Stair Performance in People Aged 75 and Older

Kathryn A. Hamel, PhD,* and Peter R. Cavanagh, PhD†

OBJECTIVES: To examine specific behaviors used by older adults while ascending and descending stairs and to assess the relationships between confidence and stair performance.

DESIGN: Cross-sectional.

SETTING: Center for Locomotion Studies, The Pennsylvania State University.

PARTICIPANTS: Sixteen male (mean age = 82.7, range = 77–89) and 16 female (mean age = 82.2, range = 77–87) community-dwelling adults.

MEASUREMENTS: A stair self-efficacy (SSE) test was created to assess individuals’ confidence in their safety on stairs. Observational stair performance measures, measures of walking speed on stairs, and the total SSE score were examined for differences due to sex, and the relationships between SSE and specific stair behaviors were assessed.

RESULTS: There was a significant relationship between SSE and the safety precautions taken during stair negotiation. Those with lower SSE were more likely to ascend and descend the stairs at a slower speed, use the handrail to a greater extent, and position themselves closer to the rail. The women had lower domain-specific SSE and tended to use the handrail to a greater extent than men even though there were no sex differences in self-reported functional ability or general falls and mobility confidence. A small group of subjects exhibited characteristics of instability, particularly during stair descent, yet most of this group had high SSE scores and failed to use the handrail.


Key words: stairs; aging; self-efficacy; falls; trips

From the *Department of Physical Therapy and Rehabilitation Science, University of California at San Francisco, San Francisco, California; and †Department of Biomedical Engineering, The Cleveland Clinic Foundation, Cleveland, Ohio.

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Address correspondence to Kathryn A. Hamel, Department of Physical Therapy and Rehabilitation Science, University of California at San Francisco, Box 0625, San Francisco, CA 94143.
E-mail: hamelk@ptrehab.ucsf.edu

A recent study in the United Kingdom found that approximately 20,000 hospitalizations and 900 deaths occurred each year in those aged 65 and older due to falls on stairs or steps.1 The number of deaths each year in the United States for stair and step-related falls is similar to the U.K. number.2 This is remarkable given that the United Kingdom has one-fifth the population of the United States and suggests that U.S. data may greatly underestimate the number of fall deaths related to steps and stairs. In the U.K. study,1 the death rate was shown to increase dramatically for those aged 65 and older, and when the number of deaths was normalized per million men or women in each age-band per year, men had a substantially higher death rate than women in every age category, whereas women had a substantially higher rate of injury than men.

The majority of biomechanical studies that have investigated age-related changes in gait have primarily used older adult subjects younger than 75.3–10 There are numerous reasons for this, including the need for strict exclusion criteria to determine true age-related changes in performance, the often lengthy and tiring process of biomechanical data collection, and difficulty in recruiting those aged 80 and older to participate in a laboratory-based study. Given that the injury rate and death rate for falls on stairs greatly increases for those aged 75 to 84 and then nearly doubles again for those aged 85 and older,1 further research is clearly necessary regarding fall mechanisms for this segment of the population.

Several researchers have applied the concept of self-efficacy, which relates to how confident a person is that he or she can perform specific activities, to fear of falling in the elderly.11–14 Most instruments have assessed self-efficacy levels regarding falling during activities of daily living (ADLs), and only a few studies have related actual performance variables to self-efficacy scores.13–15 Although scales such as the Falls Efficacy Scale11 and the Activities-specific Balance Confidence (ABC) Scale12 include items related to walking up or down stairs, stair efficacy is not assessed independent of other ADLs. Given that self-efficacy is domain specific and stair use is a risky task for the elderly, development of a stair self-efficacy (SSE) scale and investigation of the relationship between stair efficacy and behavior seems warranted.

