Falls in the Elderly and Attention Capacity Deficit Theory

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국문요약

노인 낙상과 주의력 결핍 이론

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노인에 있어 낙상 (falls)의 결과는 신체 기능상의 상실을 가져올 뿐 아니라 종종 사망에 이르게 하는 원인이 되기도 하여 중대한 건강상의 문제로 다루어 지고 있다. 정상적인 노화과정은 감각 (sensory)과 운동 (motor)계의 감퇴 그리고 주의력의 쇠퇴와 연관되어있는데, 노인들은 이러한 감각 (sensory)과 운동 (motor)계 (system)의 손상으로 여러가지 자세 (posture)와 보행 (walking) 등을 수행하는데 어려움을 겪는다. 또한 노화와 관련된 변화들은 자세를 조절 (postural control) 하는데 있어서 주의력 (attention capacity)을 감소시킨다. 이러한 조건하에서 노인들은 이중과업 (dual task)을 수행하는데 젊은 사람들보다도 더 많은 어려움을 느끼며 이는 곧바로 낙상 (falls) 의 가능성을 증가시키는 중요한 원인이 되고 있다. 이러한 점들을 고려할때 낙상 (falls) 을 방지하기위한 훈련 프로그램 (training program)은 단순한 신체운동 (physical exercise) 보다는 자세 조절 (postural control)시의 인지 시스템 (cognitive system)이 포함된 중추 통합 기전 (central integrative mechanisms) 을 최적화 (optimize) 시킬 수 있는 방향으로 구성되어야 한다.

핵심단어 : 주의결핍이론; 노화; 낙상; 주의력; 이중과업

Introduction

Falls in the elderly are considered to be one of the most important health problems because, regardless of severity, the consequences are often a significant loss of functional independence or even death. From one-fourth to one-third of persons aged 65 and older reported a fall in the previous year (Blake et al 1988; Campbell et al. 1981; Prudham &

Evans 1981; Wickham et al. 1989). From one-third to one-half of those who had already fallen in the previous year are more likely to fall again (Nevitt et al. 1989; O'Laughlin et al. 1993; Tinetti et al. 1988). Falls are more common in those who are in institutionalized settings than amongst the elderly in the community (Rubenstein et al. 1988; 1992). It is estimated that one-third and one-fifth of all injury mortality in women and men are related to falls (Sattin 1992). Falls also account for more than 50% of injury-related deaths in women and men who are around age 85 (Sattin 1992). Falls in the frail elderly appear to be closely related to increased mortality regardless of injury severity (Dunn et al. 1992; Hemenway & Colditz 1990; Campbell et al. 1990; Tinetti et al. 1993; Wolinsky et al. 1992).

Falls in the elderly are also an important economic pressure on the health system because falls in the elderly result in major medical costs. 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 activities, 369,000 hospitalizations, and direct costs of $7.8 billion in the United States (Rice et al. 1989). Research shows that fall related medical costs are attributable to almost 8% of the total lifetime economic cost of all unintentional injury in the United States. It is estimated that most of the nearly $10 billion in annual costs of osteoporosis is due to falls in the elderly (Runge 1993). Fall-related medical costs for the elderly in 1993 averaged $10,000 to $12,000, which is 50% more than for non-elderly adults hospitalized for a fall (Covington 1993).

Many falls in the elderly have a long-term effect. For example, 40% of those who fell had continuing pain or disability two months later and 16% had pain even seven months after the fall (Grisso et al. 1992). The psychological and functional consequences of falls are also significant for the elderly because fear of more falling can lead to a sequelae of restricted activity, social isolation, and increasingly greater dependence (Chandler et al. 1996; Tinetti et al. 1994). Thus, a single fall often may result in a fear of falling and an immediate activity limitation. The ensuing deconditioning results in muscle weakness that result from immobility. An inability to get up and a long bed rest may lead to serious physical complications (Maki et al. 1991; Nevitt 1990; Nevitt & Cummings 1991; Tinetti et al. 1993).

The etiology of falls in the elderly

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 (Rubenstein et al. 1988; Runge 1993; Tinetti & 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 weak muscles (Stelmach & Worringham 1985; Wolfson et al. 1992; 1995; Woollacott 1993). The physiologic effects, such as sedation, psychomotor and autonomic impairment, of many drugs may increase possibilities of falls in the elderly. The diseases, including Parkinsonism, seizures, and stroke may increase the risk of a fall (Nevitt et al. 1989). Environmental obstacles may pose serious threats to mobility and safety in those who have gait and/or balance impairment.

