J. Phys. Ther. Sci.
23: 85–89, 2011

# The Influence of a Cognitive Task on Stair Descent by Younger Adults

HYUN DONG JE, PhD[1)], SANG-YEOL MA, PhD, PT[2)], HYEONG-DONG KIM, PhD, PT[3)]

[1)]*Department of Pharmacology, College of Pharmacy, Catholic University of Daegu*
[2)]*Department of Physical Therapy, Sewoori Hospital*
[3)]*Department of Physical Therapy, College of Health Science, Korea University: #1 Jeongneung 3-dong, Sungbuk-gu, Seoul, 136-703 Republic of Korea. TEL: +82 2-940-2835, FAX: +82 2-940-2830, E-mail: hdkimx0286@yahoo.com*

**Abstract.** [Purpose] The aim of this study was to examine the center of pressure (COP) trajectory variables and response time when young adults descended stairs while simultaneously performing a concurrent secondary Stroop task that required direct attention. [Subjects and Methods] Twenty healthy young adults (10 males and 10 females) participated in the study. Each subject first completed a Stroop task while standing (baseline). Next, they stood in a predetermined position at the top of a custom-built 3-step staircase and negotiated the stairs at a self-paced speed with and without performance of a concurrent secondary Stroop task. Subjects were asked to place only one foot on each step (foot-over-foot). The response times to the secondary task and the COP trajectory with and without performance of the concurrent secondary Stroop task were measured. [Results] The Stroop task response time while descending stairs was significantly longer than the Stroop task response time during static standing. The mediolateral and anteroposterior displacements of COP and the length of COP path, as well as the average velocity of the COP, were significantly greater when subjects performed the secondary task than without the secondary task. [Conclusion] The study suggests that subjects' ability to descend stairs is lessened with the addition of the concurrent secondary attention-demanding task, and that the addition of divided attention tasks places an apparently higher demand on balance control that may prove to be challenging for subjects at high risk of falling.
**Key words:** Center of pressure trajectory, Dual-task, Stair descent

*(This article was submitted Jun. 17, 2010, and was accepted Jul. 28, 2010)*

## INTRODUCTION

Although the causes of falls among old people are many and heterogeneous, a fall on stairs is one of the most commonly reported, accounting for about 10% of total accident cases[1,2)], and the prevalence of a fall on stairs is much higher in the elderly[1,3,4)]. The likelihood of the risk of serious injury resulting from a fall on stairs is much greater for the elderly than for a fall occurring on level ground[3)].

Over the past decades, gait adjustments used to negotiate stairs have been well-studied by several investigators. Young adults show a larger range of motion and generate relatively higher moment at the knee and ankle joints during stair descent than during level walking[5–7)]. The peak moment generated at the knee joint during stair negotiation is three times higher than the one for level walking[7,8)]. Older adults demonstrate a similar peak vertical ground reaction force[9,10)] and knee joint moment, as well as similar angle changes in plantarflexion and dorsiflexion of the ankle joint while descending stairs[11)], but older adults show lower ankle joint moment than young adults[11)]. A greater joint angle in the ankle, knee, and hip, as well as greater motion of the pelvis in the frontal and transverse planes during stair descent, was also observed in the elderly, as compared to young adults[5,6,12,13)].

Attention refers to information processing capacity[14)], space[15)], or resources[16)] available to an individual, which are thought to be limited[17)]. Attention can be allocated to different tasks in any way the individual decides, and is believed to play an important role in balance control during walking. If the attention capacity of any individual is challenged, then timely corrective or adaptive strategies while negotiating stairs may consequently be compromised by a slowing of the information-processing speed to perform either task[18–20)]. Alternatively, a decreased attention capacity and/or a problem of efficiently allocating attention resources between two tasks may prove to have the same consequences[21,22)].

Several studies[23–26)] have shown that the elderly have more difficulty than young adults performing simultaneous multiple tasks, contributing to an increased likelihood of falls. For example, elderly subjects with a history of falls demonstrate longer times to regain balance during the simultaneous performance of cognitive and postural tasks than when only responding to the postural task[26)]. Other investigators have also found age-related differences in postural performance during quiet standing[23,25–29)] and walking[24,30)] when performing an attention-demanding postural task.