In a person with adequate physical capacity, a certain level of confidence in stair negotiation may facilitate continued use of stairs, whereas a lack of confidence may...
reduce stair use. Conversely, a high level of stair efficacy in a functionally limited person may increase risky behavior on stairs (not using handrail, rushing, etc.), which could lead to a fall. For a given functional capacity, there may be a particular level of efficacy that is adequate for maintaining safe but continued stair use. Although one stair-related efficacy scale, the Stair-Falls Efficacy Test, has been reported in the literature, the authors did not relate the SSE score to actual stair performance.

Given the need to study adults aged 75 and older, particularly during performance of challenging ADLs, this study was designed to examine factors that may affect safe stair negotiation in this segment of the population. The primary objectives of this study were to develop and pilot test a SSE scale and to assess the relationship between SSE and actual stair performance.

METHODS

Subjects
Thirty-two subjects (16 men: mean age = 82.7, range = 77–89, mean height ± standard deviation = 172.2 ± 8.4 cm, weight = 74.0 ± 12.0 kg; 16 women: mean age = 82.2, range = 77–87, height = 157.1 ± 7.7 cm, weight = 56.4 ± 8.7 kg) who were living independently in the community were recruited to participate in the study from advertisements in the local newspaper and an in-house database of older subjects. Subjects were initially screened over the phone using a set of questions regarding ADL-type tasks broken down into functional domains. These scores of reported difficulty in each functional domain were used to ensure a wide range of functional levels for men and women (see Results for details). Exclusion criteria for the study included history of a stroke, Parkinson’s disease, current vestibular disorder, or Ménière’s disease and the inability to go up or down stairs. The median number of prescription medications used by the subjects on a daily basis was three (range 0–6). Thirty-four percent of the subjects had a history of lower extremity surgery or fracture within the last 5 years, 28% had been diagnosed with arthritis in one or both lower extremities, 59% had vision problems, 31% had heart disease, 43% had intermittent back pain, and 13% had pulmonary disorders.

Study Protocol
Each subject completed two self-efficacy questionnaires: the ABC scale and the SSE scale developed for this study. The SSE questionnaire consisted of 10 questions assessed on an 11-point continuum (0–10), with a score of 10 equal to complete confidence for that item. All questions except one were phrased as: “How confident are you that you can…without losing your balance?” Questions included items such as walking up or down stairs in your own home, stairs that are poorly lit, going down stairs rapidly, going up or down stairs without a handrail, and using outdoor stairs or steps. An additional question assessed how confident subjects were that they could recover from a loss of balance on stairs to prevent a fall.

To gain information on stair behavior in a short visit to the laboratory, a data collection system was designed in which eight small video cameras simultaneously recorded specific views of the subject’s gait. Through the use of a Sony YS-DX316 multiplexer (Tokyo, Japan), all eight video signals were recorded at a reduced frame rate on a single videotape, enabling the data from any camera to be viewed individually at a later date. To analyze the videos, a subjective scoring system was devised that included rating the following factors as a person ascended or descended the stairs: handrail use, walking style (two feet per step or step over step), sideways positioning on the stairs, medial/lateral position on the stairs, assessment of exaggerated frontal plane movement of the upper body, and hesitation at the transition region (Table 1).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Scoring Description</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Handrail use</td>
<td>No use at all</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Use at transition or occasional touch</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Constant brushing rail with tips of fingers</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Light, continuous grasp</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Firm grasp of rail</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Aggressive pulling/pushing</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Two hands</td>
<td>6</td>
</tr>
<tr>
<td>Walking style</td>
<td>Step over step (one foot on each stair)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Two feet on each stair</td>
<td>1</td>
</tr>
<tr>
<td>Medial/lateral position on stairs</td>
<td>In middle of stairway (or further from rail)</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Between middle and rail</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Close to, or hugging the rail</td>
<td>2</td>
</tr>
<tr>
<td>Sideways</td>
<td>Facing directly up or down stairs</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Facing railing</td>
<td>1</td>
</tr>
<tr>
<td>Hesitation at initial transition from</td>
<td>No hesitation</td>
<td>0</td>
</tr>
<tr>
<td>landing to stairs</td>
<td>Hesitation</td>
<td>1</td>
</tr>
<tr>
<td>Upper body frontal plane movement</td>
<td>Stable upper body movement</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Unstable upper body movement</td>
<td>1</td>
</tr>
</tbody>
</table>
Each subject completed up to five stair-ascent and five stair-descent trials on a seven-step staircase. The subjects were harnessed into an overhead gantry system to prevent a fall from occurring after a slip or trip. Each trial was completed at the subject’s own self-selected speed, which was measured using photocells located on the second and seventh steps from the top landing.

