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ORIGINAL ARTICLE

Effects of Age and Gender on Dynamic Stability During Stair Descent

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Abstract

Objective: To determine the effects of age and sex and their interaction effects on dynamic postural stability during stair descent.

Design: Cross sectional.

Setting: Laboratory.

Participants: Healthy younger adults (N=28) and healthy older adults (N=21).

Interventions: Not applicable.

Main Outcome Measures: Spatiotemporal gait parameters, displacement of center of mass (COM), instantaneous velocity of the COM, divergence between vertical projection of the COM, and center of pressure (COP).

Results: Interaction effects of age and sex were found in stride duration, COM displacement, and instantaneous velocity of the COM in the mediolateral direction. Older adults demonstrated longer stride duration with shorter double-limb stance and longer single-limb stance during stair descent. Women have significantly longer stride duration than men. The effects of sex and age were significant in the data normalized by height. Older adults and women demonstrated larger peak-to-peak COM displacement, peak instantaneous velocity of the COM, and COM-COP divergence than the younger individuals and men, respectively. Peak instantaneous velocity of the COM was significant different in most pairwise comparisons, but the COM-COP divergence was significantly different in several comparisons.

Conclusions: This study examined the COM and COP parameters to quantify dynamic stability during stair descent across sex and age. Although older women descended stairs successfully, they demonstrated differences in control of instantaneous velocity of the COM compared with the other participants. Dynamic instability could be detected by examining the control of instantaneous velocity of the COM. In developing a better understanding of the balance control of stair descent in healthy older adults, aging patients with various pathologies can be better assessed, appropriately treated, and provided with proper assistive devices.

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The high percentage of accidents in older adults during stair negotiation is a matter of some concern because the resulting injuries can be serious and lead to permanent disability and drastic changes in lifestyle.[1-5] Svanström[6] reported that accidents during stair descent outnumber those during ascent by >3 to 1 (77% vs 23%), similar to the results of the more recent research by Startzell et al.[5] Therefore, more efforts have been put on the investigation of body mechanisms and possible biomechanical/environmental factors contributing to the changes in these mechanisms in stair descent, particularly in older adults.[7-15]

Most studies about the effect of age on stair descent focus on kinematics and kinetics,[10,14,16-22] muscle activities,[12,22-25] or the relation between the ability to ascend/descend stairs and muscle strength of the lower extremities; these studies used stair climbing to describe the changes in functional performances.[24,26,27] Only a few studies have directly focused on balance control in terms of the center of mass (COM) and center of pressure (COP) during stair descent.[17,28-31] Researchers have proposed that collaborative interpretation of the COM and COP can give a more complete assessment than examining COP and COM separately.[17,28-30] The rationale is that the body is in a more optimal and stable position when the COM is closer to the point of support or COP. Zachazewski et al[28] found greater COM-COP separation and shorter double-support phases in stair descent than stair ascent, which

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might indicate more instability in stair descent. Lee and Chou[29] discovered that the peak COM sway velocity was significantly larger in older men than younger men.

Although epidemiologic research indicates that older women appear to be at greater risk of falls and stair injury than older men,[6,32,33] there is limited research focusing on sex differences in older individuals.[24] Sex differences in walking biomechanics and possible related factors have been identified for level walking and running in a young population, but the reported differences in gait spatiotemporal parameters, kinematics, and kinetics of the lower extremity remain controversial.[34-38] No sex differences have been found in quiet standing, functional reach, or single-limb stance (SLS),[39-43] but women have been found to have poorer performance in functional activities or more challenging tasks (eg, timed Up and Go test,[44,45] time of maintaining 1-legged stance or sharpened Romberg stance,[46,47] inaccurate visual and somatosensory inputs,[39] balance recovery from released forward leans[48]). To our knowledge, no biomechanical studies to date have been conducted to compare the differences in stair locomotion between sexes, in either younger or older individuals.

The specific aims of this study were as follows: (1) to determine the interaction and main effect of age and sex on dynamic stability by investigating the displacement and instantaneous velocity of the COM and relative positions between vertical projection of the COM and COP in younger and older adults, and (2) to determine which parameters were more sensitive in detecting the differences among younger and older adults and men and women in stair descent. This knowledge may provide evidence-based data for epidemiologic findings and aid health care professionals in evaluating and training older adults in stair negotiation; it may also aid in the training of those who are responsible for planning the urban environment for older adults.

