results onto the contaminated surface. Thus, an age group difference in adjustment strategy is evident in the preliminary adjustment prior

to stepping on the contaminated floor surface for the older participant group. It was evident that older participants required an extra step in order to effectively adjust gait parameters for the slippery floor condition. Therefore, results from this study may suggest that although both participant groups had prior knowledge of the contaminated surface, it was necessary for the older participants to make gait modifications well before the step onto the contaminated surface to avoid slipping.

One could infer that it was necessary for all participants to adjust gait characteristics in order to avoid slipping on the contaminated surface. This was shown by the results of the present study. Interestingly, differences in gait adjustment strategies were found between older participants versus younger participants suggesting that the older participants required an additional step to adjust their gait. This information could be very important to take into consideration when designing environments specifically focused on an older adult population. Design consideration could be taken specifically in regards to risk communication and hazard recognition. Furthermore, conventional design considerations, such as flooring materials, environment, and lighting, may be of importance as well.

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