Author's response to reviews

Title: A perturbation-based balance training program for older adults: study protocol for a randomised controlled trial

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Author's response to reviews: see over
Dear Editor,

We are submitting the revised manuscript entitled "A perturbation-based training program for older adults: study protocol for a randomised controlled trial". Please find below a point-by-point response to concerns raised by the reviewers.

Both reviewers raise valid concerns regarding the use of platform perturbations in training. The following paragraphs have been added to the Methods section (see highlighted paragraphs on page 7 and page 8) to discuss this issue and to explain the rationale underlying our decision to use this perturbation method for the training program:

Method of perturbation

In the simplest terms, maintaining stable upright stance involves keeping the centre of mass (COM) of the body over the base of support (BOS) defined by the feet (and, in some situations, the arms). Hence, the essential defining feature of any balance perturbation is that it induces relative motion between the COM and the BOS. For stance perturbations, this relative motion can be induced by causing displacement of either the COM (e.g. via cable waist-pull systems) or the BOS (e.g. via motion platform systems). During gait, this relative motion can also be induced when the cyclic progression of the COM and BOS is disrupted due to perturbation of the BOS (e.g. due to a slip on a low-friction surface, a trip on an obstacle, or sudden acceleration or deceleration of a treadmill).

The various available perturbation methods may differ in a number of respects, such as the pattern of motion induced at specific joints, the evoked sensory inputs and the pattern of the early evoked muscle activation [40]. Nonetheless, these various methods all fulfil the fundamental biomechanical requirement (disruption of the COM-BOS relationship) and can often elicit postural reactions that are similar in many respects [40]. Hence, it is possible that the training benefits derived using one type of perturbation may generalise (at least to some extent) to the reactions evoked by other types of perturbations. This, however, remains to be established. If there is limited generalisability of training benefits, then it would be best to choose a perturbation method that closely emulates the perturbations that lead to loss of balance and falls in daily life; however, it is unlikely that this can be accomplished using any one single method of perturbation. The training perturbations would need to simulate both slips and trips (reported to account for approximately 40-60% of falls in older adults [41-43]) as well as the sizable proportion of falls that do not involve ambulation (e.g. self-induced perturbation during leaning, turning, reaching or sit-stand transfer movements; support-surface motion that occurs when standing in a moving vehicle [41, 43]).

For this study, we elected to develop a custom-designed pneumatic motion platform for the purpose of delivering the postural perturbations needed to evoke stepping and grasping reactions during training (Figure 2). One important feature of the moving-platform approach is the ease with which the direction of perturbation can be varied in an unpredictable manner [18]. Unpredictability is a critical requirement, as the CNS can learn to recognise any features of the perturbation that are predictable (direction, magnitude, waveform or timing), and can use this information to improve the efficacy of the balance reactions in a predictive manner [44-48]. This type of predictive control is unlikely to be helpful in responding to the unpredictable perturbations that commonly lead to falls in daily life; hence, the adaptations that result from training with predictable
perturbations may have limited generalisability [18]. A second practical advantage of the motion-platform approach is that large numbers of perturbations can be delivered in a short span of time, hence maximising opportunity for training while minimising the risk of fatigue, which would be more likely to occur during gait-perturbation methods [36, 39].

Responses to Dr. Duysens:

1) How relevant are the type of perturbations trained and studied? In daily life a sudden translation is likely to occur when standing in a bus which is suddenly moved. This occurs very infrequently. Perhaps the training could be expanded by having subjects also walk in place while adding the perturbations. This would already broaden the scope of related ADL situations a little.

We have added a detailed discussion of this issue, as noted above (pages 7 and 8). In addition, please note that the training does, in fact, include walking in place on the motion platform. This is indicated in Table 1 (listed under tasks involving “repetitive movement of lower body”), and we now also mention this in the main text (page 12, paragraph 3).

2) What is trained and what is tested is still very much overlapping. The authors introduced the waist pull test to counter this objection but it remains that the other test is very close to the training elements.

There are actually several key differences in the motion-platform and waist-pull perturbations. The fundamental difference, of course, is that the waist pull involves a perturbation to the center of mass, rather than the support surface; thus, the waist-pull tests serve to address criticism related to the argument that support-surface perturbations are not a very common occurrence in daily life. There are other differences as well. For example, the evoked sensory drive differs in that the platform perturbations tend to involve less vestibular stimulation (as the head remains relatively stationary in absolute space). Moreover, we have just completed a study that demonstrates several significant differences in the characteristics of the stepping and grasping responses that are evoked by the two types of perturbations. We have modified the text to make these points and have added additional supporting references, including the study that we have recently completed (page 18, paragraph 1).

Notwithstanding the above, we agree that there are also similarities in many features of the motion-platform and waist-pull perturbations, and we have now added an acknowledgement that there will be a need (in future studies) to assess the extent to which any benefits of the platform training generalise to a wider range of perturbations and loss-of-balance situations (page 24, paragraph 3).

3) One of the goals is to reduce the latency of responses. This part is weak though since it is unlikely that the fastest parts of the responses can be speeded up. This may not be a major problem though since it has been shown that behavioral reactions are only partly determined by this very early activity and rely more on later components. Instead it may be more interesting to look at how well subjects can use the rail grabbing to restore balance.

We agree that there is a strong potential to affect later components of the grasping reactions, and we have added some text to emphasise this point (page 11, paragraph 1; page 20, paragraphs 1 and 2). Although the potential for improvement in the latency of the reaction may be relatively small, there is
actually some evidence to show that balance training can reduce onset latency for triggered reactions. We have also noted this point and included supporting references (page 11, paragraph 1).

**Responses to Dr. Sherrington**

*I would like to some further justification of the choice and relevance of perturbation-based balance training when the majority of challenges to balance faced by older people in daily life are in situations where the ground is stationary.*

We have added a detailed discussion of this issue as noted above (see highlighted paragraphs on page 7 and page 8). Please also see the highlighted changes to the first paragraph on page 18.

*A reference to the Cochrane review of interventions for falls prevention would also improve this manuscript.*

Reference to the Cochrane review has now been included (reference #3, which is now cited in the first paragraph on page 4).

Regards,
Avril Mansfield