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The Effects of Dual-Task on Stepping Over Obstacles From a Position of Quiet Stance in Younger and Older Adults: A Pilot Study

Kim Hyeong-dong, M.H.S., P.T.
Dept. of Physical Therapy, University of Florida
Yoon Bum-chull, Ph.D., P.T.
Dept. of Physical Therapy, College of Health Science, Korea University

국문요약

장애물 보행시 젊은 사람과 노인들의 보행 양식에 대한 이중과업 수행의 효과

김형동
플로리다 대학교 물리치료학과
윤범철
고려대학교 병설 보건대학 물리치료과

본 연구의 목적은 이중과업 방법론(dual task methology)을 사용해서 젊은 사람과 노인을 대상으로 독립된 두 사건(two separate concurrent events)을 동시에 수행하는데 요구되는 주의력에 대한 분석과 노인에서의 특징적 차이를 찾는 것이다. 본 실험은 대상자가 힘판(force plate) 위에서 장애물(10㎝) 보행시에 경피자극(cutaneous stimulation)에 대하여 마이크로 스위치(micro-switch)를 사용하여 반응하면서 시행되었다. 힘판과 시간(temporal events) 그리고 반응시간(reaction time)에 관한 자료들은 1000 ㎐의 주파수로 수집되었다. 반응시간은 대상자들이 서 있는 상태(baseline) 장애물 보행시(dual task)에서 수집되었다. 반응시간은 이중과업 조건에서 대상자 모두에게서 긴 것으로 나타났으며 특히 노인에서 정상 성인보다 반응시간이 긴 것으로 나타났다. 이중과업 조건 하에서 노인 대상자가 정상 성인에 비해 발가락이 장애물에 닫지 않고 통과할 수 있는 공간, 즉 토우 클리어런스(toe-clearance)와 슬관전 굴곡(knee flexion) 각도가 훨씬 큰 것으로 나타났다. 그러나 젊은 대상자들은 정상보행(normal stepping)시와 이중과업시 토우 클리어런스에서 차이가 없었으며 슬관전 굴곡각도는 정상 보행에서 더 큰 것으로 나타났다. 이중과업 조건하에서 모든 대상자가 족관절 배측굴곡(ankle dorsiflexion) 각도를 감소시키는 것으로 나타났다. 노인들은 젊은 대상자들보다 훨씬 더 긴 (124 ㎳) 유각시간을 보여 주었으며 정상 장애물 보행시 유각 시간은 이중과업보다 50 ㎳ 긴 것으로 나타났다. 이러한 보행 특성의 차이는 노인대상자들이 젊은 대상자들보다 장애물 보행시에 이중과업의 영향을 더 받았기 때문인 것으로 판단된다. 이중 과업 시행시 이러한 토우 클리어런스의 감소와 장애물 통과시에 보행 속도의 증가는 아마도 낙상의 가능성을 증가시키는 요인이 될 수 있는 것으로 보여진다. 본 연구의 결과는 다중과업(multitasks)을 필요로 하는 보행 훈련 프로그램(gait training program)의 개발과 시행에 있어서 기초적인 자료를 제공할 수 있는 것으로 보여진다.

핵심단어: 낙상; 보행분석; 이중과업; 주의결핍; 주의력.

Introduction

Falls in the elderly are considered one of the most important health problems because, regardless of severity, the consequences are often a significant loss of functional independence and may even result in death. In addition, falls in the elderly place economic pressure on the health system because a major medical cost for the elderly is attributed to fall related injuries.

In 1985, there were about 2.4 million fall related injuries (requiring medical attention and causing one or more days of self reported limitation of activi- ties), 369,000 hospitalization, and direct costs of $7.8 billion in the United States (Rice and Mackenzie, 1989).

Research shows that fall related medical costs were attributable to almost eight percent of the total lifetime economic cost of all unin- tentional injury in the United States. It is estimated that the most of the nearly $10 billion in annual costs of osteoporosis is due to falls by the elderly (Runge, 1993).

