Intensity of challenge to the balance system is not reported in the prescription of balance exercises in randomised trials: a systematic review

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Question: How has balance challenge intensity been reported in trials of balance exercise interventions? Are there any instruments designed to measure the intensity of balance challenge in balance training exercises? Design: Systematic review of randomised trials of balance training exercises. Participants: Older adults, ie, the majority of subjects were aged over 55 years. Intervention: Balance exercise intervention, or multi-dimensional intervention that included a balance exercise intervention. Outcome measures: The included trials were examined for descriptions and instruments used to report the intensity of the challenge to the patient's balance system prescribed by the balance exercise prescribed. The other included studies were examined for instruments that measure balance challenge intensity. Results: In most of the 148 randomised trials identified, measures of reported balance challenge ‘intensity’ were actually measures of some other aspect of the exercise, eg, aerobic intensity or a hierarchy of task difficulty without reference to the patient's ability. Three potential systems of measuring the balance challenge intensity were identified. Two were not described in any detail. One was defined in terms of the limits of the patient’s postural stability, but this system appears not to have been validated. No adequate measures of balance challenge intensity were found among the other types of studies identified. Conclusion: The review highlights a serious gap in the methods used to prescribe, implement, and evaluate the effect of balance exercise programs. Comprehensive work in this area is required to develop a psychometrically sound measure of balance exercise intensity. [Farlie MK, Robins L, Keating JL, Molloy E, Haines TP (2013) Intensity of challenge to the balance system is not reported in the prescription of balance exercises in randomised trials: a systematic review. Journal of Physiotherapy 59: 227–235]

Key words: Postural balance, Exercise, Exercise therapy, Systematic review

Introduction

Age-related decline in balance occurs in both men and women, beginning as early as 40 years of age (Nitz and Low Choy 2008, Nolan et al 2010). Balance control is important for maintaining independence and safety. An extensive review of randomised controlled trials has reported that trials repeatedly demonstrate that exercise programs designed to challenge a person’s balance can improve balance ability in older adults (Howe et al 2011). A recent systematic review of exercise interventions to prevent falls also concluded that exercise can prevent falls, balance exercises were essential, and strength training and walking were optional (Sherrington et al 2011). A limitation previously identified in this body of work is that outcomes of exercise programs that improve balance have been reported inconsistently (Howe et al 2011). These reviewers did not comment, however, on whether the description of exercise prescription and dosage parameters had been reported consistently.

Physiological adaptations to exercise are specific to the type of exercise performed, but the principle of overload dictates that exercise needs to be performed at or near the limits of an individual's capacity to induce a training effect (Thompson et al 2010). A recommended exercise prescription method is the FITT framework, which consists of the Frequency, Intensity, Type, and Time (ie, duration) of exercises prescribed (Thompson et al 2010). While exercise frequency, type, and time are relatively easy to quantify, quantifying exercise intensity is more complex. Quantification of exercise intensity has been achieved in the domain of strength training, where intensity is routinely measured using the 1-repetition maximum (1RM) method (Thompson et al 2010). Aerobic training programs use intensity measures such as percentage of maximal oxygen uptake or percentage of heart rate maximum to determine the appropriate intensity for inducing a cardiovascular training effect (Thompson et al 2010). The Borg rating of perceived exertion scale was first developed as a measure of aerobic exercise intensity (Borg 1982) and more recently has
been validated as a measure of strength training intensity (Gearhart et al 2001).

In determining the optimum level of challenge of balance exercises, recommendations commonly relate to the difficulty of the balance task, rather than to the intensity of the activity relative to the ability of the individual (Thompson et al 2010, Tiedemann et al 2011). Therefore, although it is known a person is performing one task that may be more difficult than another, it is not clear how to quantify the challenge of that task to the balance capability of that individual. Specialist practitioners in the field of falls and balance have reported being unable to identify an ideal balance exercise intensity prescription method, other than to say that the balance exercises prescribed need to be challenging (Haas et al 2012). Given that there are four factors used to prescribe exercise, if one factor is missing or measured inconsistently, optimal prescription dosage is confounded. To date, there has been no systematic investigation of whether or how the intensity of balance exercise prescription has been determined in trials of balance rehabilitation programs.