Falls by older people are more likely to occur when they walk or step over an obstacle, or negotiate stairs[31)]. Age-related changes in musculoskeletal and neuromuscular factors may predispose older individuals to falls. Previous findings[32,33)] have only associated abnormalities of balance and gait and /or neuromuscular capabilities such as strength and flexibility with an increased risk of falling. However, factors including psychological, cognitive, and environmental issues may also contribute to falls by the elderly. Increasing evidence suggests that a slowing of central processing with aging, as seen by a reduction in the speed with which older people can respond[34,35)], is primarily responsible for impaired balanced control and the increased incidence of falls among the elderly.

Most research on the investigation of gait characteristics using the dual task paradigm has focused on the study of steady-state gait or standing. No study, to date, has utilized the dual task paradigm to examine the effects on young adults of a secondary reaction time task while descending stairs. The center of pressure (COP) is defined as the point of application of the ground reaction forces (GRFs) on a platform, and is commonly used as an indicator of balance and postural control[36)]. The Stroop task is a psychological test in which a word expressing a color is printed in a color different from the color expressed by the actual meaning of the word. Examining the COP trajectory variables and response time when young adults descend stairs, while simultaneously performing a secondary Stroop task that requires direct attention, would provide information that contributes to the understanding of the mechanisms behind falls on stairs by the elderly, since COP is a measure of the response of the central nervous system to movement of the whole body center of mass[37)]. Therefore, the aim of the current study was to examine the COP trajectory variables and response times when young adults descended stairs while simultaneously performing a secondary Stroop task that required their direct attention.

## SUBJECTS AND METHODS

The study sample consisted of 10 healthy male subjects (mean age, 24.1 ± 0.6 years; age range, 20–26 years) and 10 healthy female subjects (mean age, 23.8 ± 0.9 years; age range, 20–27 years) with no known neurological or orthopedic deficits. All participants signed an informed consent approved by the University Institutional Review Board before participating in the study. Table 1 summarizes the subject characteristics.

**Table 1.** Subject characteristics

| Group | N | Age (years) | Height (cm) | Weight (kg) |
|---|---|---|---|---|
| Male | 10 | 26.8 ± 2.8 | 177.2 ± 7.3 | 71.4 ± 4.3 |
| Female | 10 | 22.9 ± 2.4 | 165.4 ± 8.2 | 54.6 ± 3.6 |

Values are means ± standard deviations.

A custom-built standard dimension staircase of three steps including the top platform (rise height = 17 cm, tread depth = 28 cm, width = 90 cm) was used for the study. Two force platforms (AMTI, Newton, MA, USA), one mounted in the third step of the staircase as counted from the top platform and one in the level walkway (2 m in length and 1.22 m in width) directly in front of the staircase, were used to measure the three components of GRFs during stair descent. The top platform and each step in the staircase was independently constructed using a solid steel frame (vertical steel frames had a width and depth of 8 and 4 cm) that was securely bolted to the ground to ensure a mechanically stiff structure. GRFs were recorded from the first force platform on the third step and the second force platform on the ground. Amplified force platform signals were sampled on-line at a rate of 1,000 Hz for 20 seconds (AMTI). The COP trajectory variables were analyzed using BioAnalysis v2.0 software (AMTI). The secondary cognitive task was a Stroop task, and response times to the Stroop task while descending stairs were measured with a stop watch (Casio, Tokyo, Japan).

For each trial, subjects stood in a predetermined position on the top platform. Subjects were then required to descend the step on the staircase of three steps at a self-paced speed, with the right limb in response to auditory cues and continue for several strides after striking the first force platform on the third step followed by the second force platform on the floor. Subjects were instructed to place only one foot on each step (foot-over-foot). The analysis of COP trajectory variables was performed for the initial ground contact of the left foot on the second step down (first force platform) and the initial ground contact of the right foot on the floor (second force platform). This portion of data analysis was used because it represents a 'steady-state' step[6,8)].

Subjects first completed a normal stair descent to familiarize themselves with the experimental protocol. Then, a modified Stroop task was presented at 5 meters in front of the subject at eye level while initiating the stair descent. The Stroop task consisted of reading off colors from a printout of 15 words describing colors (five lines of three words) that were printed in colors different from color expressed. For example, the word "red" was printed in green ink, and subjects were required to say the color of the word, "green", rather than the actual word itself. A set of three different words was presented to each subject. Each subject completed two practice trials and five successful experimental trials under the following conditions: 1) performing the Stroop task while standing, 2) descending stairs, and 3) descending stairs while performing the concurrent secondary Stroop task.