Falls in the elderly have a multifaceted and heterogeneous etiology in which the convergence of several intrinsic, pharmacological, pathophysiological functional environmental, behavioral, and activity-related issues are involved (Runge, 1993; Rubenstein et al, 1988; Tinetti and Speechley, 1989; Wolfson et al, 1992). Factors intrinsic to the individual are deficit sensory function, impaired central nervous system to maintain stability of postural response, abnormal gait, unstable joint, and muscle weakness (Stelmach and Worringham, 1985; Wolfson et al, 1992; Woollacott, 1993). Age-related changes in pharmacokinetics and pharmacodynamics may increase vulnerability to central nerve system effects of drugs. The physiologic effects, such as sedation, psychomotor and autonomic impairment, of many drugs may increase the possibility of falls in the elderly. Diseases inclusive of Parkinsonism, seizures, and stroke may increase risk of fall (Nevitt et al, 1989), and environmental obstacles may pose serious threats to mobility and safety in those who have gaited and/or balance impairment.

Although the causes of falls for elderly people are of a multifaceted and heterogeneous etiology, tripping over an obstacle is one of the most commonly reported causes of falls for older people (Blake et al. 1988; Campbell et al. 1990; Gabell and Nayak 1984; Overstall et al, 1977; Tinetti and Speechley; 1989).

Several studies (Brown et al, 1999; Chen et al, 1996; Maylor and Wing, 1996; Shumway-Cook et al, 1997) have shown that older adults have more difficulty than young adults when they are required to perform multiple tasks at once, contributing to the increased likelihood for falls. For example, the elderly with a history of falls demonstrated a longer time to regain balance during the simultaneous performance of a cognitive and postural task than when only responding to the postural task (Shumway-Cook et al, 1997).

Attention refers to information processing capacity (Moray, 1967), space (Keele, 1973) or resources (Wickens, 1992) available to an individual.

The available information processing capacity (or resources) is thought to be limited (Schmidt and Lee, 1999), but it may be partitioned to different tasks in any way the individual decides. Attention may increasingly become more important in balance control in the elderly when attenional capacity of older adults is challenged by simultaneously performing a secondary motor or cognitive task while walking, or when impairments in postural stability lead to an increased potential for falling (Shumay-Cook and Woollacott, 2001).

If attentional capacity of older adults is challenged, then timely corrective or adaptive strategies of older adults while walking and standing may consequently be compromised by a slowing of the information-processing speed to perform either task (Cerella et al, 1980; Salthouse, 1985; Stelmach and Worringham, 1985). Alternatively, a decreased attentional capacity and/or a problem of allocating attentional resources efficiently between two tasks may prove to have the same consequences (Baron et al, 1988; Craik, 1977). These results clearly indicate that attention plays an important role in balance control in the elderly while standing and walking. Research on the investigation of the attention capacity in older groups, however, has mostly focused on the study of steady-state gait or standing.

Little is known about the abilities of older adults to negotiate obstacles while performing secondary attention demanding task from a position of quiet stance. The following pilot study was designed to examine how a secondary reaction time task would affect the ability to step over obstacles from quiet stance position in healthy older adults as compared to younger adults.

Methods

Subjects

This study sample consisted of 2 young (two males: mean : 29.0) and 2 healthy elderly (two males: mean 69.0) adults with no known neurological or orthopedic deficits. In order to qualify for this study, the elderly participants had to live independently in the community and be able to complete all activities of daily living. All subjects completed a detailed health questionnaire relevant to memory and orientation (address, age, date of birth, pharmacologic agents used, etc.). This type of questionnaire is equivalent to several of the short mental-status examinations current in use. All participants signed an informedly written consent form approved by the University Institutional Review Board prior to their participation.

Instruments

Two force platforms, embedded in a level walkway (5 m in length and 1.22 m in width), were used to detect the onset of movement and stance toe off during gait initiation. A foot switch was used to measure heel-strike of the swing limb. Footswitch and amplified force platform signals were sampled on-line at a rate of 1000 Hz for 5 seconds[1] The secondary task involves a simple reaction time task. A single one milliseconds (ms) square wave pulse was delivered from a stimulator and stimulus isolation unit[2] to an electrode that was applied to the arm.

A handheld micro-switch was used to

1) BIOPAC Systems, Goleta, CA.
2) Grass Instrument Company, Quincy, MA.

measure reaction time following the cutaneous stimulation during stepping over an obstacle. Threshold intensity level for stimulation is determined for each subject by gradually increasing the stimulus voltage until a consistent threshold is obtained. Threshold levels were checked throughout the experiment and, where necessary, adjusted accordingly.

Video data was captured at 100 ㎐ for 5 s by using the MacReflex measurement system[3]. Reflective markers were placed at the greater trochanter of the femur, lateral condyle of the femur, lateral malleolus, and head of the fifth metatarsal bone of the right stepping limb. A reflective marker was also placed on the center of the obstacle. Motion data provided information on obstacle clearance, knee and ankle joint angles and swing limb trajectory at the time of obstacle clearance. For safety, subjects wore a gait belt and were guarded by a physical therapist.