The research questions for this review were therefore:
1. How has balance exercise intensity been reported and prescribed in trials of balance exercise interventions?
2. Have any instruments been designed to measure the intensity of balance training exercises?

**Method**

**Identification and selection of studies**

A three-phase process was used to identify articles appropriate for inclusion in this review. In the first phase, the lead investigator (MF) conducted a search in December 2011 to identify all systematic reviews published between 2006 and 2011 that included balance exercise interventions. Reviews published earlier than 2006 were not included as it was reasoned that reviews published in the last five years would include most, if not all, relevant trials previously reviewed in this area. Key search terms and the databases searched are presented in Table 1. The titles and abstracts of articles identified by the search were reviewed to identify eligible systematic reviews based on eligibility criteria, as presented in Box 1. The reference lists of the eligible systematic reviews were searched for any additional relevant review articles for which title and abstract were also reviewed against the same criteria. Citation details were extracted for all randomised trials identified in all the eligible systematic reviews.

**Box 1. Eligibility criteria for systematic reviews of trials reporting balance exercise interventions.**

<table>
<thead>
<tr>
<th>Review design</th>
<th>• Publication date no earlier than 2006</th>
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<tbody>
<tr>
<td></td>
<td>• Systematic reviews of RCTs investigating a balance exercise training intervention</td>
</tr>
<tr>
<td>Participants</td>
<td>• Majority of trial participants were adults over 55 years</td>
</tr>
<tr>
<td>Intervention</td>
<td>• A review of balance exercise intervention, or</td>
</tr>
<tr>
<td></td>
<td>• A review of multi-dimensional interventions (eg, falls prevention interventions) that included balance exercise as an intervention</td>
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In the second phase, the titles and abstracts of randomised trials identified in the first phase were reviewed independently by two investigators (MF, LR) against second phase eligibility criteria, as presented in Box 2. The reference lists of the included trials were also searched for additional potentially eligible trials. The titles and abstracts of these trials were also reviewed against the criteria in Box 2. Results were compared to reach consensus on eligible trials. Where there was disagreement between the two investigators regarding eligibility for inclusion, a third investigator was consulted (TH) and disagreements resolved through discussion. Two investigators (MF, LR) read the full text of eligible trials and performed independent data extraction. Results were then compared to merge relevant data extracted. Data extracted included demographics of trial participants and information on FITT parameters for each exercise program. Where available, information on the FITT parameters was extracted for the exercise intervention as a whole, as well as for balance-specific components. The investigators extracted the words authors used to report balance intensity, as well as any instruments used to measure balance challenge intensity. If a measure of balance intensity was described, a search for any reports of scale properties was conducted.

**Box 2. Inclusion criteria for randomised controlled trials reporting balance exercise interventions.**

<table>
<thead>
<tr>
<th>Design</th>
<th>• Randomised controlled trial</th>
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<tbody>
<tr>
<td>Participants</td>
<td>• Older adults (age &gt; 55 y)</td>
</tr>
<tr>
<td>Intervention</td>
<td>• Balance exercise intervention, either a balance specific exercise program, or a mixed exercise program that included balance exercises</td>
</tr>
<tr>
<td>Document properties</td>
<td>• Full text article</td>
</tr>
<tr>
<td></td>
<td>• English language</td>
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In the third phase, a literature scan was conducted independently by two investigators (MF, LR) to identify any instruments that reportedly measure balance challenge intensity. In particular, this search was intended to identify instruments that had not yet been used in any published randomised controlled trial. The search terms are presented in Table 2.