Differences between normal stair descent and stair descent while simultaneously performing the concurrent secondary Stroop task for COP trajectory variables and stance time were tested using the paired t-test. Values of $p<0.05$ were considered statistical significant. The dependent variables included the response time, COP displacement in the anteroposterior (A-P) direction, COP displacement in the mediolateral (M-L) direction, length of the COP path, and the average COP velocity. The A-P (M-L) COP was defined as the distance between the minimum and maximum A-P (or M-L) COP positions during the time that either the right or the left foot was in contact with the force platform. The length of the COP path was defined as the length of the total distance traveled by the COP during the time either the right or the left foot was in contact with the force platform. The average velocity of the COP was defined as the COP path length divided by the time that either the right or the left foot was in contact with the force platform.

The paired t-test was used to examine the differences between the response times of the two different types of Stroop tasks (standing and descending stairs). The response time to a Stroop task was analyzed from the onset of the auditory cue to completion of identification of the print colors of a set of three different words in the modified Stroop test. SPSS 14.0 KO statistical software (SPSS, Chicago, IL, USA) was used for the statistical analyses.

## RESULTS

Participants' response times and the changes in the COP trajectory variables and stance times with and without performance of the secondary Stroop task were analyzed. The secondary Stroop task response time for the descending stairs condition was significantly longer than the secondary Stroop task response time during static standing ($p<0.01$) (Table 2). The response time for the stair descent condition was 141% greater than that for standing. The mean values of the response times for each condition are summarized in Table 2.

A significant difference was also noted in the stance time for descending stairs between with and without performance of the secondary Stroop task for both the left and right feet ($p<0.01$) (Table 3). The stance time with the secondary Stroop task condition was 123% greater than that without performance of the secondary Stroop task for both the left and the right feet.

There were also significant differences in the M-L and A-P displacements of COP and the length of the COP path as well as the average velocity of COP ($p<0.01$) for stair descent between with and without performance of the secondary Stroop task for both the left and right feet (Table 3). The M-L and A-P displacement of COP and the length of the COP path as well as the average velocity of COP in stair descent with the secondary Stroop task were significantly greater than in stair descent without performance of the secondary Stroop task ($p<0.01$). The M-L and A-P displacements of COP of both the right and the left feet while descending stairs performing the secondary Stroop task were 137% and 117% greater than their respective values in stair descent without the secondary Stroop task. The length of the COP path and the average velocity of COP for both feet while descending stairs performing the secondary Stroop task were also increased (119% and 115%, respectively), as compared with the values for both feet while descending stairs without the secondary Stroop task. The mean values for the stance times and COP trajectory variables for each condition are summarized in Table 3.

**Table 2.** Means ( ± SD) for response times (ms)

| | Standing | Stair Descent |
|---|---|---|
| Response times* | 2187 ± 400 | 3076 ± 514 |

*significant difference between standing and stair descent ($p<0.05$).

**Table 3.** Mean values (±SD) of the COP variables (cm) and the stance time (cm/sec) of the left and right feet

| Dependent variables | Stair Descent | |
|---|---|---|
| | No Stroop | Stroop |
| M-L displacement (L)* | 7.77 ± 2.05 | 9.91 ± 2.22 |
| M-L displacement (R)* | 6.71 ± 1.49 | 9.78 ± 2.08 |
| A-P displacement (L)* | 14.56 ± 2.74 | 16.44 ± 3.24 |
| A-P displacement (R)* | 12.93 ± 1.35 | 15.71 ± 4.1 |
| COPL (L)* | 77.7 ± 23.11 | 90.6 ± 16.35 |
| COPL (R)* | 73.3 ± 18.72 | 89.06 ± 13.2 |
| COPV (L)* | 116.42 ± 28 | 131.71 ± 18.95 |
| COPV (R)* | 119.9 ± 12.04 | 141 ± 6.08 |
| Stance time (L)* | 693 ± 65 | 814 ± 188 |
| Stance time (R)* | 638 ± 41 | 813 ± 134 |

*significant difference between with and without performance of the secondary Stroop task ($p<0.05$). SD: Standard deviation; M-L: mediolateral; A-P: anteroposterior; COP: center of pressure; COPL: total length of the center of pressure path; COP velocity: average velocity of the center of pressure; L: left, R: right.

