

# Emerging concept: 'central benefit model' of exercise in falls prevention

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Received 31 October 2011

Accepted 12 March 2012

Published Online First

20 April 2012

## 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 randomised controlled trials suggest that exercise reduce falls via mechanisms other than improved physiological function. The authors propose that improved cognitive function – specifically, executive functions – and associated functional plasticity may be an important yet underappreciated mechanism by which the exercise reduces falls in older adults.

## BACKGROUND

Falls are a common geriatric syndrome and are the third leading cause of chronic disability worldwide<sup>1</sup>. About 30% of community dwellers over the age of 65 experience one or more falls every year<sup>2</sup>. About 20% of falls require medical attention and 5% result in 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<sup>2</sup>. The clinical syndrome of falls is important for Sports and Exercise Medicine clinicians as there is Level 1 evidence<sup>3</sup> that targeted exercise prescription is an effective intervention strategy<sup>4</sup>. The Otago Exercise Program (OEP) – a physical therapist-delivered, or nurse-delivered, progressive home-based strength and balance training program tailored for older adults<sup>4</sup> – is the exercise training program with the strongest evidence for falls prevention in older adults. As with many conditions, exercise for falls prevention is an example of 'exercise is medicine'<sup>5</sup>.

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 randomised 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.<sup>6</sup> 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 underappreciated mechanism by which the exercise reduces falls in older adults.

## FALLS AND EXECUTIVE FUNCTIONS

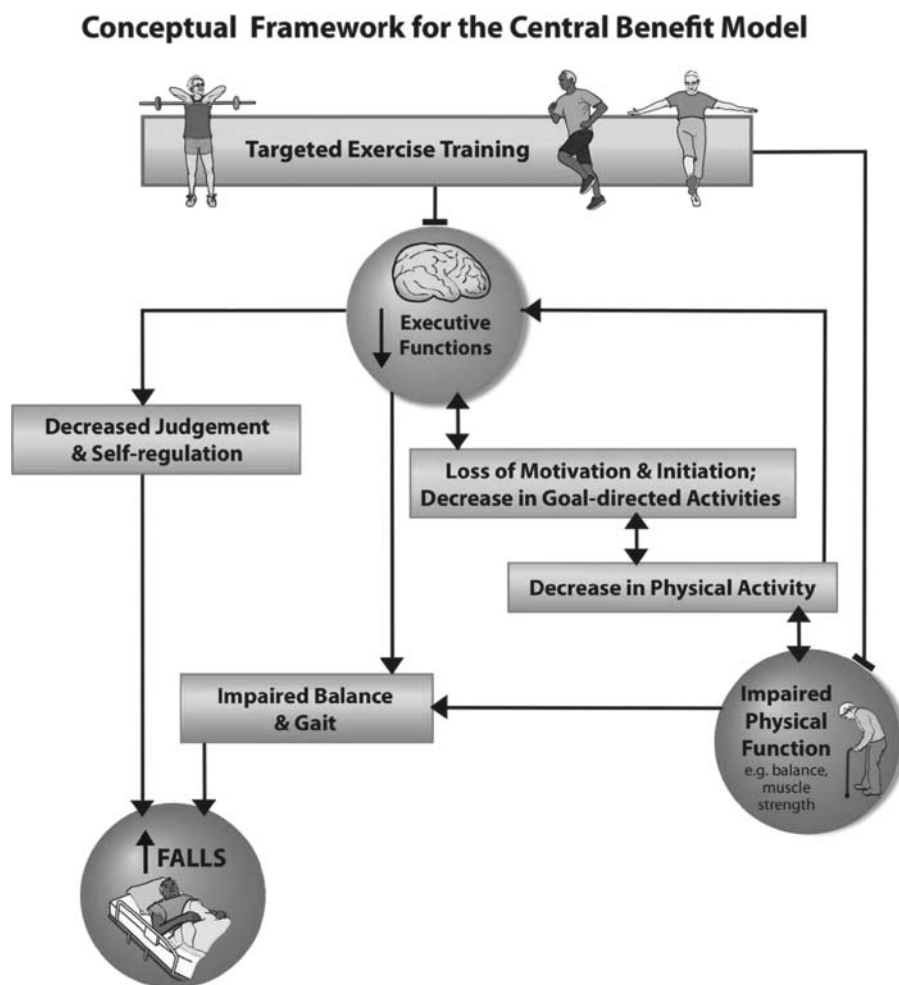
Within the multiple domains of cognitive function, reduced executive functions are associated with falls<sup>7–8</sup> and injurious falls.<sup>9</sup> Executive functions are higher order cognitive processes that control, integrate, organise and maintain other cognitive abilities. These cognitive processes include the ability to concentrate, attend selectively, plan and strategise. 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.<sup>7</sup> In addition Anstey *et al*<sup>10</sup> 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<sup>11</sup> and gait<sup>12</sup> 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 judgement and diminished self-regulation,<sup>7</sup> or indirectly increase falls risk via secondary disruptions in executive functions-related behaviour, such as a loss in motivation and initiation. Conversely, impaired balance and gait and loss of motivation and initiation<sup>13</sup> may lead to further reductions in executive functions (ie, 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 (ie, Mini-Mental State Examination (MMSE) score  $\geq 24/30$ ).<sup>14</sup> This is not surprising given many of the pathological changes (eg, white matter lesions) associated with reduced executive functions are prevalent but clinically silent.

