Investigating the Clinical Significance and Research Discrepancies of Balance Training in Degenerative Cerebellar Disease

A Systematic Review

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Objective: The aims of this study were to understand the clinical significance of balance training in degenerative cerebellar disease and to analyze inconsistencies among published data.

Design: Five databases were searched from inception to October 8, 2019. Cochrane guidelines informed review methods, and Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines were followed. The Australian National Health and Medical Research Council Evidence Hierarchy, PEDro scale, and Joanna Briggs Institute Critical Appraisal Tools were used to evaluate methodological quality. Outcome measures examined included ataxia severity, gait speed, and balance.

Results: Fourteen articles were identified that met inclusion criteria. The quality of evidence was moderate to high, with recent articles being of higher quality. Nine of 12 articles showed statistical improvements in ataxia severity (reduction ranging from 1.4 to 2.8 in the Scale for the Assessment and Rating of Ataxia points), and six of nine showed improvements in balance measures (average increase of 0.1 m/sec), and six of nine showed improvements in balance measures (average increase of 1.75 in Berg Balance Scale and 1.5 in Dynamic Gait Index).

Conclusion: Most studies showed statistical and clinically significant ataxia severity improvements in subjects who performed balance training. The amount of balance challenge and frequency of training were important factors in determining the extent of training benefit. Gait speed may also improve if walking exercises are included in the balance training, but more studies need to be conducted. Balance measures statistically improved with training, but these improvements did not meet criteria for clinical significance.

What Is Known

- Balance training is the main treatment option for individuals with degenerative cerebellar disease, although there is conflicting data on the benefit of training. A previous systematic review indicates that more articles show training benefit than do not, but do not examine the cause for discrepancies between articles.

What Is New

- The cause for the inconsistent results in the literature regarding balance training in degenerative cerebellar disease was examined, and whether improvements are clinically meaningful was determined.

Key Words: Cerebellar Ataxia, Spinocerebellar Ataxia, SCA, Ataxia, Balance, Rehabilitation, Training, Therapy, Exercise


Individuals with degenerative cerebellar disease exhibit gradual loss of coordination resulting in impaired balance, gait deviations, and severe, progressive disability. The disease encompasses a heterogeneous group of autosomal recessive, autosomal dominant, X-linked, mitochondrial, and nongenetic disorders and can affect individuals at any age.1 Numerous mutations...
in different genes have been implicated in causing cerebellar degeneration, even though up to 29% of confirmed cases do not have a known genetic cause.²⁻⁴ It is estimated that 150,000 Americans are affected with this group of diseases,² and the mean healthcare cost per individual was between US$9,224 and US$16,477 in 2010. This cost was the same as treating individuals with two or more chronic diseases in the United States.⁶

Although trials are underway, there are no available disease-modifying medications.⁷ Primary treatment is based on rehabilitative training for symptom management and maintenance of functional performance.⁸ However, the cerebellum is crucial for motor learning, and it is unclear whether rehabilitative training is effective⁹⁻¹⁰ Nonetheless, a 2014 review of prospective trials showed a beneficial effect of high-intensity coordination training in individuals with degenerative cerebellar disease. Only four studies were included for this review, however.¹¹

In 2014, Fonteyn et al. conducted a review that examined all available health interventions for ataxia. The authors found inconclusive evidence to inform guidelines for training and physical therapy.¹² They also suggested that rehabilitation is most effective early in the disease course, although this finding may have been influenced by the nondegenerative causes of ataxia, such as cerebellar stroke, that were included in the review.¹³ The latest review to tackle the question of rehabilitation’s effectiveness for degenerative cerebellar disease was conducted in 2017. The authors conclude that there is consistent evidence that rehabilitation improves function, mobility, ataxia and balance in degenerative cerebellar disease. The authors indicate that most studies examined were of moderate to low quality and effects were inconsistent between studies.¹⁴ This article does not try to determine the cause of the inconsistent results.