## DISCUSSION

This study investigated the effects on young adults of a concurrent secondary response time task while descending stairs. The current study revealed that, overall, participants had slower response times and increases in stance times, as well as increases in M-L and A-P displacements of the COP, the total length of the COP path, and the average velocity of the COP while descending stairs performing the concurrent secondary Stroop task. Changes in theses variables suggest that stair descent while performing the secondary Stroop task was more challenging for the participants than the stair descent without the secondary Stroop task.

It is thought that the ability to attend to one task declines when a second task is added. That is, either or both could suffer in performance speed or quality, or only one task would be executed while the second task would be put off[17].

Thus, interference between the simple response task and stair descent in the present experiment was expected because of the competition for attention between the two tasks. The results show that the secondary Stroop task interfered with stair descent and vice versa.

The mean response time for descending stairs with the secondary Stroop task was significantly longer than the mean response time for standing. This result suggests that the response time increases as a more demanding task is performed. This result is in accordance with the results of previous studies[24,38–40], which reported that divided attention during obstacle crossing degraded the obstacle avoidance capabilities of both older and young adults. In one of these studies, younger and older adults had longer reaction times when vision and/or proprioception were perturbed than when vision and surface conditions were normal, and the older adults were more affected by the absence of vision[39]. Another study observed that older women had slower verbal reaction times than younger women and longer reaction times in a sitting position than in a standing position[41]. Kim[42] also demonstrated that the response time for obstacle crossing when a secondary Stroop task was provided was significantly longer than the response time in static standing only.

The participants showed significantly greater M-L and A-P displacements of COP and longer length of the COP path, as well as the faster average velocity of COP while descending stairs performoing the secondary Stroop task, than in the stair descent without the secondary Stroop task. The finding of increased COP displacement in the M-L direction and length of the COP path is similar to a previous report that the M-L displacement of COP and the length of the COP path were increased in subjects performing gait initiation or obstacle crossing with a concurrent secondary task[42]. In the current study, subjects appeared to have less postural control, which was manifest as an increase in the amplitude of the displacements of COP in the M-L and A-P directions when performing the stair descent with the concurrent secondary Stroop task. These results suggest that under such a dual-task paradigm, subjects are required to allocate more attention to multiple tasks simultaneously than in a single task, and stair descent with the concurrent secondary cognitive task may have required complete attention, since subjects had poorer performance in both the primary task and the secondary task.

The average velocity of COP during a task is a postural activity index, which represents the amount of postural activity required to maintain postural stability during the certain task[43, 44]. It has been reported that moving the COP faster to the maximal COP positions at which individuals can maintain posture without falling, can be considered as an important indicator of risk of falling[45]. In the current study, the subjects who performed stair descent with the secondary cognitive task demonstrated enhanced average velocity of COP, as compared with the stair descent task without the secondary cognitive task, which could be interpreted as reduced postural performance and an increased risk of falling.

It is important to maintain appropriate scaling of gait parameters while descending stairs to ensure safe and efficient foot placement on the surface of the stair. Thus, the stance limb must also provide a stable base from which to descend the stair. The subjects of the current study demonstrated significantly longer left and right stance times while performing the stair descent with the concurrent secondary cognitive task than during the stair descent without the secondary cognitive task. This increase in stance time may be attributed to overall increased activity of the gluteus medius to maintain pelvic obliquity[46]. Furthermore, a longer stance time may reflect the fact that participants tended to use a more cautious strategy when performing the secondary task.

The current had several limitations. This study had a relatively low sample size of young adults. Furthermore, the exact timing and spatial events of gait parameters during the interference of the motor tasks with the concurrent secondary task were not investigated because only two force platforms were used. The collective analysis of kinematic and kinetic data would provide more insights on the interference between the primary motor task and the secondary cognitive task than the separate analysis of kinetic data. Finally, this study used a staircase of only three steps that may not have allowed simulation of true stair descent.