**Assessment of the depth of literature identified**

To test the comprehensiveness of this process in identifying relevant randomised trials, a capture-recapture analysis was performed on the field of trials identified from the 23 systematic reviews included. Capture-recapture analysis is a statistical analysis method used to estimate populations, more traditionally animal populations, where a total population estimate can be made from the number of a species captured, tagged, and recaptured in a geographical area. This review aimed to identify all systematic reviews published from 2006 onwards that contained randomised controlled trials of balance exercise interventions, assuming that each systematic review intended to be exhaustive in its search of the scientific literature. We have worked on the assumption that each systematic review in isolation is a ‘capture’ of trials from the total population of trials of balance exercise intervention and when a trial appeared in
With others set in residential aged care (n = 31), hospital settings (n = 6), combined community and residential aged care (n = 5), and combined community and hospital (n = 1). The number of participants in trials ranged from 13 to 3999 (mean = 204), with a range of mean ages from 59 to 88 years (mean = 77). The majority of trials (n = 135) were trials of exercise interventions only, with the remainder (n = 13) multifactorial falls prevention interventions that included a balance exercise component. Exercise programs were primarily of mixed type of which balance exercise was one component (n = 137), while 11 trials investigated balance exercise only interventions. Some trials (n = 27) used published exercise programs such as the Otago program (Accident Compensation Corporation 2003) or the High Intensity Functional Exercise (HIFE) program (Littbrand et al 2006a). A small number of trials used Tai Chi interventions (n = 21). Details of the published exercise programs used in the included trials are presented in Table 3.

### Description of information reported in reviewed trials

The FITT parameters reported for each exercise intervention are displayed in Appendix 3 (see eAddenda for Appendix 3). A large number of studies failed to report all four FITT elements of their exercise interventions (n = 102). These cells are marked ‘NR’ (not reported). A small number of studies (n = 25) reported balance exercise intensity parameters. To evaluate if the construct reported as balance challenge intensity was accurate, a decision tree was used, as presented in Figure 2. First, reported data was deemed not to be balance exercise intensity if it clearly constituted another FITT construct. For example, a measure of frequency or duration was reported for intensity in seven studies (Lord et al 1996, MacRae et al 1994, Rubenstein et al 2000, Sattin et al 2005, Silsupadol et al 2006, Urbscheit and Wiegand 2001, Wolf et al 2003). If an intensity measure was reported, it was considered to be a measure of balance challenge intensity if it was an intensity measure of some other aspect of exercise. For example, intensity using the Borg rating of perceived exertion of either aerobic exertion or mental concentration was reported as balance exercise intensity in four studies (Nelson et al 2004, Pereira et al 2008, van Uffelen et al 2008, Zhang et al 2006). Lastly, a hierarchy of task difficulty, which was reported in 10 trials, was considered to be a measure of balance challenge intensity. This was commonly the report of a narrowing of the base of support or an increase in complexity of tasks performed over time in the exercise program (Chin A Paw et al 2004, Chin A Paw et al 2006, Davison et al 2005, Englund et

Analysis of reports of balance challenge intensity

Where the reported intensity was not dismissed as a misrepresentation, this was considered a potential report of balance challenge intensity and examined further. In two instances the report was non-descriptive: ‘based on set criteria’ (Arai et al 2007) and ‘easy/medium/hard’ (Wolfson et al 1996). Of interest, two studies utilising the HIFE exercise program reported the balance exercise as high intensity. The definition of balance intensity was determined relative to the limits of postural stability (Littbrand et al 2006b, Rosendahl et al 2006). This was a novel intensity rating developed by the researchers for use in prescribing their exercise program (Littbrand et al 2006a). While this measure of balance challenge was not excluded by the process in Figure 2, the reliability and validity of this approach is unknown as no

Figure 1. Flow of studies through the review.

Figure 2. Balance intensity decision tree.
Three of the instruments – the Performance Oriented Mobility Assessment (Tinetti 1986), the Community Balance & Mobility Scale (Howe et al 2006), and the Unified Balance Scale (La Porta et al 2011) – measure balance performance but do not rate balance exercise intensity (ie, they measure how many of a hierarchical set of challenges can be performed rather than a rating of how difficult an individual finds it to perform a scale item). Two global balance ratings were identified (Howe et al 2006, Leahy 1991). One, the functional balance grades first described by Leahy (1991), is a general rating of the balance and mobility of an individual that does not measure the intensity of balance exercise but describes balance as normal, good, fair, poor, and zero with standard definitions. The second, described by Howe et al (2006), is a general rating of balance and mobility used in the process of validating the Community Balance & Mobility scale. Again it is not a measure of balance exercise intensity. No instruments to rate the intensity of balance exercise were identified.