This review will expand upon the previous in the following ways. First, by examining the different training strategies and methods, the causes for the inconsistent results in the literature regarding balance training in degenerative cerebellar disease will be considered. Second, the clinical significance of improvements seen with training will be assessed. The goal of the review is to try to determine which training strategies and methods were most beneficial in improving ataxia severity, gait speed, and balance for people with degenerative cerebellar disease.

METHODS

The review protocol was registered on the International Prospective Register of Systematic Reviews.¹⁵ The review methods were informed by Cochrane guidelines.¹⁶ The review is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (see Supplemental Checklist, Supplemental Digital Content 1, http://links.lww.com/PHM/B14).¹⁷,¹⁸

Eligibility Criteria

The eligibility criteria form that was applied to each study is listed in Supplemental Table 1 (Supplemental Digital Content 2, http://links.lww.com/PHM/B15). Studies were included if they were on genetic causes of degenerative cerebellar disease, peer reviewed in English language, and available in full text. They could be of any design and conducted in any setting. The intervention must include balance training. Other training modalities, such as gait training, could be performed in addition to balance training. For inclusion, the articles must include at least one outcome measure examining function, gait, balance, ataxia, and/or mobility. Reported data must be measured at baseline and within or following the therapy intervention period.

Search Strategy

The search strategy consisted of five electronic databases from inception up until October 8, 2019: CINAHL, Cochrane, MEDLINE, PEDro, and PubMed by title and abstract with synonyms for cerebellar degenerative disease. A second search used all identified keywords and index terms. All studies that met the inclusion criteria were then hand-searched for additional references. The PubMed search strategy is included in Supplemental Table 2 (Supplemental Digital Content 2, http://links.lww.com/PHM/B15). The PubMed search strategy was adapted to other databases, and these are available upon request from the first author.

Search Process

Finding from the search were compiled and duplicate titles were deleted. The first reviewer (S. Barbuto) then screened each title using previously determined eligibility criteria. The abstracts were then screened by both reviewers (S. Barbuto and S.-H. Kuo), and the full text was read to identify articles that met eligibility criteria. Agreement was reached by discussion without the need of the third reviewer.

Quality Assessment

Two reviewers (S. Barbuto and S.-H. Kuo) independently evaluated eligible studies for method quality using the Australian National Health and Medical Research Council Evidence Hierarchy. This hierarchy assigns levels of evidence I to IV, with the highest level of evidence, level I, being a systematic review (Supplemental Table 3, Supplemental Digital Content 2, http://links.lww.com/PHM/B15). The methodological quality of the included randomized clinical trials was further rated using the PEDro rating scale. When interpreting scores, studies of high quality score between 7 and 10, studies of fair quality score between 4 and 6, and studies of poor quality score 3 or below. Other study types were rated using the appropriate Joanna Briggs Institute Critical Appraisal Tools database. When interpreting scores for these scales, studies of high quality score greater than 7, studies of fair quality score between 4 and 6, and studies of poor quality score 3 or below. Articles were graded by two examiners (S. Barbuto and S.-H. Kuo), and when a difference in grading was found, a third reviewer (J. Stein) graded the article to determine the final grade.

Data Extraction

For the selected articles, the following data were extracted into a standardized table by one reviewer (S. Barbuto): author, publication year, training type, sample size, training intensity, frequency, and duration, Australian National Health and Medical Research Council Evidence Hierarchy score, PEDro or Joanna Briggs Institute score, outcome measures with clinical significance, and comments. The extracted data were checked by the other two reviewers (S.-H. Kuo and J. Stein) for accuracy. Meta-analysis
was not performed in this current study because of the heterogeneity of the studies reviewed.

RESULTS

The results are presented in text format, with a flowchart, summary tables, and narrative summaries. From a yield of 3945 titles, a final 14 studies were included. Figure 1 contains a PRISMA-compliant flowchart of search results and selection into the review. The two independent reviewers were able to reach consensus on all stages of selection process. Meta-analysis could not be conducted because of data heterogeneity, low study number, and limited power in the studies included. Table 1 shows the summary of the balance training articles selected.22–35 PEDro and Joanna Briggs Institute grading scores can be found in Supplemental Table 4a to d (Supplemental Digital Content 2, http://links.lww.com/PHM/B15). Figure 2A to C depicts balance training characteristics in graphical form. Figure 2D shows the forest plot for changes in balance, gait, and ataxia severity measures for all studies that provided standard errors or confidence intervals.