Procedures

For each trial subjects stood in a predetermined position with each foot on a force platform. While standing upright and stationary, the subject was instructed to respond to the electrocutaneous stimulation by pressing a handheld micro-switch as soon as they felt the stimulation. Next, subjects were asked to step over a 10 ㎝ high obstacle at self-paced speed to a visual cue. One small red light emitting diode was set in the center of the obstacle. The experimental setup is shown in Figure 1. The light dictated when subjects stepped. A single one ms square wave pulse was delivered to the arm. For example, when the light comes on, the subject steps over the obstacle with the right limb. However, if the electrocutaneous stimulation occurs during stepping, the subject must press a micro-switch button as quickly as possible following the cutaneous stimulation. The electrocutaneous stimulation was provided at a mean time of 480 ㎳ following the onset of movement and occurred after toe-off of the swing limb. Subjects completed practice trials and approximately 100 successful experimental trials in the following conditions:

1) Baseline reaction time task
2) Normal stepping initiated by the light signal.
3) Normal stepping with the presentation of electrocutaneous stimulation on random trials.

The third condition was presented in random order.

Data Analysis

Means and standard deviations were used to describe a difference between the reaction times, swing and stance time, joint angles and toe-clearances in the older group and the younger group. Time to swing heel strike toe-off and stance toe-off were also analyzed. Timing data was referenced from the first detectable onset of force platform activity. The toe-clearance, ankle angle, and knee angle at toe clearance were also analyzed via video analysis. Simple reaction time was analyzed from the onset of stimulus to subject's response.

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3) Qualisys Inc. Glastonbury, CT.

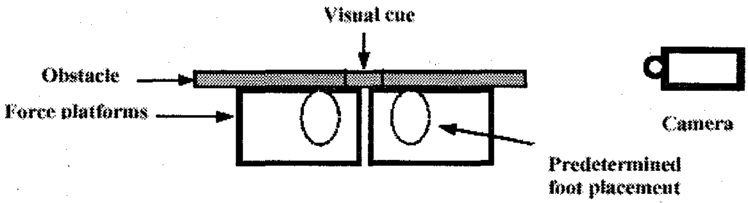

Fig 1. Experimental setup

Table 1. Means for simple reaction time to the presentation of cutaneous stimulation during baseline testing and stepping

	Younger			Older		
Subject	Age	Baseline (ms)	Dualtask (ms)	Age	Baseline (ms)	Dualtask (ms)
1	26	223 (33)	338 (44)	65	345 (53)	625 (312)
2	32	337 (33)	442 (111)	72	502 (40)	633 (170)
X (SD)[a]	29(4)	285 (81)	390 (74)	69 (5)	424 (111)	629 (6)

[a]Mean (Standard deviation)

Results

Reaction time

Table 1 describes the reaction times for each subject under the baseline and dual task condition. There was a difference in the simple reaction time between the age groups(Figure 2). In all subjects, there was a difference between the baseline and dual task conditions for the simple reaction time to a cutaneous stimulation. Regardless of age, simple reaction time was slower in the dual task condition than with normal stepping(Figure 2). There was also a difference in the simple reaction time to a cutaneous stimulation during the dual task condition within each age group. The older subjects showed much slower reaction times in dual task condition than the younger subjects.

Joint angles

Means and standard deviations for toe clearance, knee and ankle angles in each condition (normal stepping and dual task) in young versus old adults are summarized in Table 2. There were differences in the variables on stepping between normal and dual task conditions within both the younger and older groups. Both the younger and older groups demonstrated reduced toe clearance, knee and ankle angles while performing dual task compared to normal stepping. However, the older group showed a greater reduction than young adults. Toe-clearance differed between the two groups with older subjects clearing 4.1 ㎝ higher than younger subjects during normal stepping (Figure 2). There was a 3.2 ㎝ decreased toe clearance during dual task condition in the older subjects compared to normal

