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Comparison of utilized coefficient of friction during different walking tasks in persons with and without a disability

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Abstract

The purpose of this study was to determine if older persons with a disability have greater utilized coefficient of friction requirements than healthy older and younger adults during various walking conditions. Forty-eight community-dwelling adults were divided into five groups based on medical diagnosis and age: CVA (unilateral stroke; mean age 63 years), DM (diabetes mellitus; mean age 70 years), ARTH (lower extremity arthritis; mean age 69 years), SENIOR (healthy; mean age 73 years), and YOUNG (healthy; mean age 29 years). Ground reaction forces (GRF) were recorded as subjects walked across a walkway, ascended and descended stairs, and negotiated a turn. The utilized coefficient of friction (COF_U) throughout stance was calculated as the ratio of shear to vertical GRFs, and the peak COF_U resulting from a shear force that would contribute to a forward foot slip was identified. Separate one-way ANOVAs were used to identify differences in peak COF_U across subject groups for each walking task. The results of this study found that for all conditions evaluated, those with a disability did not demonstrate greater friction requirements then adults without a disability. Friction requirements for the YOUNG group were significantly greater than all disability groups while negotiating a turn, and were greater than the DM group during level walking. These results indicated that the diagnostic groups evaluated in this study are not at any greater risk for slip initiation than the healthy older or younger adults during the tasks evaluated.

Keywords: Slip resistance; Gait; Age; Medical condition; Forensic science

1. Introduction

Among older persons, slips have been identified as a primary cause of falls in the work and home environments [1,2]. An investigation of occupational injuries to civilian workers over the age of 55 years, reported that slips accounted for more than half (57%) of the falls occurring on level surfaces [2]. Slips contributed to 38% of falls in men and 17% of falls in women in a 1-year study of accidental falls experienced by community dwelling older adults (60–88 years) [1]. Falls are the leading cause of unintentional injuries resulting in death in persons over the age of 65 years [3] and account for 87% of all fractures occurring in this age group [4]. The serious consequences of falls is underscored by the inclusion of the reduction of ''deaths from falls'' as a national priority within the *Healthy People 2010 Objectives for Improving Health* (Objective 15–27) [5].

During walking, slips result from a loss of *traction* between the foot and the floor. In the *research* setting, the traction that an individual requires from the floor surface during walking, or ''utilized'' coefficient of friction (COF_U), can be determined from force plate recordings of ground reaction forces (GRF) [6]. The COF_U is defined as the ratio between the horizontal and vertical components of the GRF generated by a person while walking across a dry, non-contaminated surface. The probability of a slip rises when either the friction that an individual utilizes increases or the friction available from the floor surface decreases [7].

As COF_U is determined by the ratio of shear to vertical GRFs, it is likely that changes in gait patterns may influence the potential for slip initiation. For example, previous studies

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have shown that peak COF_U varies with age [8], gender [8], walking speed [8–10], and the presence of a disability [11]. Those with a disability would appear to be at potentially greater risk owing to the larger changes in gait characteristics and GRFs. To date, only one published study has examined the influence of various medical conditions on peak COF_U. Buczek et al. [11] found that persons with a disability had higher peak COF_U during level walking when compared to persons without a disability. Only nine persons with disabilities participated in this study and data were averaged across various diagnoses (e.g., amputations, broken leg, osteotomy of the fifth metatarsal). In addition, this study did not systematically examine medical conditions likely to be prevalent in older adults nor did it examine COF_U values across a series of walking tasks necessary to function in most work and home environments.

The purpose of the current investigation was to compare COF_U between persons with and without a disability during selected walking conditions. It was hypothesized that the peak COF_U of older persons who have medical conditions that might influence their gait (osteoarthritis, diabetes mellitus, and cerebral vascular accident) would exceed those of younger and older healthy controls during level walking, and while negotiating stairs and turns. Data from this study may be used to guide recommendations related to flooring modifications and environmental design to reduce the risk of injuries related to slips and falls.

2. Methods

2.1. Subjects

Community-dwelling adults were divided into five groups based on medical diagnosis and age (Table 1). Thirty-eight subjects, over the age of 55 years, were assigned to one of the following four groups based on medical history: CVA (sustained a unilateral stroke), DM (diagnosis of diabetes mellitus), ARTH (presence of lower extremity arthritis), SENIOR (healthy). A fifth group, YOUNG, consisted of 10 healthy adults between the ages of 20 and 40 years. The three diagnostic groups (CVA, DM, and ARTH) were selected as they are among the top five conditions that persons over 70 years of age identified as limiting their ability to perform activities of daily living [12]. Additionally, altered gait and ground reaction force patterns might arise due to the presence of weakness (CVA, ARTH, DM), reduced sensation (CVA, DM), impaired motor control (CVA), and pain (ARTH).

Subjects were recruited by word of mouth from the student and faculty population at the University of Southern California (Los Angeles, CA) and from medical facilities around the greater Los Angeles area. Only subjects capable of walking with minimal to no physical assistance across level surfaces and on stairs were included. Subjects with relatively high ambulatory function were selected as they were expected to be the individuals most likely to navigate a variety of situations that might pose a slip risk.

Persons in the CVA group were greater than 6 months post a unilateral cerebral vascular accident (diagnosed by a physician) and lacked selective control of the involved lower extremity. Individuals in the DM group had been diagnosed by a physician as having either insulin dependent or non-insulin dependent diabetes mellitus, and demonstrated evidence of peripheral neuropathy (reduced sensation based on a Semmes–Weinstein monofilament testing and bilateral reductions in calf strength as documented by an inability to complete five unilateral heel raises). Subjects in the ARTH group had a physician diagnosis of lower extremity osteoarthritis (hip or knee) which had been previously documented by X-ray or MRI. Subjects with lower limb amputation, joint replacement, or additional neurologic conditions that would influence gait were excluded from participation. In addition, potential subjects were excluded if they had medical conditions that would qualify them for more than one group (e.g., a history of diabetes mellitus and stroke).

Subjects in the SENIOR and YOUNG groups had no neurologic or orthopaedic conditions that would alter gait, and denied any history of stroke, diabetes mellitus, or osteoarthritis. Prior to participation, each subject was fully informed of the nature of the study, and signed a human subject's consent form approved by the Institutional Review Board of the University of Southern California Health Sciences Campus.

Table 1
Subject characteristics (mean (S.D.))

	SENIOR (n = 10)	CVA (n = 10)	ARTH (n = 8)	DM (n = 10)	YOUNG (n = 10)
Age (years)	72.5 (8.7)	62.7 (7.2)	68.9 (11.8)	69.7 (5.5)	28.8 (4.5)
Gender	5 females, 5 males	2 females, 8 males	7 females, 1 males	4 females, 6 males	5 females, 5 males
Height (cm)	164.0 (11.6)	174.9 (10.2)	167.0 (9.3)	163.1 (11.6)	171.8 (7.4)
Mass (kg)	73.0 (17.1)	83.7 (18.9)	71.7 (18.4)	71.1 (18.8)	74.2 (24.2)
Involved limb	10 left	2 right, 8 left	3 right, 5 left	10 left	10 left
Assistive device used	None	4 cane	1 cane	None	None
Assistance required	Independent	SBA on stairs	Independent	Independent	Independent

SBA: stand-by assistance.