Data Analysis and Statistics
Interrater reliability for two raters of the observational stair parameters scoring system was evaluated by calculating the Cohen kappa statistic. Both raters were blinded to the stair efficacy scores until after the observational stair scoring was completed. Cronbach alpha was used to test the internal consistency of the SSE, along with item-total correlations and the correlation between the ABC and SSE scores. For the observational stair parameters, the scores of the lead investigator were used for all assessments. The mode (if the observational variable was binary) or the median (if the observational variable was ordinal) of each parameter was calculated for each block of five stair-ascent and five stair-descent trials within each subject. Linear regression and ordinal and binary logistic regression models were used to examine the relationships between stair negotiation speed or certain objective stair parameters and the total SSE score. The average ABC scores and the SSE scores were tested for significant differences due to sex using two-sample independent t tests. Sex differences in the binary observational stair parameters such as walking style, sideways position, hesitation at the transition, and upper body instability were determined using the chi-square ($\chi^2$) test statistic or the Fisher exact test if the expected cell frequencies were below five. Sex differences in the ordinal dependent variables such as handrail use, medial/lateral position on the stairs, and the functional ADL score were tested for significance using the Kruskal-Wallis test statistic. Differences between stair ascent and descent were explored using the chi-square test for binary variables or the Friedman test for those measures that were ordinal variables. Statistical tests were performed using MINITAB (Minitab Inc., State College, PA) and SAS (SAS Institute, Inc., Cary, NC).

RESULTS
Twenty-six of the 32 subjects had stairs in their homes, and 25 subjects reported that they used stairs at least once per day. Nine of the subjects recalled falling at least once on stairs. The median number of ADL tasks with which the subjects had difficulty was one for both men and women (Kruskal-Wallis: $P = .390$), indicating that there was no significant difference in self-reported functional level between men and women. The range of scores for difficulty with ADLs was zero to six tasks for the women and zero to four tasks for the men.

Psychometric Properties

Stair Self-Efficacy
Cronbach alpha was 0.79 for the SSE and was unchanged after stepwise deletion of each question, indicating good internal consistency of the scale. The item-total correlations ranged from 0.83 to 0.92. The total SSE scores for all subjects ranged from 9 to 97, with a mean $\pm$ standard deviation of 65.9 $\pm$ 22.6. The total SSE score was strongly correlated with the ABC score ($r = 0.727$, $P < .001$), whereas the number of ADL tasks a person had difficulty with accounted for only 26.5% of the variance in total SSE score (coefficient of determination ($r^2$) = 0.265, $P = .003$).

Observational Stair Scores
The Cohen kappa statistic, which was used to assess the interrater reliability of the observational stair scores, ranged from 0.60 for fronto-plane motion during stair ascent and descent to 1.0 for walking style (two feet on each step or step over step). Handrail-use scores had high interrater reliability, with weighted kappas of 0.92 for ascent and 0.88 for descent. Medial/lateral position on stairs and sideways positioning scores were 0.7 or greater for ascent and descent, whereas hesitation scores and instability of the upper body in the frontal plane were lower and ranged from 0.60 to 0.66.

Relationship Between SSE and Stair Performance

Stair Negotiation Speed
The total SSE score was moderately correlated with average stair descent speed ($r = 0.464$, $P = .007$) and average stair ascent speed ($r = 0.349$, $P = .050$). Subjects with lower SSEs tended to walk more slowly.

