Gait & Posture 34 (2011) 529–532

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

# Relationship between stair ambulation with and without a handrail and centre of pressure velocities during stair ascent and descent

Samantha M. Reid [a], Alison C. Novak [b], Brenda Brouwer [a,b], Patrick A. Costigan [a,b,*]

[a] School of Kinesiology and Health Studies, Queen's University, Kingston, ON, Canada
[b] School of Rehabilitation Therapy, Queen's University, Kingston, ON, Canada

ARTICLE INFO

*Article history:*
Received 26 July 2010
Received in revised form 9 July 2011
Accepted 11 July 2011

*Keywords:*
Centre of pressure
Stair negotiation
Older adults
Fear of falling
Handrail
Balance

ABSTRACT

*Introduction:* Stair ambulation is one of the most challenging and hazardous types of locomotion for older adults and often requires the adoption of compensatory strategies such as increased handrail use to mitigate disability and increase stability. Centre of pressure velocity (VCOP) describes the neuromuscular response to shifts of the body's centre of mass and serves as an indicator of stability. Knowledge of VCOP may provide some understanding of strategies to improve measured and perceived stability during stair negotiation. The aim of this study was to compare VCOP during stair ascent and descent with and without a handrail in young, older and older adults with a fear of falling (FOF) populations.

*Methods:* COP velocities of 23 young adults (23.7 ± 3.0 yrs), 26 older adults (66.4 ± 8.3 yrs), and 3 older adults with FOF (80.2 ± 8.0 yrs) were analyzed while they ascended and descended a custom 4-step staircase. VCOP were obtained using a force plate mounted on concrete blocks centered on the second step of the staircase.

*Results:* During stair ascent and descent with and without a handrail, the VCOP between young and older adults were comparable. The three adults with FOF demonstrated reduced VCOP during ascent and descent without the handrail and even slower VCOP when ascending and descending stairs with the handrail. These results suggest that handrail use does not increase biomechanical stability for healthy, older adults. However, in the presence of fear of falling the use of the handrail enhances dynamic stability, particularly during stair descent.

*Conclusions:* This study provides the first detailed description of dynamic stability during stair ambulation with and without a handrail. Observations from those with FOF aid in understanding the nature of compensations to improve actual and perceived stability.



## 1. Introduction:

Older adults are often forced to adjust their gait patterns during stair ambulation due to decrements in muscular strength [1–3], decreases in proprioceptive acuity [1], and impaired balance [2,3] associated with age and disease [4,5]. As a result, compensatory gait strategies are often adopted to counterbalance or offset a disability or perceived disability. In general, alternate gait patterns [use of handrail and/or alternate stepping patterns] adopted by older adults during stair ambulation tend to deviate from the traditional step-over-step (SOS) pattern used by young, healthy individuals. These deviations in stair gait patterns result in higher energy costs and lower efficiency particularly during stair descent [5,6].

There are several variations of stair climbing patterns, one of which is the use of the handrail. A handrail is a multipurpose tool that provides both physical and psychological support that may prevent falls after a trip or slip [7], decrease loads through the lower limb, or simply augment stability while negotiating stairs [5]. Only a few studies have investigated the joint kinematics and kinetics of stair ambulation with and without a handrail [8,9]. However, they do not address the issue of stability which is of concern among older adults.

Dynamic stability during gait is the ability to control one's centre of mass (COM) within a moving base of support [10–12]. Centre of pressure (COP) has been defined as the neuromuscular response to shifts in the body's COM and measures of COP have been used as an indicator of dynamic stability [10,12]. Previous studies have quantified displacement of the COM and COM–COP separation during level walking [13] and stair ambulation [11,14]. Only one study has assessed age-related changes of the COP trajectory during stair descent. Kim [12] reported that older adults displayed significantly less anterior–posterior and medio-lateral

* Corresponding author at: School of Kinesiology and Health Studies, Biomechanics and Ergonomics Laboratory, Queen's University, Canada K7L 3N6.
Tel.: +1 613 533 6601; fax: +1 613 533 2009.
*E-mail address:* pat.costigan@queensu.ca (P.A. Costigan).

0966-6362/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.gaitpost.2011.07.008

displacements of the COP and reduced VCOP compared to their younger counterparts, indicating that slower COP movement may be beneficial in maintaining dynamic stability while a faster COP motion may make it more difficult to maintain stability [12]. Currently, we have little understanding of stability during various stair negotiation strategies in older adults. A detailed analysis of VCOP associated with various strategies of stair descent in older adults is important in establishing normative data, understanding the relative merits of different stair negotiation strategies, and lastly, may aid in the identification of risk factors associated with falls during stair ambulation.

The objective of this investigation was to assess VCOP during stair ascent and descent in healthy young and older adult populations using the traditional SOS pattern with and without a handrail, to provide normative data as well as identify which strategies of stair negotiation provide more stability. Observations from a few subjects with a fear of falling (FOF) are included to demonstrate the impact of fear of falling on measures of dynamic stability.

## 2. Methods

### 2.1. Participants

Twenty-three (6 M) young adults and twenty-six (13 M) older adults were recruited for the study. In addition, three older adults with FOF were also examined. All participants were free from any lower limb orthopaedic or neurological condition affecting their walking ability. Participants with FOF responded yes to the questions 'do you have a lasting concern a about falling causing you to avoid/curtail activities that you felt capable of doing' and; 'do you have concerns about using the stairs' [15,16]. The University Research Ethics Board approved the procedures and all participants provided informed, written consent.