Methods

The younger and older adult volunteers were recruited via oral or written announcements made throughout the campus of a university and churches and community centers, respectively. The potential participants were interviewed about their medical history and health. Those who met the inclusion criteria were informed of the general purposes of the study.

The inclusion criteria were as follows: being able to ascend and descend stairs without using any assistive device or the handrail; not having any current orthopedic problems, neurologic diseases, dizziness, or major visual deficits; and having no history of falling. Each participant read and signed an informed consent approved by the institutional review board. Sample sizes were estimated based on the effect sizes calculated from the normalized instantaneous velocity of the COM and COM-COP divergence of the first 16 participants to obtain an α level of .05 and a statistical power of .80 while detecting the main effect of age and sex. At least 20 participants were needed in each age or sex group. Twenty-eight healthy younger adults (12 men, 16 women) aged <40 years and 21 older adults (10 men, 11 women) aged >65 years were included and divided into 4 groups based on age and sex: younger women, older women, young men, and older men. The participants' characteristics are presented in table 1.

A 5-step wooden staircase with a slope of 32.7° and a step height, tread depth, and width of 18, 28, and 90cm, respectively, was used.[32,49] The fifth step was created by a 240-×90-cm platform. Two portable force plates,[a] sampling at 1000Hz, were secured on the second and third treads; an 8-camera Eagle Motion Analysis System,[b] sampling at 120Hz, was used to capture the 3-dimensional trajectory data of the 25 reflective markers (modified Helen Hayes marker set) affixed to the participant's anatomic landmarks.

All participants were asked to wear a tight-fitting tank top and shorts while testing. Because the older people might feel insecure about descending the stairs barefoot, all participants wore their soft casual shoes, with heels <1cm. The participants descended at their own self-selected speed with a reciprocal pattern. Practice trials were allowed before data acquisition, and a 5-minute break was allotted between the practice session and formal data collection to avoid fatigue. One investigator stood close to the staircase to protect the participant in case they tripped or fell.

One stride cycle began with foot contact on step 3 and terminated with foot contact of the same foot on the first step. The data were normalized to a stride period of 100% to determine the temporal percentage of stance and swing phases in 1 stair descent gait cycle. A 14-segment model with the anthropometric data provided by Ho et al[50] was used to calculate the overall COM. Walking speed was calculated from the change in position of the COM in the direction of progression and the corresponding time change during a complete stair descent stride. The raw (absolute) data were normalized by body height to remove stature differences. A modified stair descent gait cycle consisted of the SLS of each foot (SLS of the leading leg, SLS of the trailing leg) and a double-limb stance (DLS) to describe the divergence of the COM and COP (fig 1). All the participants were healthy younger and older adults and walked symmetrically; therefore, the SLS of the leading leg was equal to the SLS of the trailing leg.

Each dependent variable was averaged over 4 trials with similar walking speeds. Statistical analyses were performed on both absolute and normalized data. Descriptive statistics were calculated for the time-distance parameters, peak-to-peak values of the COM, peak values of the instantaneous velocity of the COM, and COM-COP divergence. Two-way analysis of variance was used to examine the effects of age and sex on the variables. A significance level of .05 was adopted. Pairwise comparisons were acquired via 1-way analysis of variance with Scheffe adjustment for each dependent variable. All data were analyzed using SPSS version 17.0 for Windows.[c]

Results

Spatiotemporal parameters

Although all participants walked at their comfortable speeds, the stride characteristics were significantly different between the

Table 1 Age, body mass, and height of the 4 groups

Group	Age (y)	Mass (kg)	Height (cm)
Younger women (n=16)	28.7±5.6	52.4±6.4	159.3±6.4
Older women (n=11)	70.4±4.4	54.0±9.0	152.9±3.0
Younger men (n=12)	23.3±0.7	72.2±11.0	174.0±7.6
Older men (n=10)	72.1±5.3	67.6±6.6	166.8±5.8

NOTE. Values are mean ± SD.

List of abbreviations:

AP anteroposterior
COM center of mass
COP center of pressure
DLS double-limb stance
ML mediolateral
SLS single-limb stance