Observational Stair Measures

Confidence in stair negotiation was associated with two observational performance measures (Table 2). There was a significant relationship between SSE score and median handrail-use score for stair descent ($P = .001$, odds ratio (OR) = 1.07, Goodman-Kruskal gamma = 0.61). Subjects

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stair ascent speed, $R^2$</td>
<td>0.216</td>
<td>.007</td>
</tr>
<tr>
<td>Stair descent speed, $R^2$</td>
<td>0.122</td>
<td>.050</td>
</tr>
<tr>
<td>Stair ascent median handrail use, OR (95% CI)</td>
<td>1.06 (1.03–1.10)</td>
<td>.001</td>
</tr>
<tr>
<td>Stair descent median handrail use, OR (95% CI)</td>
<td>1.07 (1.03–1.11)</td>
<td>.001</td>
</tr>
<tr>
<td>Stair ascent medial/lateral position on stairs, OR (95% CI)</td>
<td>1.05 (1.01–1.09)</td>
<td>.013</td>
</tr>
<tr>
<td>Stair descent medial/lateral position on stairs, OR (95% CI)</td>
<td>1.04 (1.01–1.07)</td>
<td>.051</td>
</tr>
<tr>
<td>Stair descent upper body frontal plane movement, OR (95% CI)</td>
<td>1.02 (0.98–1.07)</td>
<td>.265</td>
</tr>
</tbody>
</table>

$R^2$ = coefficient of determination; OR = odds ratio; CI = confidence interval.
The median and mode scores from the observational measures for five trials during stair ascent and descent are broken down into frequency distributions in Table 3. Although there was a wide range of stair confidence levels among subjects in the study, the majority of the subjects were capable of negotiating the stairs efficiently.

In general, the women had a tendency to take greater precautionary measures when negotiating the stairs, particularly during descent. Although there was no significant sex difference in median handrail use score during stair ascent (Kruskal-Wallis, $P = .222$), evidence of caution in women was seen in the trend toward a significant sex difference during stair descent and the higher median handrail use scores of women (Kruskal-Wallis, $P = .077$). When handrail score was dichotomized to did not use the rail (0) or used the rail in any manner (1), six men and 10 women used the rail going up the stairs ($\chi^2, P = .157$), whereas eight men and 13 women used the rail going down the stairs ($\chi^2, P = .063$). There were no significant sex differences for the median medial/lateral position on the stairs for ascent (Kruskal-Wallis, $P = .744$) or descent (Kruskal-Wallis, $P = .238$). For walking style during stair negotiation, no one used the two feet on each stair pattern during stair ascent; whereas two women placed two feet on each stair during all five of their stair descent trials. All other subjects used a normal, step-over-step pattern of stair negotiation. No one faced the railing during stair ascent, but during stair descent, three women turned their bodies toward the rail. Two of these three women were the same ones who used the two-feet-per-step walking style for stair descent. Only one female subject hesitated at the lower transition region during stair ascent; she was one of the four women who hesitated at the upper landing transition region during stair descent. There was a significant sex difference for hesitation at the transition region during stair descent, with no men but four women hesitating (Fisher exact test, $P = .050$). There were no significant sex differences in upper-body frontal-plane instability during stair ascent (1 man, 1 woman unstable) or stair descent (6 men, 2 women; Fisher exact test, $P = .11$).

### Stair Ascent Versus Stair Descent

**Stair Ascent**

Sex Differences: There were no significant sex differences in the measured speeds of stair ascent (men: average $= 0.51 \pm 0.09$ m/s, range $= 0.40-0.73$ m/s; women: average $= 0.49 \pm 0.13$ m/s, range $= 0.27-0.81$ m/s; $P = .51$) or stair descent (men: average $= 0.56 \pm 0.16$ m/s, range $= 0.33-0.93$ m/s; women: average $= 0.48 \pm 0.17$ m/s, range $= 0.23-0.88$ m/s; $P = .16$). The women had significantly lower total SSE scores ($58.1 \pm 25.1$) than the men ($73.6 \pm 17.3$) ($P = .052$), but there was no significant difference in the ABC scores between the women ($75.2 \pm 22.7$) and the men ($82.4 \pm 14.1$) ($P = .29$).