A total of 255 participants were included in the studies that met inclusion criteria for review. Sixty-two of these individuals had the diagnosis of autosomal recessive ataxia, whereas 193 subjects were diagnosed with autosomal dominant ataxia. Thirty-nine individuals were diagnosed with either idiopathic cerebellar ataxia or sporadic adult-onset ataxia. Spinocerebellar ataxia 6 and 3 were the most frequent diagnosis of the autosomal dominant ataxias, and Friedrich’s ataxia was the most frequent diagnosis of the autosomal recessive ataxia. Age ranges for participants with dominant cerebellar ataxia ranged from 26 to 82 yrs, whereas age for participants with autosomal recessive disease ranged from 11 to 61 yrs. All participants with dominant cerebellar ataxia were able to ambulate, whereas only 19 of the 62 participants with autosomal recessive ataxia were able to ambulate at the time of training. The participants in all studies had at least mild ataxia (Scale for the Assessment and Rating of Ataxia [SARA] ≥ 3 or International Cooperative Ataxia Rating Scale [ICARS] ≥ 10).36

Study designs included six randomized controlled trials, five quasi-randomized controlled trials, one retrospective cohort study, and two case series. Method quality appraisal indicated
<table>
<thead>
<tr>
<th>Study</th>
<th>Intervention</th>
<th>Sample Size</th>
<th>Training Dose and Frequency</th>
<th>Disease Severity</th>
<th>Δ SARA (P)</th>
<th>Δ ICARS (P)</th>
<th>Δ Gait Speed (P)</th>
<th>Δ FIM (P)</th>
<th>Δ Balance (P)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ilg 2009²²</td>
<td>Supervised inpatient training focused on balance</td>
<td>10</td>
<td>1 hour sessions 3 × per week for 4 weeks</td>
<td>−5.2 (&lt;0.001)</td>
<td>Not given (0.005)</td>
<td>&gt;0.1 m/s (&lt;0.05)</td>
<td>Clinically significant</td>
<td>NA</td>
<td>BBS: Not given (0.005)</td>
<td>Assessors not blinded No controls. Benefits retained with home training</td>
</tr>
<tr>
<td>Ilg 2010²³</td>
<td>Unsupervised home balance training after inpatient training</td>
<td>8</td>
<td>1 hour sessions 7 × per week for 1 year</td>
<td>−2.3 (0.03)</td>
<td>NA</td>
<td>Not given &gt;0.05</td>
<td>Clinically significant</td>
<td>NA</td>
<td>BBS: 1.5 (0.24)</td>
<td>Home training after 4-week training above. No walking exercises</td>
</tr>
<tr>
<td>Miyai 2012²⁴</td>
<td>Supervised inpatient training focused on balance</td>
<td>42</td>
<td>2 hour sessions 7 × per week for 4 weeks</td>
<td>−2.8 (&lt;0.001)</td>
<td>NA</td>
<td>0.137 m/s (&lt;0.01)</td>
<td>Clinically significant</td>
<td>1.2 (&lt;0.05)</td>
<td>NA</td>
<td>Benefits declined back to baseline after training</td>
</tr>
<tr>
<td>Keller 2014²⁵</td>
<td>Unsupervised home balance training</td>
<td>14</td>
<td>20 minute sessions 4–6 × per week for 6 weeks</td>
<td>NA</td>
<td>Not given &gt;0.05</td>
<td>0.1 m/s (&lt;0.001)</td>
<td>Clinically significant</td>
<td>NA</td>
<td>DGI: 1.5 (&lt;0.001)</td>
<td>III-3 JBE: 7 Short training intensity (20 minutes) Balance Challenge important</td>
</tr>
<tr>
<td>Bunn 2015²⁶</td>
<td>Unsupervised home balance training</td>
<td>12</td>
<td>15 minute sessions 5 × per week for 4 weeks</td>
<td>−1.8 (&gt;0.05)</td>
<td>NA</td>
<td>NA</td>
<td>−1.8 (&gt;0.05)</td>
<td>BBS: 1.7 (&gt;0.05)</td>
<td>II PEDro: 6 Short training intensity (15 minutes)</td>
<td></td>