In conclusion, the results of the current study give an increased understanding as to how participants descend stairs when they have to attend to a concurrent secondary cognitive task. The results suggest that participants' ability to descend stairs is lessened with the addition of a concurrent secondary attention demanding task, and addition of divided attention tasks places an apparently higher demand on balance control that may prove challenging for subjects at high risk of falling. Finally, it would be necessary to examine and/or compare a wide variety of geriatric populations and subjects with neurological and orthopedic deficits under various types of secondary tasks to fully appreciate the effects of all aspects of the secondary motor task performance performing more demanding or dynamic conditions. Moreover, the investigation of the effects of a wider range of dual tasks could assist in the identification of individuals at high risk of falling.

## REFERENCES

1) Svanström L: Falls on stairs: an epidemiological accident study. Scand J Soc Med, 1974, 2: 113–120.
2) Startzell JK, Owens DA, Mulfinger LM, et al.: Stair negotiation in older people: a review. J Am Geriatr Soc, 2000, 48: 567–580.
3) Nevitt MC, Cummings SR, Hudes ES: Risk factors for injurious falls: a prospective study. J Gerontol, 1991, 46: M164–M170.
4) Hemenway D, Solnick SJ, Koeck C, et al.: The incidence of stairway injuries in Austria. Accid Anal Prev, 1994, 26: 675–679.
5) Andriacchi TP, Andersson GB, Fermier RW, et al.: A study of lower-limb mechanics during stair-climbing. J Bone Joint Surg Am, 1980, 62: 749–757.
6) McFadyen BJ, Winter DA: An integrated biomechanical analysis of normal stair ascent and descent. J Biomech, 1988, 21: 733–744.
7) Riener R, Rabuffetti M, Frigo C: Stair ascent and descent at different inclinations. Gait Posture, 2002, 15: 32–44.
8) Nadeau S, McFadyen BJ, Malouin F: Frontal and sagittal plane analyses of the stair climbing task in healthy adults aged over 40 years: what are the challenges compared to level walking? Clin Biomech, 2003, 18: 950–959.

