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Aging and Balance Control: Analyzing the Increased Attentional Demands – A Comprehensive Review

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ABSTRACT

As individuals age, the need for attentional resources to maintain postural control increases due to changes in sensorimotor functions. Older adults often prioritize balance over secondary tasks to preserve function. Reduced or conflicting sensory information further increases these demands. Performing a secondary task in such conditions can strain attentional resources, potentially compromising stability and increasing fall risk. The attention required for maintaining balance is affected by the characteristics of secondary tasks, including their complexity, type (motor, cognitive, visual, or auditory), visual demands, working memory involvement, and the need for articulation. Understanding these factors is crucial for creating strategies to improve postural control and prevent falls in the elderly. Understanding the varying attentional demands in different postures and positions aids clinicians and physiotherapists in assessing and selecting appropriate secondary tasks for effective rehabilitation in the elderly.

Keywords: Aging; Attention; Balance; Older Adults; Sensory

Abbreviation: RT: Reaction Time

Introduction

Compared to young adults, healthy older adults exhibit reduced performance in both balance and cognitive tasks when these tasks are performed simultaneously. This relationship has been studied across various aspects, including postural sway, neuromuscular activity, stepping behavior, postural control recovery from self-induced or external displacements, and walking [1].

Attentional Requirements of Maintaining an Upright Stance

Lajoie et al. investigated the attentional requirements for maintaining posture and walking in both young and elderly individuals. They evaluated reaction times (RT) to an auditory task in four different positions: seated, standing with a broad base of support, standing with a narrow base of support, and walking. Elderly participants had slower RTs and shorter stride lengths in challenging positions, indicating that postural tasks required more attention with age [2]. Melzer et al. studied postural control while performing cognitive tasks in young and older adults. Older adults showed increased postural sway and muscle activity, especially in dual-task conditions and with a narrower base of support, indicating a greater impact on balance [3]. Berger and Bernard-Demanze explored the impact of a spatial memory task on postural control, discovering that younger adults prioritize cognition while older adults prioritize posture when performing dual tasks [4].

Attentional Requirements for Postural Recovery Following Voluntary Movements

Stelmach, Zelaznik, and Lowe investigated postural control during voluntary arm movements in eight older and eight younger adults, incorporating secondary tasks (a cognitive math task or a motor hand squeeze) during the latter half of a 50-second standing trial. They measured the impact on the center of foot pressure's speed, range, and variability during arm swinging and recovery. Older adults took longer to recover from arm swinging while performing the cognitive task, unlike the motor task, which had no significant difference between age groups. The study also revealed that simple manual tasks had less impact on postural control compared to complex cognitive tasks [5].

The Attention Required for Stepping in Response To Perturbations

Automatic postural responses are rapid, involuntary actions that help maintain balance in response to unexpected stimuli, typically initiated by somatosensory inputs within 250 milliseconds [6]. These responses include four main strategies: ankle, hip, suspensory, and stepping. Individuals with neurological disorders often adopt abnormal strategies. For instance, those with vestibular disorders tend to rely on the ankle strategy, while those with somatosensory loss use the hip strategy. The stepping strategy is employed when other strategies are insufficient or when the center of gravity exceeds the base of support. Older adults predominantly use the stepping strategy to recover from balance disturbances [7,8]. Melzer and Oddsson investigated 66 healthy elderly individuals and 12 young subjects, examining rapid voluntary stepping in various directions on a force platform under single- and dual-task conditions. The elderly participants were significantly slower in all stepping parameters in both conditions, with dual tasks increasing the initiation phase by 108% in the elderly group. This suggests that balance loss in the elderly may stem from insufficient neural resources for multitasking [9].

Brown, Shumway-Cook, and Woollacott investigated how postural recovery places differing attentional demands on young and older adults, revealing that older adults need to allocate more attention to execute effective recovery strategies. In older adults, stepping strategies were more attentionally demanding, and failure to allocate sufficient attention could lead to falls [10]. Zettel, McIlroy, and Maki studied how attentional demands affect stepping reactions and gaze behavior in both young and older adults. Their findings revealed that older adults exhibited diminished anticipatory postural adjustments during tracking tasks, resulting in heightened lateral center-of-mass movement. This suggests that impaired attentional shifting among older adults could elevate the likelihood of falls. [11].

The Cognitive Demands of Walking

Research frequently investigates how aging influences dual-task walking, where individuals must walk while simultaneously engaging in attention-demanding activities like conversation or monitoring their surroundings for vehicles. Lindenberger, Marsiske, and Baltes: Examined 47 young, 45 middle-aged, and 48 older adults trained in a mnemonic technique. Participants walked on narrow tracks while encoding word lists. Dual-task costs increased with age, indicating a greater need for cognitive control as one age [12]. Li, Lindenberger, Freund, and Baltes examined cognitive (memorization) and sensorimotor (walking on a narrow track) performance. They found that older adults prioritize walking over memory tasks and can improve their walking performance by using external memory aids [13]. Hollman, Kovash, Kubik, and Linbo investigated gait velocity and variability in young, middle-aged, and older adults under dual-task conditions. They found that older adults showed slower walking speeds and increased variability in their stride, which were associated with diminished cognitive performance [14]. Priest, Salmon, and Hollman: Found similar detrimental effects on gait parameters in older women, suggesting increased attentional requirements for walking with age and a higher risk of falls during cognitively demanding tasks [15].