</tr>
<tr>
<td>Burciu 2013²⁷</td>
<td>Supervised balance training on tilt plate</td>
<td>19</td>
<td>1 hour sessions 7 × per week for 2 weeks</td>
<td>−0.8 (&gt;0.05)</td>
<td>−1.0 (&gt;0.05)</td>
<td>NA</td>
<td>NA</td>
<td>BBS: 1.8 (0.02)</td>
<td>III-3 JBE: 6 Short training duration (2 weeks)</td>
<td></td>
</tr>
<tr>
<td>Milne 2012²⁸</td>
<td>Supervised inpatient rehab with balance included</td>
<td>42</td>
<td>Not specified</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>8.5 (&lt;0.05)</td>
<td>Clinically significant</td>
<td>NA</td>
<td>III-3 JBE: 3 Retrospective, Δ FIM after acute rehab stay</td>
</tr>
<tr>
<td>Nardone 2014²⁹</td>
<td>Supervised inpatient rehab with balance included</td>
<td>13</td>
<td>90 minute sessions 5 × per week for 3 weeks</td>
<td>NA</td>
<td>Not given &gt;0.05</td>
<td>Not given &gt;0.05</td>
<td>BBS: 2.0 (&lt;0.05)</td>
<td>Not clinically significant</td>
<td>NA</td>
<td>IV JBE: 7 Retrospective, compared with cerebellar stroke</td>
</tr>
<tr>
<td>Seco 2014³⁰</td>
<td>Supervised inpatient rehab with balance included</td>
<td>10</td>
<td>1 hour sessions 3 × per week for 5 years</td>
<td>NA</td>
<td>(See comment) NA</td>
<td>10.0 (&lt;0.01)</td>
<td>Clinically significant</td>
<td>NA</td>
<td>II PEDro: 9 ICARS unchanged in intervention group, but 15-point increase in control ICARS scores</td>
<td></td>
</tr>
<tr>
<td>Study Year</td>
<td>Type of Therapy</td>
<td>Patient Characteristics</td>
<td>Session Details</td>
<td>Outcome Measures</td>
<td>Evid. Level</td>
<td>PEDro</td>
<td>Clinical Significance</td>
<td>Notes</td>
<td></td>
<td></td>
</tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>Ilg 201231</td>
<td>Unsupervised exergame balance</td>
<td>10</td>
<td>1 hour sessions 7× per week for 6 weeks</td>
<td>-2.0 (&lt;0.001) Clinically significant</td>
<td>NA</td>
<td>Not given (&lt;0.05)</td>
<td>NA</td>
<td>DGI: 1.5 (0.01) Not clinically significant</td>
<td>III-3 JBE 8</td>
<td>Intensity of training important</td>
</tr>
<tr>
<td>Wang 201832</td>
<td>Unsupervised exergame balance</td>
<td>9</td>
<td>30 minute sessions 3× per week for 4 weeks</td>
<td>-1.5 (&lt;0.05) Clinically significant</td>
<td>NA</td>
<td>-0.13 m/s (&lt;0.05)</td>
<td>NA</td>
<td>NA</td>
<td>II PEDro: 7 SCA3 patients No walking exercises</td>
<td></td>
</tr>
<tr>
<td>Rodriguez-Diaz 201833</td>
<td>Supervised physical therapy with balance included</td>
<td>38</td>
<td>1 hour sessions 5× per week for 24 weeks</td>
<td>-2.0 (0.002) Clinically significant</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>II PEDro: 7 SCA2 patients No change in INAS</td>
<td></td>
</tr>
<tr>
<td>Tercero 201934</td>
<td>Supervised physical therapy with balance included</td>
<td>18</td>
<td>2 hour sessions Moderate: 3× per week Intense: 5× per week for 24 weeks</td>
<td>Mod: -0.5 Int: -1.4 (&lt;0.05) Clinically significant</td>
<td>NA</td>
<td>NA</td>
<td>No change in Barthel index</td>
<td>NA</td>
<td>II PEDro: 7 SCA7 patients</td>
<td></td>
</tr>
<tr>
<td>Fonteyn 201435</td>
<td>Supervised balance training on treadmill</td>
<td>10</td>
<td>1 hour sessions 2× per week for 5 weeks</td>
<td>-0.4 (0.011) Not clinically significant</td>
<td>NA</td>
<td>-0.01m/s (&lt;0.05)</td>
<td>NA</td>
<td>BBS: 0.3 (&gt;0.05)</td>
<td>IV JBE 5 Improved obstacle avoidance</td>
<td></td>
</tr>
</tbody>
</table>