### 2.2. Gait analysis

Participants completed three stair ascent and three stair descent trials at a self-selected pace with and without a handrail. Ground reaction forces were recorded with a force plate (AMTI, Newton, MA, USA) mounted on concrete blocks centered on the second step of a standard dimension four-step staircase (rise: 15 cm, run: 26 cm, width: 56 cm). The removable handrail was placed on the non-dominant hand-side of the staircase for both ascent and descent and their dominant leg was tested in all participants. Participants were instructed to use the handrail simply for guidance rather than for assistance, specifically they were asked not to pull during ascent or to accept their body weight during descent. Force plate data were sampled at 100 Hz, filtered using a second order, low pass Butterworth filter with a cutoff frequency of 6 Hz and processed using custom software developed using Matlab R2007a (The Math Works Inc., Natick, MA, USA). The gait cycle was defined from foot contact of the test leg to subsequent foot contact of the same test leg, forming a stance-swing sequence with the stance phase on the force plate step. Upon completion of the stair ascent and descent tasks, older adults and adults with FOF were asked to identify which was their most preferred method for ascending and descending stairs.

### 2.3. Data processing

Custom software, developed using Matlab R2007a (The Math Works Inc, Natick, MA, USA), was used to process the data. The COP was defined as the point of application of the ground reaction force (GRF) vector on the force platform [10]. For each participant, we calculated the location of the centre of pressure in the anterior-posterior ($COP_{AP}$) and medio-lateral directions ($COP_{ML}$), the corresponding velocities in those directions ($VCOP_{AP}$ and $VCOP_{ML}$, respectively) and the velocity of the net centre of pressure (VCOP). For all these parameters, the average velocity computed over the stance phase was the outcome variable.

Differences between conditions for the COP parameters were tested using a three way ANOVA with repeated measures of condition (no handrail/handrail), direction (ascent/descent), and a between subject factor (SPSS 17, SPSS, Chicago, IL, USA). Following the identification of a significant interaction effect, paired *t*-tests were used to identify the source of the difference. Statistics were not performed on adults with FOF; due to the small sample size, only observations were made.

Lastly, the older adults and older adults with FOF completed three questionnaires: the Activities Specific Balances Confidence (ABC) Scale [17], Human Activity Profile (HAP) [18,19], and the Stair Self-Efficacy Scale (SSE) [20], to assess their balance confidence, activity levels and self-efficacy, respectively.

## 3. Results

### 3.1. Participants

Participant characteristics are summarized in Table 1. Both the older adults and older adults with FOF chose handrail use as their most preferred method when ascending and descending the stairs, further indicating no preference regarding the side of handrail use.

### 3.2. Cadence of stair ascent and descent

Stair cadence was not different between the young & older adults ($p = .16$) but differed between directions ($p \leq .001$) reflecting faster descent than ascent. There was no main effect of handrail use on cadence ($p = .67$); however, in young adults, using the handrail reduced the cadence ($p = .024$). In comparison to the older adults, older adults with FOF appeared to ascend and descend the stairs with a lower cadence and handrail use increased their stair cadence in both ascent and descent (Table 2).

### 3.3. COP velocity: healthy young and older adults

There was no difference in VCOP during stair ascent between the young and older adults ($p = .143$). However, there was interaction between handrail condition and direction ($p = .024$) and post hoc analysis revealed that handrail use increased VCOP by an average of 1.4 cm/s during ascent only. Similar to stair ascent, there was no difference between the young and older adult groups for stair descent ($p = .143$). Investigation of $VCOP_{ML}$ and $VCOP_{AP}$ did not reveal any significant differences between groups or handrail conditions for either stair ascent or descent ($p > .130$, $p > .053$, respectively).

Although there were no differences due to handrail use, there were differences between ascent and descent indicating a reduced VCOP during stair ascent ($p < 0.001$). Data are summarized in Table 2.

### 3.4. COP velocity: adults with a fear of falling

The older adults with FOF show a reduced VCOP during stair ascent compared to the healthy young and older adults (Table 2). However, similar to the young and older adults, those with FOF demonstrated no change in VCOP during stair ascent with a

**Table 1**
Participant characteristics.

| | Age (years) | Height (cm) | Weight (kg) | ABC | HAP | SSE |
|---|---|---|---|---|---|---|
| Young adults | 23.7 (3.0) | 171.2 (7.7) | 62.7 (10.8) | – | – | – |
| Older adults | 66.4 (8.3) | 170.5 (8.7) | 71.5 (10.2) | 93.5 (5.4) | 78.1 (12.5) | 9 (0.78) |
| Fearful of falling older adults | 80.2 (8.0) | 166.7 (3.6) | 66.9 (16.0) | 77 (10.7) | 47.3 (17.7) | 6 (0.31) |

All values are presented as means (SD).
ABC, Activities Specific Balance Scale [15]; HAP, Human Activity Profile (HAP) adjusted activity scores [16,17]; SSE, Stair Self Efficacy Scale [18].
Young adults did not complete ABC, HAP or SSE questionnaires.