**Stair Descent**

Sex Differences: There were indications that subjects exhibited more cautious behavior during stair descent than during stair ascent. (Twenty-one of 32 subjects used the handrail during stair descent, whereas only 16 used the rail during ascent; three turned sideways during descent, whereas none turned during ascent; and four hesitated at the transition region going down stairs, whereas only one hesitated going up the stairs.) No significant differences were found between stair ascent and stair descent except for a greater number of subjects exhibiting upper-body frontal-plane instability during stair descent (descent $= 8$, ascent $= 2$; Fisher exact test, $P = .04$).

### DISCUSSION

Because of self-selection bias, it is likely that the subjects in this study represent a healthy subset of the population of adults aged 75 and older. Overall, they performed well during stair negotiation despite reporting difficulty with up to six ADLs. Even though most subjects could still negotiate...
the stairs adequately, many of them had little confidence in their ability to do so safely (half scored < 70 on the SSE).

The SSE scores indicate that the women were less confident than the men in their ability to negotiate stairs safely. The sex difference in SSE was especially interesting in light of the fact that there was no significant difference in self-reported functional level or in ABC score. This indicates a need to use a domain-specific self-efficacy scale. The women tended to regard the stairs with more caution, particularly during stair descent, with a trend toward women using the handrail to a greater extent, and only women hesitated at the upper landing (4 women), used a two-footed strategy on every step (2 women), and positioned the body sideways to face the railing (3 women). Four out of the five women who exhibited all or some of these characteristics had SSE scores below 50, with one woman as low as a total score of 9 out of 100. All five of these women used the handrail continuously in some manner.

In general, as confidence decreased, the older adults took greater precautions when negotiating the stairs, such as increasing the degree of handrail use or moving closer to the railing. Of particular interest were the eight subjects who demonstrated unstable characteristics during stair descent (exaggerated frontal plane movement of the upper body). Although two of these subjects used the handrail during the entire descent phase and had SSE scores of 65 and 38, four of them did not use the handrail at all while descending the stairs, and one used the rail only briefly at the transition. Four of these five subjects who did not use the railing were male, and all five subjects had relatively high SSE scores (69, 70, 80, 84, 87, 97), suggesting overconfidence and risky stair behavior. The increased occurrence of unstable behavior during stair descent as opposed to stair ascent also suggests that observing older adults as they descend stairs may provide a simple method with which to determine who may be at risk for falling, and warrants further investigation.

An alternative explanation for these findings could be that stair efficacy and functional ability are closely linked, leading subjects with low functional abilities to feel less secure on stairs. This explanation seems unlikely in view of the sex differences in SSE but not in speed of locomotion and in the relatively low amount of explained variance in the relationship between SSE and the number of difficult ADLs.

The requirement that all subjects wear a safety harness during the stair negotiation trials limited the study. The use of the harness may have affected the subjects’ confidence while performing the trials, but the study could not have been performed without assuring the subjects’ safety in the event of a loss of balance.

Even though older adults may have a fear of stairs (as indicated by low SSE scores) and declining functional ability, those with stairs in their home are forced to use them daily. This group of older adults was quite capable of safely negotiating stairs, but their level of confidence in their abilities played a large role in determining the safety precautions they took, especially when descending the stairs. The small group of subjects who demonstrated significant instability while descending the stairs is of particular interest, given their high SSE. The potential sex differences in SSE and handrail use are important in light of the recent report from the U.K. Department of Trade and Industry, which indicates that, in people aged 75 and older, men have almost twice the death rate as women due to falls on steps or stairs in the home each year.

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REFERENCES