SARA, Scale for the Assessment and Rating of Ataxia; ICARS, International Cooperative Ataxia Rating Scale; FIM, Functional Independence Measure; NHRMC, Australian National Health and Medical Research Council Evidence Hierarchy; JBI, Joanna Briggs Institute; BBS, Berg Balance Scale; DGI, Dynamic Gait Index; Exergame training on 3 Microsoft Xbox Kinect.
that the risk of bias was low, medium, and high. The study designs, small sample sizes, and method quality appraisals demonstrated that the elements of chance were generally controlled in about half of the included studies. The sources of bias included sampling, selection, performance, and measurement biases.

The sample sizes ranged from 8 to 42 people diagnosed with cerebellar degeneration. In terms of training, 117 of the 255 subjects primarily participated in balance training, and 138 received balance training in combination with other training such as strengthening, stretching, and gait training. Supervised training was conducted on 209 of these subjects whereas 46 participants completed unsupervised training at home. Of the 209 subjects who received supervised training, 75 participants received mostly balance training and 134 people received a broad range of training that included balance training. For the home training, 19 subjects used exergames for training, whereas 26 did not.

**Ataxia Severity**

Ataxia severity was determined before and after training in 12 of the 14 articles. Nine of the 12 articles showed a positive benefit of balance training on ataxia severity.22–24,30–35 Three of the articles showing benefit encompassed home training, whereas six of the articles relied on supervised training. Of the three articles that did not demonstrate improvements in ataxia severity with balance training, one had supervised training whereas two had home-based training.

In terms of outcome measures, two articles used the ICARS, a validated measure of ataxia severity, with higher scores indicating greater impairment.27 Ten articles used the SARA, another validated scale for ataxia severity, with 0 indicating no signs of ataxia and a score of 40 indicating the most severe ataxia.28 Neither study that used ICARS showed a significant improvement in ataxia severity. For the studies that used SARA, improvements in ataxia severity ranged from a statistically significant decrease of 0.4 to 5.2 points.22,35

**Gait Speed**

Eight of the 14 balance training articles examined gait speed as an outcome measure. Three of these eight articles had a statistically significant change in gait speed with balance training for subjects with cerebellar degeneration.22,24,25 These three articles included two inpatient balance programs and one home training balance program that all included walking exercises as part of the training. Of the five articles that did not show improvements of gait speed with balance training, two articles were exergame training articles,31,32 one was an unsupervised home training program that was partaken after inpatient training,23 one was supervised balance training on a treadmill,29 and the last was supervised inpatient training that included balance training.28 An improvement in gait
speed of 0.1 to 0.157 m/sec was seen in the studies that showed improvement.\textsuperscript{22,24,25}

### Balance

Balance is measured by multiple tests in the selected studies. Of the 14 articles selected, 9 measured balance before and after training, and 6 of these articles showed statistically significant improvements in at least one balance measure.\textsuperscript{22,24,25,27,29,31} Home training was conducted in two of the three nonsignificant balance test studies,\textsuperscript{23,26} and the other nonsignificant study used supervised training, but training frequency was only two times per week.\textsuperscript{35}

#### Ataxia Severity

Improvements in ataxia severity varied significantly for the participants with degenerative cerebellar disease who engaged in balance training. With much of the literature of similar quality, examination of the methods used in the different studies is warranted.

