Emerging Concept: ‘Central Benefit Model’ of Exercise in Falls Prevention

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Abstract

Falls are a common geriatric syndrome and are the third leading cause of chronic disability worldwide. Falls are not random events and occur, at least in part, due to impaired physiological function, such as impaired balance, and cognitive impairment. The clinical syndrome of falls is important for sports and exercise medicine clinicians as there is Level 1 evidence that targeted exercise prescription is an effective intervention strategy. The widely accepted dogma is that improved physical function, balance and muscle strength, underlies the effectiveness of the exercise in reducing falls. However, findings from randomized controlled trials suggest that exercise reduce falls via mechanisms other than improved physiological function. We propose that improved cognitive function – specifically, executive functions – and associated functional plasticity may be an important yet under-appreciated mechanism by which the exercise reduces falls in older adults.

Keywords

Executive Functions; Exercise; Falls

BACKGROUND

Falls are a common geriatric syndrome and are the third leading cause of chronic disability worldwide.[1] About 30% of community-dwellers over the age of 65 experience one or more falls every year.[2] About 20% of falls require medical attention and 5% result in

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CONTRIBUTORSHIP STATEMENT

TLA conceived the conceptual framework. TLA, LSN, CLH, and NB drafted the manuscript. All authors read and approved the final manuscript.

COMPETING INTERESTS

None to declare

fracture, with one-third of those being hip fractures. Falls place a major and increasing demand on the public health system.

Falls are not random events and occur, at least in part, due to impaired physiological function, such as impaired balance, and cognitive impairment.[2] The clinical syndrome of falls is important for sports and exercise medicine clinicians as there is Level 1 evidence [3] that targeted exercise prescription is an effective intervention strategy.[4] The Otago Exercise Program (OEP) – a physical therapist-delivered, or nurse-delivered, progressive home-based strength and balance training program tailored for older adults – is the exercise training program with the strongest evidence for falls prevention in older adults.[4] As with many conditions, exercise for falls prevention is an example of ‘exercise is medicine’.[5]

The widely accepted dogma is that improved physical function, balance and muscle strength, underlies the effectiveness of the exercise in reducing falls. However, in a meta-analysis of four OEP randomized trials, falls were significantly reduced by 35% while postural sway significantly improved by only 9% and there was no significant improvement in knee extension strength.[6] These data demand explanation – does exercise reduce falls via mechanisms other than improved physiological function? We propose that improved cognitive function and associated functional plasticity may be an important yet under-appreciated mechanism by which the exercise reduces falls in older adults.

FALLS AND EXECUTIVE FUNCTIONS

Within the multiple domains of cognitive function, reduced executive functions are associated with both falls [7, 8] and injurious falls.[9] Executive functions are higher order cognitive processes that control, integrate, organize, and maintain other cognitive abilities. These cognitive processes include the ability to concentrate, attend selectively, plan, and strategize. In a prospective study of inpatient falls in an urban rehabilitation hospital, performance on the Stroop Color-Word Test, a standard neuropsychological test of selective attention and conflict resolution, predicted falls status beyond that explained by age and functional motor ability.[7] In addition, Anstey and colleagues [10] reported that senior fallers (both single and recurrent) performed significantly worse on a measure of selective attention and conflict resolution compared with non-fallers. Given that movement through the environment requires attending to relevant stimuli and inhibiting prepotent, yet potentially unsafe, responses, it is logical that selective attention and conflict resolution is related to falls.

Our conceptual framework for the proposed central benefit model is illustrated in Figure 1. This framework highlights that reduced executive functions may increase the propensity to fall via various pathways including impaired balance [11] and gait [12] secondary to reduced attentional capacity, impaired central processing and integration, and impaired execution of postural responses. Reduced executive functions may also increase falls risk via decreased judgment and diminished self-regulation,[7] or indirectly increase falls risk via secondary disruptions in executive functions-related behaviour, such as a loss in motivation and initiation.[13] Conversely, impaired balance and gait and loss of motivation and initiation may lead to further reductions in executive functions (i.e., feedback loop). Notably, targeted

exercise training reduces falls risk in older adults by maintaining or promoting executive functions.