The three most critical senses for balance and gait include visual, vestibular, and somatosensory systems. The aging process affects the sensory system (i.e. visual impairment, mild proprioceptive and vibratory sense loss). With aging it appears that there is increased incidence of proximal to distal sequencing of lower extremity muscle activation in response to perturbation being opposite to that in young adults whose response is distal to proximal sequencing of lower extremity muscle activation in response to perturbation (Inglin & Woollacott 1988; Lord et al. 1994; 1996; Woollacott 1990; Woollacott et al. 1986; 1989). Further, there are increased incidence of co-contraction of antagonist muscle groups, increased static sway, and increased number of steps required to recover balance from perturbation.

Muscle torque and power is a major factor in balance recovery. However, there is a significant weakness of distal lower extremity torque (ankle and knee) in the elderly fallers comparing to healthy older adults (Studenski, et al. 1991; Whipple et al. 1987). Thelen et al. (1996) also have shown that older adults have a limited ability to develop ankle torques compared to younger adults. There is also age related losses in joint range of motion and flexibility leading to a less efficient response strategy.

Other studies (Heitmann et al. 1989; Wolfson et al. 1995) have shown that older individuals with a history of falls have significant change in gait characteristics compared to younger adults. For example, Wolfson et al. (1995) have reported that older adults who fall have reduced stride length and walking speed. Heitmann et al. (1989) also have shown that older adults with a history of falls or poor balance performance have increased step width during walking.

Attention deficit theory in falls in the elderly

Imagine 20-year-old and 80-year-old pedestrians walking down a busy street. 80-year-old individuals will need, on average, to exert more attention to accomplish this task than will 20-year-old individuals because of motor and sensory function losses in the elderly. As a result, one may hypothesize that old adults will be more likely than young adults to interrupt a cellular phone to call a friend while walking down a busy street.

As suggested by this illustration, it is predicted that walking becomes more attention demanding as people age. Thus, with aging increased attention is required to compensate decreased balance control, either due to injury or sensory system deterioration. Therefore, increased attention is properly allocated to heighten the signal coming from these systems in order to gain the necessary information for postural control (Stelmach et al. 1990).

It was previously thought that postural control only requires an automatic response, and is independent of cognitive processing (Diener & Horak 1991; Macpherson et al. 1989; McIlroy & Makai 1993; Nashner 1976; Nashner & Woollacott 1979). However, several investigators have begun to question this hypothesis and to study how attentional capacities affect balance control in the elderly. In fact, there is a strong casual relationship between attentional capacities and postural control. For example, several studies (Colledge et al. 1994; Teasdale et al. 1991a; Teasdale et al. 1993; Wolfson et al. 1992; Lajoie et al. 1996) have shown that a slowing of central processing with aging, i.e. as seen by a reduction in the speed with which older people can respond (Welford 1982), is primarily responsible for the impaired balance control and the increase of incidence of falls.

Attention refers to information processing capacity (Moray 1967), or space (Keele 1973) or resources (Wickens 1992) in an individual. The available information processing capacity (or resources) is thought to be limited to handle information for any individual (Schmidt 1999), but it may be partitioned to different tasks in any way the individual decides. Thus, if two tasks are performed at the same time and both require more than the total resources of attention capacity, interference between two tasks could occur. 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. The patterns of interference that are observed between two different tasks presumably provide important information about the nature of the limitations in capacity to different individuals (Schmidt 1999).

Attentional capacity of older adults is thought to be challenged while walking and simultaneously performing a secondary motor or cognitive task (Shumay-Cook 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 & 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).

Several studies have focused on reduced and/or conflict paradigms to examine the central integrative mechanisms in the elderly. In studies of postural stability in the elderly and young adults when both visual and proprioceptive inputs are altered, Straube et al. (1988) and Teasdale et al. (1991a) have found more postural instability in the elderly than in young adults. These studies, in addition to a reduced peripheral sensibility suggest evidence for the impairment or slowing of the central integrative processes responsible for reconfiguring postural set in the elderly (Teasdale et al. 1991b).

Another line of evidence for a deficit in the central integrative mechanisms comes from the work of Teasdale et al. (1992). Elderly and young subjects were submitted to successive reduced and augmented sensory conditions (i.e., no-vision/vision transition). Results showed that the elderly exhibited an increased sway dispersion, but young adults adapted rapidly to the augmented sensory conditions and reduced a sway dispersion. Teasdale et al. (1993) have also shown similar results. When young and elderly subjects were given an auditory stimulus in four conditions of vision/surface, that is (a) vision/normal surface, (b) no-vision/normal surface, (c) vision/altered surface, and (d) no-vision/altered surface (the subjects's task was to respond as rapidly as possible to an unpredictable auditory stimulus by pressing a handheld button), the elderly required more reaction time than the young adults as sensory information decreased.