Three of 12 articles did not show improvement in ataxia severity with balance training in patients with degenerative cerebellar disease. In one of the articles, balance training was conducted for only 2 wks. All other balance training articles conducted training for at least 4 wks. Thus, it is possible that this article did not show improvement in ataxia severity because of this limited training duration.\textsuperscript{27} The other two articles that did not show improvement in ataxia severity after balance training were both home based.\textsuperscript{25,26} This leads to the following possibilities for why balance training did not change ataxia severity in these studies: (1) The training at home was not long enough. The total time of training per day for these studies was 15 and 20 mins. This was significantly less training time than the 30- to 60-min training sessions done in other studies. (2) Participants did not perform the training as instructed. Although the researchers called the participants weekly, self-reporting was used to determine how often the subjects trained. (3) The subjects did not challenge themselves with the balance training. Indeed, even though improvements in ataxia severity were not seen in the study, Keller et al.\textsuperscript{25} found in a secondary analysis that the individuals who reported the greatest challenge in their training improved the most.

The challenge level of training was also shown to be important in an exergame (video games used as a form of exercise) training study. In 2012, Ilg et al.\textsuperscript{31} reported that participants’ improvements in ataxia severity were dependent on the self-reported intensity of the home training. It is important to notice that the only home balance training programs that showed a reduction in ataxia severity scores were conducted with exergame training. This finding supports that the exergame training may provide challenge in addition to promoting adherence. Indeed, in another exergame balance training study, participants had similar reductions in ataxia severity to a control group that received conventional supervised balance training.\textsuperscript{32}

The benefit of balance training for patients with degenerative cerebellar disease ranged from a reduction of 0.4 to 5.2 SARA points. Although the minimally clinically important difference is not clearly defined, the natural disease progression of spinocerebellar ataxia is 0.6 to 2.5 points per year.\textsuperscript{36} If a reduction of 1 SARA point is deemed clinically significant as in one clinical trial,\textsuperscript{39} eight of the nine articles where balance training improved ataxia severity would be considered clinically significant. In the one article that found nonclinically significant improvement, balance training was conducted only twice a week, which was the lowest frequency seen for all studies examined.\textsuperscript{35} Thus, the frequency of training may be important. This is supported further in another article that compared moderate-intensity (2 hrs, three times a week) and high-intensity (2 hrs, five times a week) training.\textsuperscript{34} Results indicated that the moderate training group had an average reduction of 0.5 SARA points, whereas the high-intensity training group had an average reduction of 1.5 SARA points.

The largest effect of balance training in degenerative cerebellar disease was seen in the 2009 Ilg et al.\textsuperscript{22} However, assessors were not blinded, leaving the possibility of a biased result. With this result removed, as well as the other articles described above, balance training in subjects with degenerative cerebellar disease reduced SARA scores by 1.4 to 2.8 points.

#### DISCUSSION

This systematic review shows that the existing literature depicting the benefit of balance training in subjects with genetic degenerative cerebellar disease is improving, with 6 of the 14 studies included representing high-quality research. Since the last systematic review, three randomized clinical trials have been conducted on the subject. Sample size for most of the studies, however, remains relatively low, with only three studies enrolling more than 20 subjects. As shown in Table 1, balance studies vary greatly in terms of types of exercises performed; frequency, duration, and intensity of training; and outcome measures used. As such, there is a great degree of variation in improvement with the subjects who participated in these studies.