### Discussion

A substantial number of clinical trials investigating balance exercise were identified in this review. The reporting of the intensity of balance exercises prescribed was, however, largely overlooked. This review therefore provides empirical and objective evidence of a serious gap in this wide field of research and clinical practice. Of 148 randomised trials reporting balance exercise interventions, none reported a validated measure of balance exercise intensity. Instead, the most common approach adopted was to describe of taxonomy of task difficulty that trial participants progressed through as they performed activities of increasing difficulty (Chin A Paw et al 2004, Chin A Paw et al 2006, Davison

### Table 3. Characteristics of published exercise programs that include balance training.

<table>
<thead>
<tr>
<th>Program (Included trials)</th>
<th>Reference Origin</th>
<th>Summary of program content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stand-up/step-up (n = 2)</td>
<td>Liss (1976) USA</td>
<td>7 levels of exercise: 1) sit to stand x 5, 2) step up x 5, 3) sit to stand x 10, 4) Step up x 10, 5) sit to stand x 15, 6) step up x 15, 7) repetitions increased relative to HR.</td>
</tr>
<tr>
<td>Square-stepping exercise program (n = 2)</td>
<td>Shigematsu et al (2008) Japan</td>
<td>Square stepping exercise program – agility training, resistance band exercises, balance activities, single leg and double leg balance with heels/toes raised, tandem, eyes open and closed.</td>
</tr>
<tr>
<td>HIFE program (n = 2)</td>
<td>Littbrand et al (2006a,b) Sweden</td>
<td>Strength exercises, balance exercises, combined strength and balance exercises. Static and dynamic functional exercises with progressive decreasing support or more challenging surface.</td>
</tr>
</tbody>
</table>

Supporting evidence of this was presented by the authors or found by the investigators of this review.

A measure of aerobic exercise intensity was reported in three studies. These programs used a Borg rating of perceived exertion scale to measure the intensity of the exercise intervention. One study of a balance rehabilitation intervention prescribed exercises that began at 11 (light) and progressed to 13 (somewhat hard) on the 6–20 Borg scale (Means et al 2005). In this study the balance intervention included strengthening, stretching, postural control, walking and coordination exercises, and the Borg scale target was not specific to the balance exercises but rather a rating for the intensity of the exercise intervention in its entirety. A Borg scale was also used to rate the mental concentration demanded during Tai Chi exercise (Pereira et al 2008), with participants aiming for 1 or 2 on Borg’s Effort Subjective Perception (ESP) scale (Pereira et al 2008 p. 123). An article describing the ESP scale has not been published in English. The third study instructed participants to exercise at 7 to 8 on the 0–10 Borg scale during a strength and balance exercise program; again balance exercise intensity was not specifically targeted in this rating (Nelson et al 2004).

### Analysis of potential measures of balance challenge intensity

The searches for instruments to measure balance exercise intensity yielded eight studies that reported seven outcome measures of interest. Scanning of reference lists yielded an additional instrument. Two of the instruments, the Activities of Balance Confidence scale (Powell and Myers 1995, Schepens et al 2010) and CONFbal (Simpson et al 2009) measure the construct of balance confidence (ie, the confidence of an individual to perform a particular task).
et al 2005, Englund et al 2005, Hauer et al 2001, Hauer et al 2002, Helbostad et al 2004, Netz et al 2007, Sjösten et al 2007, Tinetti et al 1994). One could argue that this approach is sufficient to challenge participant balance capabilities and induce an overload effect. However, this approach provides no indication of how difficult the individual performing the task found this at the time. There is an underlying assumption that all individuals have the same balance capacity and are consistently challenged by the introduction of a ‘subsequent task’ in the hierarchy. This is analogous to a strength-training program where participants were asked to perform a leg press against resistance of 5 kg, 10 kg, and 15 kg weights in successive weeks. Although we know the resistance is increasing, we do not know what percentage of 1RM these weights represent for the participant. For a frail older adult this may be a very difficult activity, but for a younger, fitter individual it may not, and it would not be possible to monitor the exercise intensity level in either individual in terms of a proportion of their capability.