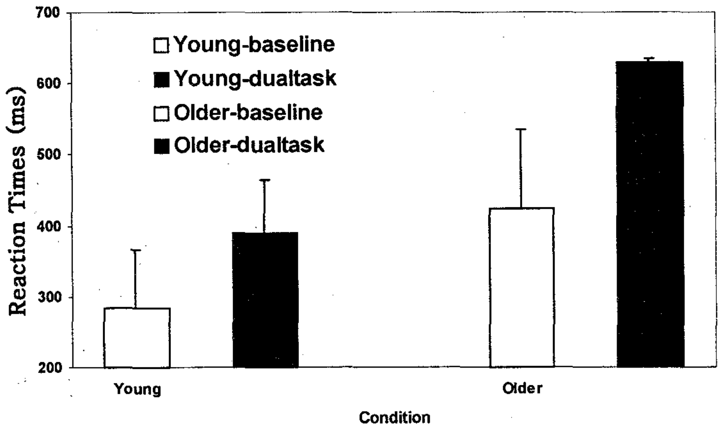

Fig 2. Mean simple reaction time (s) during baseline and dual task for the younger and older groups. Note the difference in reaction times between the two groups for both baseline and dual task.

Table 2. Means (SD) for the four variables selected to measure toe clearance, knee angle and ankle angle

Age	Phase	Toe clearance (cm)	Knee angle (°)	Ankle angle (°)
Young	normal stepping	11.9 (1.4)	78.9 (7.8)	5.9 (14.6)
	dual ask	10.2 (0.0)	74.3 (5.1)	1.2 (13.1)
Older	normal stepping	16.0 (1.1)	89.6 (5.7)	3.3 (3.7)
	dual task	12.8 (1.0)	82.5 (1.9)	-1.92 (12.9)

stepping, but the reduction in toe clearance was only 1.7 cm between two conditions in the young subjects (Figure 2). Initially, knee flexion angle was 78.9 for the younger subjects and 89.6 for the older subjects during normal stepping condition. Both groups appeared to decrease knee angle while performing dual task. Mean knee angle decreased by 6% for younger adults and 9% for older adults in dual task condition as compared to normal stepping. Ankle angle at toe clearance was 5.9 dorsiflexion for the younger subjects and 3.3 dorsiflexion for the older subjects during normal stepping. The mean ankle angle decrease was by 80% for the younger subjects and by 160% for the older subjects while performing the dual task.

Swing and stance time

Swing time differed between the two age groups for both the normal and dual task conditions (Figure 3). The older subjects showed 124 cm longer in swing time than the younger subjects. Both groups appeared to decrease swing time while performing the dual task. However, the relative decrease in swing time for the older subjects was 3.7 times as great as that for the younger subjects during the

Table 3. Means (SD) for the four variables selected to measure swing and stance time.

Age	Phase	Swing time (ms)	Stance time (ms)
Young	normal stepping	556 (47)	1071 (66)
	dual ask	537 (12)	1003 (107)
Older	normal stepping	706 (148)	1277 (121)
	dual task	635 (181)	1185 (219)

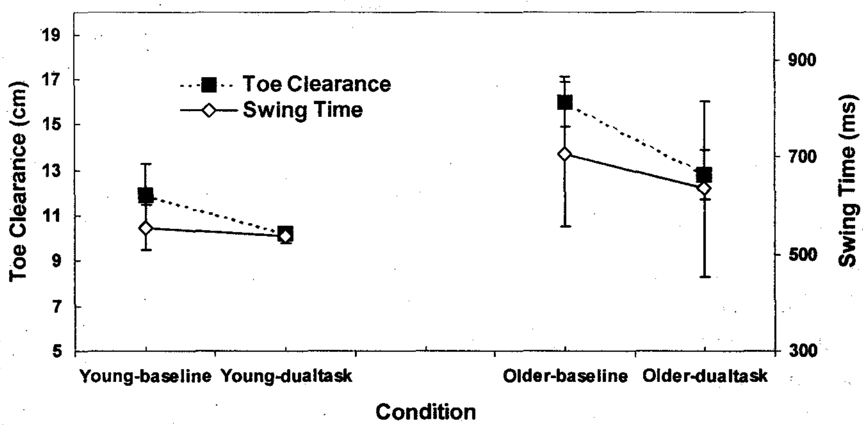

Fig 3. Means for toe clearance and swing time. Note that the values for both variables were greater for normal stepping than dual task condition within the older subjects. However, the younger subjects showed relatively small changes between two tasks.

dual task condition. Regardless of age, stance time decreased in the dual task condition by 7% compared to normal stepping. However, the decrease in stance time was 24 ㎝ greater for the older subjects than for the young subjects. Table 3 shows the means and standard deviations for swing and stance times.