#### Gait Speed

Although not determined for patients with degenerative cerebellar disease, a systematic review determined that changes in gait speed between 0.10 and 0.20 m/sec may be clinically important across multiple patient groups.\textsuperscript{40} If a minimally clinical important difference of 0.1 m/sec is assumed from the study above, then all three articles that showed a benefit in walking speed with balance training was clinically significant.\textsuperscript{22,24,25}

Of the five articles that did not show a benefit to gait speed after balance training, two were exergame training articles. Training for these subjects did not include walking exercises, which may contribute to the lack of improvement in gait speed.\textsuperscript{31,32} Another article without gait speed benefit was a result of an unsupervised home balance training program that lasted a year after an intensive inpatient program.\textsuperscript{25} Upon examining exercises listed in the appendix for the home training, it seems walking exercises were not part of this training regimen. Compliance may also be a factor in lack of improvement in gait speed as data regarding compliance to the exercise program are not listed for this study. Another article without gait speed improvement had participants perform ten 1-hr gait adaptability training sessions on a treadmill over 5 wks. This training was performed the least frequently out of all articles examined, which may attribute to the lack of benefits seen. Finally, the last article in which gait speed was not improved was a retrospective inpatient rehabilitation study with focus on gait.
and balance. It is unclear why training did not improve gait speed in this article, although participants partook in training for only 3 wks, which is limited compared with other studies. Overall, more studies need to be conducted in this area, but a clinical benefit in gait speed was seen in most balance training studies on degenerative cerebellar disease if walking exercises were included in training.

Balance

Balance is measured by multiple tests in these rehabilitation studies. One of the most common methods is the Berg Balance Scale, a 14-item scale with a maximum score of 56, originally designed to measure balance of the elderly.41 At least a 4-point change is required to be clinically significant using this scale.42 The Dynamic Gait Index is another common method used to monitor balance. It assesses an individual’s ability to modify balance while walking in the presence of external demands. The minimal detectable change ranges from 2.6 to 2.9 depending on the population tested.43,44 Finally, some studies use the timed up and go test, which is a complex task that measures function, balance, and fall risk. The minimal detectable change ranges from 2.9 to more than 4 secs for other neurologic diseases.44

Six of the 14 studies examined used Berg Balance Scale, Dynamic Gait Index, and/or timed up and go to monitor balance after training for subjects with degenerative cerebellar disease. Although all these studies showed statistical improvement in scores after balance training, none of these changes were clinically meaningful when extrapolating data from studies involving other neurologic diseases.22,24,25,27,29,33,34 For example, Parkinson’s disease, as another movement disorder, may be most meaningful for comparison. A change of 2.9 points is considered clinically meaningful on the Dynamic Gait Index scale for this population.44 Balance training only improved, on average, Dynamic Gait Index scores by 1.5 points for individuals with degenerative cerebellar disease. Thus, it seems training may improve balance, but not in a way that is clinically meaningful.

Coordination Verse Balance Training

The type of exercises performed during training was diverse from the 14 articles selected. Some of the articles described exercises focused on the coordination of movements. Sample exercises include bird-dog; performing lateral, backward, and forward steps in sequence; and going from standing to hands and knees on floor.22–24 Articles that used exergame training and obstacle avoidance on a treadmill can also be described as coordination training.31,32,35 Other articles had participants perform exercises focusing on balance. Sample exercises include standing on one leg, walking on a straight line, and standing with feet together.25,26,29,33,34 Improvements in ataxia severity ranged from 1.5 to 5.3 SARA points for those who performed coordinative training, whereas those who performed balance exercises saw improvements of 0 to 2.0 SARA points. However, this does not demonstrate coordination training was better than balance training for the following reasons: (1) More of the coordination training articles were supervised, (2) some of the balance training articles had limited training duration (15–20 mins),25,26 and (3) some coordination training articles had unblinded assessors, which may have boosted benefits.22,23 Thus, future studies are needed that directly compare balance and coordination training to determine which is better for degenerative cerebellar disease.