Of the few studies that purported to report balance exercise intensity explicitly, intensity was represented inaccurately. In other words, authors used other parameters as surrogates for intensity. Some authors reported balance exercise intensity in terms of time spent balance training. For example Silsupadol et al (2009) state that the ‘duration and intensity of this training was chosen based on previous studies showing that 10-hour to 12-hour balance training and 1-hour to 5-hour dual-task training programs were effective’ (p. 382). Similarly Rubenstein et al (2000) reported an increase in balance exercise difficulty by increasing the time spent training from 5 min to 15 min over the 12 weeks of their program, and Wolf et al (2003) who report increasing the intensity of their Tai Chi intervention by increasing duration of sessions from 60 to 90 min over the course of a year.

Authors also reported an increase in task difficulty as a proxy for balance exercise intensity. This was primarily done with exercise programs that progressed through standardised levels of difficulty (Davison et al 2005, Tinetti et al 1994) or with reference to task taxonomies (Helbostad et al 2004, Silsupadol et al 2006), for example Gentile’s taxonomy of movement tasks (Gentile 1987) or the task manipulations described by Geurts et al (1991). Other authors discussed the principles used to increase task complexity such as reducing the base of support or increasing complexity by making ‘multi-factorial’ environmental changes to exercises (Chin A Paw et al 2004, Chin A Paw et al 2006, Englund et al 2005, Hauer et al 2001, Hauer et al 2002). If task difficulty is used as the indicator for balance exercise intensity, exercise prescription across broad populations cannot be monitored or graded to ensure training effects for individual patients. If all patients had the same balance capacity at the beginning of a program, then a linear progression in task difficulty through a program may represent an increase in balance exercise intensity for individuals from session to session. Apart from the fact that no group of participants is ever homogeneous, one would still be left with this dilemma regarding the level at which the exercise intensity was pitched through the program. It would be unclear whether all participants started the balance exercises at a low intensity and stayed low, or started at a moderate intensity and practised high intensity exercises by the end of the intervention.

One program that explicitly presented a rubric to guide balance exercise intensity prescription was identified (Littbrand et al 2006a). This HIFE program includes a table (p. 8) that defines low, medium, and high intensity exercise prescriptions. For the strength training exercises, the repetition maximum principle is used. For balance exercise a three-point scale ranging from ‘no challenge’ to ‘fully challenged’ postural stability is used. The authors provide a definition for full challenge of postural stability as ‘balance exercises performed near the limits of maintaining postural stability’ (Littbrand et al 2006a p. 8). This attempt at standardisation carries some face validity given that repetitive work at the limits of stability is likely to represent an overload, however the ordinal scaling limits the usefulness of this rating of balance exercise intensity. If the level of balance exercise intensity cannot be measured in a reliable and valid way then questions of how hard we need to challenge balance in order to induce improvements in balance cannot be answered. This issue is of particular relevance for the development and implementation of home exercise or unsupervised programs, as it has been found that clinicians often prescribe programs of lower challenge in the home environment compared to supervised situations (Haas et al 2012).

While still ordinal in nature, another rating scale that may inform a future measure of balance exercise intensity is the Borg scale. Studies in this review that utilised the Borg scale, also known as the rating of perceived exertion scale, reported the intensity of interventions of mixed exercise types, attributing the rating to the program in its entirety (Means et al 2005, Nelson et al 2004, Pereira et al 2008). This intensity rating appears to apply more to the aerobic and strength training elements of these exercise programs; researchers have not specifically applied this rating to how hard individuals were working at maintaining balance. The observation of these generalised ratings of exercise intensity across modalities are in accordance with a previous review examining dosage and intensity of multi-modal exercise programs that concluded ‘few studies with robust interventions prescribing individually assessed intensities of each modality have been conducted’ (Baker et al 2007 p. 380). In particular, the Baker et al (2007) review of 15 trials found that balance training exercise intensity was reported using the rating of perceived exertion in one instance and otherwise was not reported (n = 9) or was reported as ‘progressive’ without use of any intensity-rating instrument (n = 5), which is consistent with the findings of this much larger review.

