Available online at www.sciencedirect.com
ScienceDirect
Gait & Posture 26 (2007) 142–149
www.elsevier.com/locate/gaitpost

Age-related slip avoidance strategy while walking over a known slippery floor surface

Thurmon E. Lockhart [a,*], Jeremy M. Spaulding [a], Sung Ha Park [b]

[a] *Grado Department of Industrial and Systems Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA, United States*
[b] *Department of Industrial and Systems Engineering, Hannam University, Daejeon, South Korea*

Received 9 August 2005; received in revised form 9 August 2006; accepted 14 August 2006

Abstract

When confronted with impending slip/fall situations, gait parameters are adjusted accordingly to avoid slipping. This study was conducted to assess age-related slip avoidance strategy by measuring gait parameters and muscle activity characteristics of the lower extremities (hamstrings, calves, and quadriceps) of both young and older participants while ambulating successfully over a known slippery floor surface. Fourteen younger and 14 older adults participated in this study. First, a baseline measure was collected to study normal gait prior to any exposure to slipping. A second measure was collected following a slip from a contaminated floor surface, but before the initiation of a second slip, where the participants were able to view the contaminated surface before traversing it. The results indicated that there were significant gait parameter differences between normal-dry walking conditions and contaminated-slippery walking conditions. In general, participants (young and old) reduced step length, friction utilization, and heel contact velocity from normal gait to adjusted gait conditions. Furthermore, results also indicated that there were differences in gait parameters and muscle activity characteristics between the two age groups for both a normal gait condition and a gait condition requiring adjustment. Findings suggested that older individuals required an additional step to properly adjust gait for a contaminated walking surface.

Keywords: Gait; Age; Slips; Falls; Electromyography

1. Introduction

Reducing slip and fall accidents among older individuals has been a goal for many researchers for several decades. Numerous studies have shown that with advancing age, there is an increasing incidence of falling [1–4]. In the age 65 and over population, for example, 35–40% of community dwelling, generally healthy elderly persons fall annually [28,29]. In those aged 75–80 years, falling becomes more prevalent as 35–50% will fall every year [28]. When a fall does occur, older individuals are much more likely to suffer from injury. In fact, falls are the leading cause of injury-related deaths among people 65 years and older [30,31]. In 1998, approximately 10,000 people over the age of 65 year died from fall-related injuries [30]. Specifically, 75% of deaths due to falls in the United States occur in 13% of the population aged 65 and over [4]. Physical injury is only part of the problem. Falls have also become an expensive cost to society. Fall-related injuries account for 6% of all medical expenditures for persons aged 65 year and older in the United States [32]. The total cost of all fall injuries for people aged 65 or older in 1994 was US$ 20.2 billion. By 2020, the cost of fall injuries is expected to reach US$ 32.4 billion [32]. Furthermore, the elderly population is also increasing. 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 [5]. 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.

* Corresponding author. Tel.: +1 540 231 9088.
E-mail address: lockhart@vt.edu (T.E. Lockhart).

0966-6362/$ – see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.gaitpost.2006.08.009

Although epidemiological findings clearly indicate increasing rate of fall accidents among the elderly, comprehensive understanding of age-related mechanisms associated with fall accidents is lacking. Specifically, age-related slip avoidance strategy has not been investigated. The primary goal of this study was to assess age-related slip avoidance strategy by measuring gait parameters and muscle activity characteristics of the lower extremities (hamstrings, calves, and quadriceps) of both young and older participants during the heel contact phase of the gait cycle while ambulating successfully over a known slippery floor surface. This type of situation is frequently encountered, for example, during walking over a freshly mopped surface at a grocery store. Understanding age-related differences in gait parameters and muscle activity characteristics during this period of adjustment, for both age groups, may add to previous knowledge and ultimately help in proactively reducing slip and fall accidents among the elderly.