Several investigators have also measured the reaction time when subjects have to reintegrate visual or proprioceptive information to examine the role of attention to the age related changes while either standing or walking. These studies clearly suggest that age related changes limit an attentional capacity for the integration of postural set. For example, Teasdale & Simoneau (2001) studied capacity limitations of central processing (or integrative) mechanisms in the elderly by measuring reaction time. The elderly and young subjects were exposed to series of reduced sensory and proprioceptive information while standing on a movable platform. At the same time subjects were also required to respond to an unpredictable auditory cue. They found that elderly showed more increased postural instability under conditions of proprioceptive reintegration compared to young adults. Longer reaction time while performing a postural task has been observed for both the elderly and young adults only when proprioceptive information was reintegrated without vision.

Redfern et al. (2001) have also found that aging has an adverse effect on the interaction between sensory integration of postural control and attentional processing by measuring simple and inhibitory reaction time while seated and standing under different postural challenge conditions. In that experiment, increased postural sway in the elderly subjects was observed when a reaction time task was performed simultaneously, but not in young subjects. This increase in sway in the elderly was particularly significant under a high degree of sensory conflict (i.e., both the floor and visual scene were sway referenced). These studies clearly suggest that age related changes limit an attentional capacity for the integration of postural set. Furthermore, the above results clearly suggest that the elderly suffer from decreased attentional capacities and/or defective allocation of the resources available with advancing age (Baron et al. 1988; Craik 1977).

The dual-task paradigm is based on the hypothesis that, with increasing age, it is more difficult to perform two tasks at once (Cerella et al. 1980; McDow & Craik 1988), 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). In dual-task paradigms, investigators generally combine cognitive tasks (i.e., a math task or a sentence completion task) and/or reaction time tasks (i.e., auditory or visual stimulus) with sensorimotor tasks such as standing and walking to measure how successfully the individuals manage to divide attention between two different tasks. Several studies have used the dual-task paradigm to study the attentional demand of postural control during quiet standing (Brown et al. 1999; Maylor & Wing 1996; Maylor et al. 2001; Shumway-Cook et al. 1997; Stelmach et al. 1990; Teasdale et al. 1993) and walking (Chen et al. 1996).

Several standing studies under the dual-task paradigms (Brown et al. 1999; Maylor & Wing 1996; Maylor et al. 2001; Shumway-Cook et al. 1997) have shown significant age differences when the platform is compliant or moving under dual-task paradigms primarily due to higher cognitive control demands, but not the case for the solid platform. The above studies examined attentional constraints on older adults in standing, but it is interesting to know whether more demanding motor tasks such as walking require more attention for the older adult than the young. A recent experiment by Chen et al. (1996) provided some information on this issue. They measured the success rate of avoiding a virtual obstacle when both young and old adults were required to negotiate obstacles that was suddenly projected across their pathways. Subjects were asked simultaneously to respond vocally as quickly as possible when the visual cue was provided. Older adults had a significantly increased risk of contacting the obstacle compared to young adults while negotiating obstacles when their attention was divided. Thus, problems in the performance of the secondary task while negotiating obstacles may contribute to falls in the elderly. This is consistent with the notion of the impairment of the attention in the elderly when individuals walk.

In summary, normal aging is associated with changes in both the sensory and motor systems as well as in attention. Because of the deficit in motor and sensory function in the elderly they have more difficulty in performing postural or stepping tasks. In addition, age related changes limit the attentional capacity for performing postural control in quiet stance and walking. Under these circumstances 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.

Conclusion

Based on previous studies it is clearly suggested that the decreased balance control and increased incidence of falls observed in the elderly could be explained by problems in the interdependence between sensorimotor and the cognitive system, rather than only by a decreased integrity of the peripheral sensory systems. Simple mechanical and/or peripheral models of postural control and gait cannot explain the current data we reviewed. In addition, we may have to change the concept that the problems in the postural control are mainly due to the nerve system deterioration (i.e. an irreversible loss of function) (Crilly et al., 1989). Possibly, the training program for prevention of falls in the elderly may need to more focus on optimizing the central integrative mechanisms between postural control and cognitive system to yield improvement in balance control and gait, rather than just simple program of physical exercise. For example, clinicians could use the concept of multiple hierarchies in both postural and cognitive tasks when developing balance-retraining programs designed to reduce the likelihood for injurious falls in older adults. Initially, tasks that are low on the postural hierarchy could be retrained; as balance improves, secondary attention demanding tasks of varying difficulty could be added to further challenge and improve the postural stability.

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