Critically, reduced executive functions are prevalent among healthy, community-dwelling seniors with intact global cognitive function (i.e., MMSE score $\geq 24/30$).^[14] This is not surprising given many of the pathological changes (e.g., white matter lesions) associated with reduced executive functions are prevalent but clinically silent.

EXERCISE AND EXECUTIVE FUNCTIONS

Physical activity maintains and enhances cognition across the lifespan.^[15] A meta-analysis concluded that aerobic training had robust but selective benefits for cognition; the largest benefits occurred for executive functions.^[16] Resistance training also benefited executive functions and its associated functional plasticity.^[17, 18]

DOES EXERCISE REDUCE FALLS BY IMPROVING EXECUTIVE FUNCTIONS & ASSOCIATED FUNCTIONAL PLASTICITY?

Recent evidence from randomized controlled trials supports the hypothesis that exercise may reduce falls by improved executive functions. This concept challenges the current paradigm of falls prevention strategies that focus solely on improving physical function and minimizing environmental hazards. Critically, our proof-of-concept randomized controlled trial found that the OEP significantly reduced falls by 47% among older adults with a significant history of falls -- in the absence of significant improvement in physical function (i.e., balance and muscle strength).^[19] Notably, cognitive performance of selective attention and conflict resolution improved in the OEP group as compared with the usual care (i.e., control) group. Another randomized controlled trial demonstrated that improved selective attention and conflict resolution secondary to 12 months of progressive resistance training was associated with improved usual gait speed.^[17] Gait speed is a significant and independent predictor of falls and fracture risk in older women.^[20] Moreover, improved gait speed is a predictor of substantial reduction in mortality.^[21] Providing additional support for the central benefit theory, Li and colleagues demonstrated five sessions of non-motor cognitive dual-task training results in significant improvements on measures of dual-task standing balance and mobility, compared with an untrained control group.^[22]

Emerging evidence from neuro-imaging studies also support our proposed central benefit model. Baseline functionality of brain regions that are part of the neural network associated with selective attention and conflict resolution [23, 24] were independently associated with change in falls risk profile.^[25] Critically, both aerobic [26] and resistance training [18] can significantly enhance the functional plasticity of these regions associated with falls risk profile. Additional future research is needed and welcomed to assess the validity of our proposed central benefit model.

CLINICAL IMPLICATIONS OF THE CENTRAL BENEFIT MODEL IN FALLS PREVENTION

Given the strong association between executive functions and falls, we recommend that falls risk screening include far greater attention to assessment of cognitive processes – in particular executive processes of selective attention and conflict resolution and dual-tasking. In addition, future falls prevention strategies should consider intervention components that target executive functions. For example, both aerobic exercise training and progressive resistance training have specific benefits on functional plasticity in brain regions that are responsible executive functions.[18, 26] Therefore, both types of exercise training should be incorporated into the current exercise-based falls prevention strategies that focus on primarily on balance training.

Acknowledgments

Teresa Liu-Ambrose is a Michael Smith Foundation for Health Research Scholar, a Canadian Institutes of Health Research New Investigator, and a Heart and Stroke Foundation of Canada's Henry JM Barnett's Scholarship recipient. Lindsay Nagamatsu is a Michael Smith Foundation for Health Research Senior Graduate trainee and a Natural Sciences and Engineering Research Council of Canada Doctoral trainee.

FUNDING

This work was supported by the Canadian Institutes of Health Research (MOB-93373) to TLA.

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Conceptual Framework for the Central Benefit Model

Figure 1. Conceptual Framework for the Central Benefit Model

Arrows indicate direct consequence. T-bar indicates prevention. This framework highlights that reduced executive functions may increase the propensity to fall via various pathways including impaired balance [11] and gait [12] secondary to reduced attentional capacity, impaired central processing and integration, and impaired execution of postural responses. Reduced executive functions may also increase falls risk via decreased judgment and diminished self-regulation,[7] or indirectly increase falls risk via secondary disruptions in executive functions-related behaviour, such as a loss in motivation and initiation.[13] Conversely, impaired balance and gait and loss of motivation and initiation may lead to further reductions in executive functions (i.e., feedback loop). Notably, targeted exercise training reduces falls risk in older adults by maintaining or promoting executive functions.