9) Christina KA, Cavanagh PR: Ground reaction forces and frictional demands during stair descent: effects of age and illumination. Gait Posture, 2002, 15: 153–158.
10) Hamel KA, Okita N, Bus SA, et al.: A comparison of foot/ground interaction during stair negotiation and level walking in young and older women. Ergonomics, 2005, 48: 1047–1056.
11) Reeves ND, Spanjaard M, Mohagheghi AA, et al.: The demands of stair descent relative to maximum capacities in elderly and young adults. J Electromyogr Kinesiol, 2008, 18: 218–227.
12) Livingston LA, Stevenson JM, Olney SJ: Stair climbing kinematics on stairs of differing dimensions. Arch Phys Med Rehabil, 1991, 72: 398–402.
13) Mian OS, Thom JM, Narici MV, et al.: Kinematics of stair descent in young and older adults and the impact of exercise training. Gait Posture, 2007, 25: 9–17.
14) Moray N: Where is attention limited? A survey and a model. Acta Psychol, 1967, 27: 84–92.
15) Keele SW: Attention and human performance. Goodyear, Pacific Palisades, 1972.
16) Wickens CD: Engineering psychology and human performance (2nd ed). New York: Harper Collins Publisher Inc., 1992.
17) Schmidt RA, Lee TD: Motor control and learning (4th ed). Human Kinetics, Champaign, 2005.
18) Cerella J, Poon LW, Williams DM: Age and the complexity hypothesis. In Poon LW (ed) Aging in the 1980s. American Psychological Association, Washington (DC): 1980.
19) Salthouse TA: A theory of cognitive aging. Amsterdam: Elsevier Science Publishers, 1985.
20) Stelmach GE, Worringham CJ: Sensorimotor deficits related to postural stability: implication for falling in the elderly. Clin Geriatr Med, 1985, 1: 679–694.
21) Baron A, Myerson J, Hale S: An integrated analysis of the structure and function of behavior: aging and the cost of dividing attention. In Davey G, Cullen C (eds) Human operant conditioning and behavior modification. New York,: John Wisley & Sons, 1988.
22) Craik FIM: Age differences in human memory. In Birren JE, Schaie KW (eds) Handbook of the psychology of aging. New York: Van Nostrand Reinhold, 1977.
23) Brown LA, Shumway-Cook A, Woollacott MH: Attentional demands and postural recovery: the effects of aging. J Gerontol A Bio Sci Med Sci, 1999, 54: M165–M171.
24) Chen HC, Schultz AB, Ashton-Miller JA, et al.: Stepping over obstacles: dividing attention impairs performance of old more than young adults. J Gerontol A Biol Sci Med Sci, 1996, 51: M116–M122.
25) Maylor EA, Wing AM: Age differences in postural stability are increased by additional cognitive demands. J Gerontol B Psychol Sci Soc Sci, 1996, 51: P143–P154.
26) Shumway-Cook A, Woollacott M, Kerns KA, et al.: The effects of two types of cognitive tasks on postural stability in older adults with and without a history of falls. J Gerontol A Biol Sci Med Sci, 1997, 52: M232–M240.
27) Maylor EA, Allison S, Wing AM: Effects of spatial and nonspatial cognitive activity on postural stability. B J Psychol, 2001, 92: 319–338.
28) Stelmach GE, Zelaznik HN, Lower D: The influence of aging and attentional demands on recovery from postural instability. Aging, 1990, 2: 155–161.
29) Teasdale N, Bard C, LaRue J, et al.: On the cognitive penetrability of posture control. Exp Aging Res, 1993, 19: 1–13.
30) Eichhorn J, Orner J, Richard K, et al.: Aging effects on dual-task methodology using walking and verbal reaction time. Issues Aging, 1988, 21: 8–12.
31) Chen HC, Ashton-Miller JA, Alexander NB, et al.: Stepping over obstacles: gait patterns of healthy young and older adults. J Gerontol Med Sci, 1991, 46: M196–M203.
32) Lord S, McLean D, Stathers G: Physiological factors associated with injurious falls in older people living in the community. Gerontology, 1992, 38: 338–346.
33) Prudham D, Evans J: Factors associated with falls in the elderly: A community study. Age ageing, 1981, 10: 141–146.
34) Redfern MS, Jennings JR, Martin C, et al.: Attention influences sensory integration for postural control on older adults. Gait Posture, 2001, 14: 211–216.
35) Teasdale N, Simomeau M: Attentional demands for postural control: the effects of aging and sensory reintegration. Gait Posture, 2001, 14: 203–210.
36) Doyle RJ, Hsiao-Wecksler ET, Raganc BG, et al.: Generalizability of center of pressure measures of quiet standing. Gait Posture, 2007, 25: 166–171.
37) Martin M, Shinberg M, Kuchibhatla M, et al.: Gait initiation in community-dwelling adults with Parkinson disease: comparison with older and younger adults without the disease. Phys Ther, 2002, 82: 566–577.
38) Lajoie Y, Teasdale N, Bard C, et al.: Attentional demands for static and dynamic equilibrium. Exp Brain Res, 1993, 97: 139–144.
39) Teasdale N, Stelmach GE, Breuning A: Postural sway characteristics of the elderly under normal and altered visual and support surface conditions. J Gerontol, 1991, 46: B238–B244.
40) Kim HD, Brunt D: The effect of a dual-task on obstacle crossing in healthy elderly and young adults. Arch Phys Med Rehabil, 2007, 88: 1309–1313.
41) Marsh AP, Geel SE: The effects of age on the attentional demands of postural control. Gait Posture, 2000, 12: 105–113.
42) Kim HD. The effect of a dual-task on the center of pressure trajectory of healthy young adults during obstacle crossing. J Phys Ther Sci, 2009, 21: 99–104.
43) Geurts AC, Nienhuis B, Mulder TW: Intrasubject variability of selected force-platform parameters in the quantification of postural control. Arch Phys Med Rehabil, 1993, 74, 1144–1150.
44) Maki BE, Holliday PJ, Fernie GR: Aging and postural control. A comparison of spontaneous- and induced-sway balance tests. J Am Geriatr Soc, 1990, 38, 1–9.
45) Pai YC, Patton J: Center of mass velocity-position predictions for balance control. J. Biomech, 1997, 30, 347–354.
46) Kim HD, Brunt D: Will a sensory perturbation differentiate between the stepping behavior of young and healthy adults who are elderly? The Annual Conference & Exposition of the American Physical Therapy Association, Orlando, USA, 2006.