The original rating of perceived exertion scale described by Borg (1970) ranged from 6 to 20, with the intention that the ratings could be multiplied by 10 to estimate heart rate between 60 and 200, respectively. This scale has been shown to have linear relationships with heart rate and work intensity (Borg 1973, Borg 1982, Skinner et al 1973). Initially, Borg designed the scale to measure exertion during physical activity (Borg 1973) but it has been more widely applied and numerous variants have been reported. The Borg scale has been reported as a reliable and valid means of rating the intensity of cardiovascular exercise such as treadmill running and cycling (Dunbar 1993), as well as strength training exercise through a linear relationship between proportion of repetition maximum and rating of perceived exertion (Gearhart et al 2001). Apart from the limitations of an ordinal scale and being a rating of overall
exertion, there would be difficulty applying this instrument in some populations due to cognitive impairment, language, and literacy. Therefore, a scale is yet to be found that could be applied in these circumstances.

The searches for scales of balance exercise intensity did not identify an appropriate rating scale. The instruments that were found attempt to quantify aspects of balance from a systems approach, using task performance criteria to assess balance performance rather than rating the intensity at which a task is completed. It is important to differentiate the concept of increasing task difficulty along a predictable trajectory from the measurement of the intensity, or difficulty, an individual experiences in trying to perform an activity or task anywhere along that spectrum of simple to complex tasks.

The review has highlighted an important gap in the methods used to prescribe, implement and evaluate the effect of balance exercise programs. At this time, it is not clear if balance exercise intensity can be measured accurately. The implications of not yet having an accurate measure of balance exercise intensity is that only three of the four fundamental exercise prescription factors that can be prescribed in balance exercise programs are able to be manipulated. Therefore the effectiveness, or not, of an intervention program cannot be evaluated or reproduced reliably if the intensity at which exercises are performed is not known. If balance exercise intensity could be quantified then research could then compare higher and lower intensity balance exercises while frequency, type and time of exercise could be held constant. We could then examine how intense balance exercises need to be to induce a training effect. This would inform balance rehabilitation exercise prescription. If low intensity is effective it may be cost effective for older adults to exercise at home unsupervised, however if only the highest intensities of exercises are effective there may need to be investment in the health workforce to supervise older adults completing more challenging exercise programs to reduce the risk of incident or harm while achieving a training effect.

As demonstrated in part by the capture-recapture analysis there is a possibility that this review may have missed a small number of papers, programs, or instruments reported to measure the intensity of balance exercises. However, the searches in this review were rigorous, identifying 148 trials, supplementing these with published exercise programs when available, and seeking instruments not yet used in randomised trials. The different foci of the 23 systematic reviews included in our capture recapture analysis would have served to inflate our estimate of the number of trials missed. This is because systematic reviews with different foci are more likely to contain unique papers, which would increase the estimate of missing trials.

An instrument to measure the intensity of balance challenge is needed to consistently describe the intensity of balance exercises prescribed in research and clinical practice. Once an instrument to rate the intensity of balance exercises has been developed, further research could determine the level of balance exercise intensity required to improve the balance of older adults, and how to prioritise resources to fund the most cost-effective program delivery models that best reduce falls, fall-related injuries, and subsequent health and aged care costs.

The review demonstrates overwhelmingly that the reporting of the intensity of balance exercise programs is grossly inadequate. To date, the intensity prescription of balance exercises has not been clearly described or adequately measured in research studies. The use of taxonomies of task difficulty as a proxy for balance exercise intensity does not show how an individual experiences balance challenges. The adaptation of the rating of perceived exertion to measure balance exercise intensity may be worthy of further investigation. Comprehensive work in this area is required to develop a psychometrically sound measure of balance exercise intensity.

**eAddenda:** Appendices 1, 2, and 3 available at jop.physiotherapy.asn.au

**Competing interests:** Terry Haines is the director of Hospital Falls Prevention Solutions Pty Ltd. He has authored trials included in this review but he was not involved in the evaluation of these trials for the purpose of this review.

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