Long-term Effects

A few of the studies examined the long-term benefits of training. For example, Miyai et al.24 showed that training effects of decreased SARA score and increased gait speed were maintained 12 wks after intervention but trended back to baseline by 24 wks posttreatment. Ilg et al.23 followed eight subjects who underwent in home coordinative training for 1 hr every day for a year after intensive inpatient training. Although SARA scores increased, on average, 2.9 points after the year of home training, SARA scores remained significantly lower (2.3 point reduction) than baseline assessments before inpatient training. Gait speed and balance measures, on the other hand, all declined back to baseline level assessment after the year.23 In 2014, Seco et al.30 followed individuals with Friedreich’s ataxia for 5 yrs. Results indicated that ICARS scores in the training group (60-min sessions, three times a week) remained stable over the 5-yr treatment, whereas ICARS scores significantly increased in a control group that did not get training. Overall, it seems that training stabilizes or at least slows symptoms of the disease. If training is stopped, however, benefits seem limited as subjects revert back to baseline.

Study Limitations

This systematic review has several limitations worth comment, particularly with respect to the heterogeneity of training regimens and outcome measures. For example, some articles used SARA to rate ataxia, severity whereas others used ICARS. Moreover, several articles did not determine how the implemented exercise program affected ataxia severity at all. Although most training programs lasted about 4 wks, the number of days trained and duration of training varied greatly between studies. Thus, there is limited ability to draw conclusions based on pooled results, and a meta-analysis of the data was not feasible. It is recommended that future research use consistent outcome measures and aim to compare different frequencies, intensities, and durations of exercise.

Most of the older studies on this topic represent level III-3 evidence with a lack of control group. Most of the newer studies have started to include control groups for comparison, and more high-quality studies will be needed to determine the benefit of balance training in degenerative cerebellar disease.

Finally, there are limited studies focusing on the mechanism by which training improves degenerative cerebellar disease. Future studies should address whether training impacts disease progression or primarily helps patients by providing better compensation for deficits.

Future Studies

Future studies should be conducted to address the knowledge gaps regarding balance training in degenerative cerebellar disease. First, how much training should be conducted? There was one previous study that demonstrated that training five times a week was better than training three times a week.34 There is also evidence that training improvements revert back...
to baseline if training is halted.23,24,30 However, no study has examined the optimal duration of balance training. Is training 30 mins enough or is training 60 or 120 mins better? Upon completion of this study, the training frequency and duration for future studies should be fixed to enable better comparisons among studies.

After determining optimal training frequency and duration, the best type of training should be determined. A comparison between training focused on coordination and balance exercises should be conducted. Training should ideally be performed at home, owing to the cost of long-term supervised training. An option of therapists using telemedicine to observe training remotely would be of value to determine if supervision is crucial for improvements.

Although difficult to perform because of the rarity of these diseases, it would be important to determine if certain degenerative ataxias improve more with training than others. Although more recent studies are beginning to address this question,33,34 standardization of training methods will allow better comparisons to be determined.

Finally, it is important to determine whether balance training improves ataxia by modifying disease progression or allowing better compensation for deficits. One possible method for examining this may be to use brain imaging to determine if training slows cerebellar atrophy.

CONCLUSIONS

In conclusion, it seems that balance training reduces scores in ataxia severity measurements. A reduction between 1.4 and 2.8 SARA points may be a good estimate for the expected benefit with certain outlier studies excluded. Balance training may also improve gait speed in individuals with degenerative cerebellar disease by about 0.1 m/sec as long as the training includes walking exercises. Balance measures improve statistically but not in a clinically meaningful way with training. There is some evidence that training at least five times a week is better than training three times a week. Training should continue indefinitely as benefits regress to baseline when training halts, and it has not been studied whether there is a certain time point for restarting therapy that will prevent functional decline. The optimal duration of daily training has not been adequately studied. There is preliminary evidence that training in a supervised setting is more beneficial than unsupervised training. Individuals who report greater balance challenge with training had more improvement than individuals who reported less balance challenge. There is insufficient evidence to conclude whether individuals with specific degenerative cerebellar diseases improve more than others.

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