When confronted with impending slip/fall situations, gait parameters are adjusted to maintain optimal friction demand of the foot/floor interface to avoid slipping [23]. Reduction of friction demand, step length, and heel velocity all occur as a result of gait adjustment [17,18,23]. However, age-related gait adaptations and muscle activity patterns may hinder these gait adjustments. Gait adaptation frequently occurs as a result of aging. Elderly people often walk with shorter step length with a wider base of support, and slower transitional acceleration of the whole body center-of-mass (COM) [13,24]. Additionally, higher heel contact velocities have been reported for the frail elderly population at the time of the heel contact phase of the gait cycle [13]. These gait adaptations further increase risk of slipping, for example, higher heel contact velocity can increase horizontal ground reaction force in relation to vertical ground reaction force and as a result, friction demand can increase [25]. Furthermore, slower transitory acceleration of the whole body COM among the elderly can also increase friction demand at the shoe/floor interface and increase risk of slipping [24]. In case of eliciting gait adjustments (during slip avoidance), elderly individuals' gait adaptation may encumber optimal gait adjustment strategy.

Furthermore, older adults' lower extremity muscle activity characteristics during gait adjustment period may be important for assessment of slip avoidance strategy. Older adults exhibit reduction in fast twitch muscle fibers in comparison to slow twitch muscle fibers [26,27]. The age-related changes in the skeletal muscle property, such as muscle fiber types may hinder quick gait adjustments required for successful ambulation over slippery floor surfaces.

In this study, age-related gait characteristics while ambulating over a known slippery floor surface were investigated. Additionally, age-related lower extremity muscle activity characteristics associated with these gait adaptation were investigated. We hypothesized that older adults' gait characteristics would be different than their younger counterparts while ambulating over a known slippery floor surface due to their gait adaptations and associated muscle activity characteristics of the lower extremities.

Table 1
Participant characteristics (age, weight, and height)

	Young (19–35 years old), mean (S.D.)	Old (67–79 years old), mean (S.D.)
Age (year)	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)

2. Methods

2.1. Participants

Fourteen older individuals (65 years and older) and 14 younger individuals (18–35 years of age) participated in the experiment (Table 1). Both groups consisted of seven females and seven males. The young adults were recruited from general student population at Virginia Tech and older adults were recruited from the local community. Participants' anthropometric characteristics were matched so that participants between the 5th and 95th percentiles of height and weight were represented. The older participants were required to have successfully completed a medical examination within the past 6 months, be in good physical and mental heath (dementia), and have no restrictions to physical activity. Furthermore, the younger individuals were in good physical and mental heath, and had no physical restrictions to activity. Each participant completed an inform consent form approved by the Virginia Tech Internal Review Board (IRB).

2.2. Apparatus

A linear walking track (Fig. 1) was used to conduct the walking trials. An overhead track supporting a fall-arresting

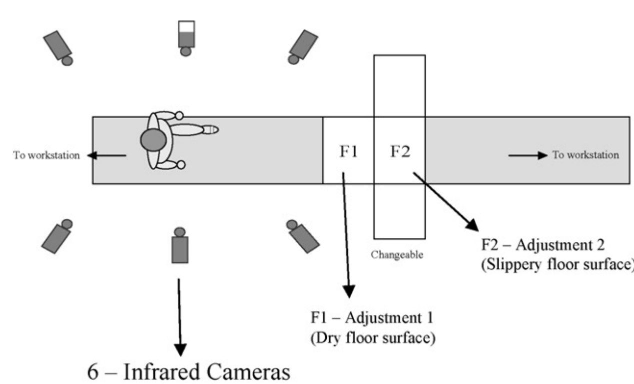

Fig. 1. Walking track with fall arresting harness. The flooring in the middle is interchangeable from slippery to non-slippery floor surface. The 6 infrared cameras are for use with the Qtrac motion capture. F1, adjustment 1 is associated with gait adjustment (one leg) on force plate 1 prior to stepping onto a known slippery floor surface located at F2 (force plate 2 location). F2, adjustment 2 is associated with gait adjustment (another leg) on the slippery floor surface on force plate 2.