Discussion

This shows, for the first time, a comparison between young adults and healthy elderly adults in selected kinematic and timing characteristics with simple reaction time task during obstacle crossing. Tripping or tripping over an obstacle is one of the most commonly reported causes of a fall (Blake et al, 1988; Campbell et al, 1990, Overstall et al, 1977; Tinetti and Speechly, 1989). The present study shows that the reaction time to the cutaneous stimulation was slower when subjects performed the dual task compared to performing simple reaction time task alone. The slowness in reaction time was not as great as for the young adults. These findings lend support to the assumption that the ability to attend to one task declines when a second task is added

(Wickens et al, 1987). That is, either or both could suffer in performance speed or quality, or only one task would be executed while the second task could be prevented from occurring (Schmidt and Lee, 1999). In the present study, both young and older adults appeared to choose to sacrifice responding as quickly as possible to the cutaneous stimulation and stepping performance. However, the older adults were more affected in the measures of performance by dual task than the younger adults.

Appropriate scaling of toe clearance during obstacle-crossing is crucial for ensuring a safe and efficient foot crossing. It is known that most falls are more likely to occur with inadequate toe clearance, rather than obstacle contact with heel (Chou and Draganish, 1997). It has been reported that the toe clearance over an obstacle ranges from approximately 9 to 13 cm for either young or healthy elderly subjects (Berg et al, 1992; Patla and Rietdyk, 1993). The present study shows a toe clearance ranging from 16.0 cm to 10.2 cm. It was interesting that in the dual task condition, the elderly subjects decreased toe clearance 3.2 cm compared to normal stepping. Toe clearance for the normal stepping condition in the younger subjects was relatively similar to the dual task condition compared to the older subjects (Figure 3). This decrease in toe clearance for the older subjects is probably explained by the fact that the dual task has a greater impact on stepping performance in the older adults than in the younger adults. It has previously been shown that older adults have more difficulty than younger adults when they are required to perform multiple tasks at once, contributing to the increased likelihood for falls (Shumway-Cook et al, 1997). For example, the elderly with a history of falls demonstrated a longer time to regain balance during the simultaneous performance of a cognitive and postural task than when only responding to the postural task (Shumway-Cook et al, 1997).

Increased toe clearance is obtained by increased flexion of the swing limb (Patla and Rietdyk, 1993). As seen in the current study, the knee flexion was greater for the normal stepping condition than for the dual task condition. In addition, the older adults demonstrated greater knee flexion than the younger adults. When combined for both the younger and older subjects, the ankle was dorsiflexed 5.3 more for the normal stepping condition when compared to the dual task condition. Both the younger and older adults tend to decrease dorsiflexion in the dual task condition.

Sufficient swing limb flexion for adequate toe clearance by itself is not enough for a safe crossing. The stance limb must also provide a stable base from which to cross an obstacle. Single limb stance for normal stepping was only 45 ms longer than for dual task. The older subjects demonstrated much longer single stance (671 ms) than the younger subjects (547 ms). This increase can be attributed to the overall ability of the older adults to maintain pelvic obliquity by contraction of the gluteus medius (Brunt et al, 2001 unpublished).

Swing time for normal stepping was 50 ms greater than for dual task. In addition, the older adults showed greater swing time (124 ms difference) than the younger adults.

It is interesting to note that toe clearance was also greater in the normal stepping than in the dual task. In addition, older adults demonstrated greater toe clearance than the younger adults. Thus, as toe clearance is less, presumeably due to limb trajectory, less swing time was needed while performing dual task (Figure 2). This result implies that the older adults adopt different strategy to perform the dual task. It has previously been reported that older adults use a more cautious strategy while negotiating an obstacle, reducing speed (Pavol et al, 1999). However, in the present study, the older subjects appeared to increase stepping speed, seen in decreased swing and stance time, while performing the dual task. This suggests that older adults have more interference on stepping performance than the younger adults during a dual task condition. A decrease in toe clearance and increased stepping speed may be a contributing factor to falls in the elderly.

The findings from this study provide preliminary data, which can be served as a basis for the development and the implementation of new gait training program with the use of multiple tasks. In addition, although continued research is needed to substantiate the effects of dual tasks, current findings support a gait training program that involves protocol beginning with simple tasks and moving to multitasks that progress in difficulty.

References

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 Wiley & Sons, 1988:139-166.

Berg KO, Maki BE, Williams JI, et al. Clinical and laboratory measures of postural balance in an elderly population. Arch Phys Med Rehabil. 1992;73(11): 1073-1080.