**To cite:** Liu-Ambrose T, Nagamatsu LS, Hsu CL, *et al.* *Br J Sports Med* 2013; **47**, 115–117.

**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<sup>11</sup> and gait<sup>12</sup> 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,<sup>7</sup> or indirectly increase falls risk via secondary disruptions in executive functions-related behaviour, such as a loss in motivation and initiation.<sup>13</sup> Conversely, impaired balance and gait and loss of motivation and initiation may lead to further reductions in executive functions (ie, feedback loop). Notably, targeted exercise training reduces falls risk in older adults by maintaining or promoting executive functions.



### EXERCISE AND EXECUTIVE FUNCTIONS

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

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

Recent evidence from randomised 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 minimising environmental hazards. Critically, our proof-of-concept randomised 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 (ie, balance and muscle strength).<sup>19</sup> Notably, cognitive performance of selective attention and conflict resolution improved in the OEP group as compared with the usual care (ie, control) group. Another randomised 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.<sup>17</sup> Gait speed is a significant and independent predictor of falls and fracture risk in older women.<sup>20</sup> Moreover,

improved gait speed is a predictor of substantial reduction in mortality.<sup>21</sup> Providing additional support for the central benefit theory, Li *et al* 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.<sup>22</sup>

Emerging evidence from neuroimaging 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<sup>23 24</sup> were independently associated with change in falls risk profile.<sup>25</sup> Critically, both aerobic<sup>26</sup> and resistance training<sup>18</sup> 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.<sup>18 26</sup> Therefore, both types of exercise training should be incorporated into the current exercise-based falls-prevention strategies that focus primarily on balance training.

**Acknowledgements** 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.

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

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

**Competing interests** None.

**Ethics approval** UBC CREB.

**Provenance and peer review** Not commissioned; externally peer reviewed.

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*Br J Sports Med* 2013 47: 115-117 originally published online April 20, 2012

doi: 10.1136/bjsports-2011-090725

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## Corrections

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Liu-Ambrose T, Nagamatsu LS, Hsu CL, *et al.* Emerging concept: ‘central benefit model’ of exercise in falls prevention. *Br J Sports Med* 2013;**47**:115–7. This paper was published as a ‘Commentary’, but should have been an ‘Editorial’.

*Br J Sports Med* 2013;**47**:856. doi:10.1136/bjsports-2011-090725corr1