The Cognitive Demands Involved in Avoiding Obstacles

Chen et al.: Compared young and older adults stepping over a virtual obstacle. Both groups had an increased risk of contact when attention was divided, with a significantly greater effect in older adults [16]. Schrodt, Mercer, Giuliani, and Hartman: Analyzed gait and cognitive task performance in older adults under dual-task conditions. Gait parameters changed minimally, but cognitive performance decreased, suggesting older adults prioritize gait to maintain stability [17].

Influence of Secondary Task Characteristics on Attentional Demands for Balance Control

Previous sections reviewed the impact of concurrent cognitive tasks on balance, noting increased attentional demands with the difficulty of balance tasks in older adults. The characteristics of secondary tasks also influence attention requirements for balance, with varying effects depending on the cognitive task's complexity [18]. Stelmach et al. 5 found that simple manual tasks are less disruptive to postural control compared to complex cognitive tasks. Lajoie et al. 2 reported that a simple reaction time task did not affect posture, contrasting with findings suggesting more complex tasks may impact balance. Shumway-Cook, Brauer, and Woollacott observed that secondary tasks, whether manual (e.g., carrying a full cup of water) or cognitive (e.g., counting backward by threes), increased completion time for the Timed Up and Go Test uniformly, without enhancing its predictive ability [19]. Daily activities often involve secondary tasks like talking and affecting posture. Yardley et al. [20] studied young adults performing tasks on static and unstable surfaces, finding that articulation increased postural sway, attributed to respiratory activity or central interference between speech and balance. This concept underpins the "Stops Talking While Walking" test, identifying older adults at fall risk [21]. Dault, Yardley, and Frank [22] noted in young adults that articulation tasks increased sway while non-articulation tasks increased stiffness, suggesting motor task requirements influence postural sway changes [23].

Older adults, relying more on vision due to sensory declines, show prolonged reaction times during walking tasks, suggesting increased attention demands and fall risk from visual demands [24]. Bock highlighted visually demanding tasks' impact on dual-task performance and potential fall risk in older adults during walking and visual obser-

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vation [25]. In contrast, Jamet et al. [26] found a visual-verbal Stroop task did not affect postural control in healthy older adults, while mental counting increased instability, tied to visual reliance and internal visual imagery. Memory task impacts on postural control show older adults sway more with visual-spatial working memory tasks (Maylor and Wing) [23], or exhibit postural instability with various working memory tasks (Dault, Frank, Allard) [27]. Beauchet et al. [28] noted arithmetic tasks disrupt lateral gait stability in frail older adults, unlike semantic memory-dependent verbal fluency tasks. Redfern et al. [29] found age groups engaged attention for postural control during reaction time tasks, with auditory responses more impacted in older adults during perturbations.

Sensory Influences on Attentional Demands of Balance Control

Balance relies on somatosensory, visual, and vestibular inputs 6, [30-33]. Reduced sensory inputs increase balance attentional demands, especially in older adults (Teasdale, Bard, LaRue, Fleury) [34]. Shumway-Cook et al. found cognitive tasks affect older adults' postural stability, more so with falls history [35]. They studied sensory context on postural stability in young and older adults during dual-tasking, finding older adults unstable without reliable visual and somatosensory signals. Redfern et al. found sensory integration demands attention, increasing sway during conflicts in older adults. With age, walking, obstacle avoidance, and balance control's attentional demands increase, heightening fall risk.

Summary

This study highlights that compared to younger adults, maintaining balance is more demanding for older adults, especially when simultaneously performing cognitive tasks, which can significantly impair balance and recovery abilities. Older adults place a higher priority on preserving balance than on secondary tasks to maintain overall functionality. Woollacott and Shumway-Cook attribute these preferences to age-related declines in sensory and motor systems, as well as reduced attentional capacity, either individually or in combination. Paul, Ada, and Canning also link these issues to decreased physical activity and subsequent loss of multitasking ability due to disuse [36-38]. The attentional demands associated with maintaining balance are affected by several characteristics of secondary tasks, such as their complexity, type (whether motor or cognitive), sensory requirements, and whether they involve working memory or articulation. As age increases, postural control necessitates greater attentional resources, exacerbated by age-related sensorimotor changes. Diminished sensory inputs or conflicting sensory information can further elevate the attentional demands required for maintaining postural control, potentially increasing the risk of falls. These situations are common in daily activities like crossing streets while talking or carrying groceries, highlighting the heightened fall risk for older adults.

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Ethics Statement

This article is a literature review, with no new empirical data collected from human participants or animals. Therefore, ethical approval was not sought.

Author Contributions

SG and DS contributed to the first draft of the paper equally. SG and DS revised it critically for intellectual content. All authors gave final approval of the version to be published and agreed to be accountable for all aspects of the work.

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Data Availability Statement

Data sharing does not apply to this article as no new data were created or analyzed in this study.

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