Blake AJ, Morgan K, Bendall MJ, et al. Falls by elderly people at home: Prevalence and associated factors. Age Ageing. 1988;17(6):365-372.

Brown LA, Shumway-Cook A, Woollacott MH. Attentional demands and postural recovery: The effects of aging. J Gerontol Med Sci. 1999;55A:M165-M171.

Brunt D, Santos V, Kim HD. Characteristics of obstacle crossing in healthy and frail elderly. 2001; Unpublished.

Campbell AJ, Borrie MJ, Spears GF, et al. Circumstances and consequences of falls experienced by a community population 70 years and over during a prospective study. Age Ageing. 1990; 19(2):136-141.

Cerella J, Poon LW, Williams DM. Age and the complexity hypothesis. In: Poon LW, ed. Aging in the 1980s. Washington DC: American Psychological Association. 1980:332-339.

Chou LS, Draganich LF. Stepping over an obstacle increases the motions and moments of the joints of the trailing limb in young adults. Biomechanics. 1997;30(4):331-337.

Chen HC, Schultz AB, Ashton-Miller JA, et al. Stepping over obstacles: Dividing attention impairs performance of old more than young adults. J Gerontol

Med Sci. 1996;51(A):M116-M122.

Covington DL, Maxwell JG, Clancy TV. Hospital resources used to treat the injured elderly at North Carolina Trauma Centers. J Am Geriatr Soc. 1993;41:847-852.

Craik FIM. Age differences in human memory. In: Birren JE, Schaie KW, eds. Hanbook of the Psychology of Aging. New York, Van Nostrand Reinhold, 1977:384-420.

Gabell A, Nayak USL. The effect of age on variability in gait. J Gerontol. 1984;39:662-666.

Keele SW. Attention and human performance. Pacific Palisades, CA, Goodyear, 1973.

Maylor EA, Wing AM. Age differences in postural stability are increased by additional cognitive demands. J Gerontol Psychol Sci. 1996;51B:P143-P154.

Moray N. Where is attention limited? A survey and a model. Acta Psychologica. 1967;27:84-92.

Nevitt MC, Cummings SR, Kidd S, et al. Risk factors for recurrent nonsyncopal falls: A prospective study. JAMA. 1989;261(18):2663-2668.

Overstall PW, ExtonSmith AN, Imms FJ, et al. Falls in the elderly related to postural imbalance. British Med J. 1977;1:261264.

Patla AE, Rietdyk S. Visual control of limb trajectory over the obstacles during locomotion: Effect of obstacle height and width. Gait Posture. 1993;1:45-60.

Pavol MJ, Owings TM, Foley KT, et al. The sex and age of older adults influence the outcome of induced trips. J Gerontol Biol Sci Med Sci. 1999;54(2):M103-M108.

Rice DP, Mackenzie EJ. Cost of injury in the United States, A report to Congress. San Francisco, Institute for Health and Aging. 1989.

Rubenstein LZ, Robbins AS, Schulman BL, et al. Falls and instability in the elderly. J Am Geriatr Soc. 1988;36(3):266-278.

Runge JW. The cost of injury. Emerg Med Clin North Am. 1993;11(1):241-243

Salthouse TA. A Theory of Cognitive Aging. Amsterdam, Elsevier, 1985.

Schmidt RA, Lee TD. Motor Control and Learning. 3rd ed. IL Human Kinetics, Champaign, 1999.

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 Med Sci. 1997;52A:M232-M240.

Shumway-Cook A, Woollacott M. Motor Control. 2nd ed. Philadelphia, Lippincott Williams & Wilkins, 2001.

Stelmach GE, Worringham CJ. Sensorimotor deficits related to postural stability: Implication for falling in the elderly. Clin Geriatr Med. 1985;1(3):679-694.

Tinetti ME, Speechley M. Prevention of falls among the elderly. N Engl J Med. 1989;302(16):1055-1059.

Wickens CD, Braune R, Strokes A. Age differences in the speed and capacity of imformation processing: A dual-task approach. Psychol Aging. 1987;2:70-78.

Wickens CD. Engineering Psychology and Human Performance. 2nd ed. New York, Harper Collins, 1992.

Woollacott MH. Age related changes in posture and movement. J Gerontol.

1993;48(S):56-60.
Wolfson L, Whipple R, Derby CA, et al. A dynamic posturography study of balance in healthy elderly. Neurology. 1992;42:2069-2075.