The Effect of Balance Training on Balance Performance in Individuals Poststroke: A Systematic Review

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Background and Purpose: Stroke is a leading cause of long-term disability, and impaired balance after stroke is strongly associated with future function and recovery. Until recently there has been limited evidence to support the use of balance training to improve balance performance in this population. Information about the optimum exercise dosage has also been lacking. This review evaluated recent evidence related to the effect of balance training on balance performance among individuals poststroke across the continuum of recovery. On the basis of this evidence, we also provide recommendations for exercise prescription in such programs.

Methods: A systematic search was performed on literature published between January 2006 and February 2010, using multiple combinations of intervention (eg, "exercise"), population (eg, "stroke"), and outcome (eg, "balance"). Criteria for inclusion of a study was having at least 1 standing balance exercise in the intervention and 1 study outcome to evaluate balance.

Results: Twenty-two published studies met the inclusion criteria. We found moderate evidence that balance performance can be improved following individual, "one-on-one" balance training for participants in the acute stage of stroke, and either one-on-one balance training or group therapy for participants with subacute or chronic stroke. Moderate evidence also suggests that in the acute stage, intensive balance training for 2 to 3 times per week may be sufficient, whereas exercising for 90 minutes or more per day, 5 times per week may be excessive.

Discussion and Conclusions: This review supports the use of balance training exercises to improve balance performance for individuals with moderately severe stroke. Future high-quality, controlled studies should investigate the effects of balance training for individuals poststroke who have severe impairment, additional complications/comorbidities, or specific balance lesions (eg, cerebellar or vestibular). Optimal training dosage should also be further explored. Studies with long-term follow-up are needed to assess outcomes related to participation in the community and reduction of fall risk.

Key words: *balance*, *exercise*, *stroke*, *systematic review*, *training*

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INTRODUCTION

Stroke is the most common cause of long-term disability.[1] Impaired balance early after stroke is strongly associated with future function and recovery.[2] Among home-dwelling individuals with chronic stroke, balance problems, especially during performance of complex tasks, have been identified as the strongest predictor of falling.[3] In addition, Belgen et al[4] reported that for individuals with chronic stroke, history of falls was associated with fall-related self-efficacy, fear of falling, and depressive symptoms. They also found that history of multiple falls was associated with poor balance. Fear of falling may lead to reduced activity and sedentary lifestyle, which further disrupt function and health status (the vicious cycle of disability).[5] As rehabilitation is often an integral element in achieving functional recovery in individuals poststroke,[2] rehabilitation researchers and clinicians strive to identify the most effective treatment approaches to enhance balance performance in these individuals.

Recent systematic reviews have not established a significant improvement in balance as a result of resistance training in older adults[6] or gait-oriented training in individuals poststroke.[7] These reviews suggest that balance control is achieved via a unique, complex combination of systems, and as such requires task-specific complex rehabilitation. Another missing element in most studies has been failure to address questions related to the optimum dosage of exercise needed to improve balance and decrease falls. In a 2008 review, Eng et al[5] discussed the potential for balance exercise programs to improve balance for individuals poststroke, mentioning that the body of literature (published through 2005) was small. Similarly, in a systematic review, Hammer et al[8] examined the effect of physical therapy on balance performance poststroke in 14 randomized clinical trials published between 1998 and 2005. The authors concluded that balance ability poststroke can be improved by various physical therapy interventions. Moreover, individuals can regain balance through exercise that targets balance even in the subacute and chronic stage poststroke. In the included papers, interventions had to be performed at least twice a week for a minimum of ten sessions, and no other specifics of training dosage were discussed in their review.

In light of these findings, the primary purpose of this systematic review was to investigate the recent literature related to the effect of balance training on balance performance across the continuum of recovery in individuals poststroke. Since the largest proportion of spontaneous poststroke recovery occurs during the acute stage (0-6 months poststroke), it is important to learn whether performing balance exercises during this period encourages the recovery of balance performance to a greater extent than does other interventions. In the subacute (6-12 months) and chronic stages (more than 12 months) poststroke, large amounts of additional spontaneous motor recovery are typically not anticipated.[9] Consequently, evidence of balance improvement as a result of exercise during these periods would support the value of developing and implementing long-term programs. A secondary objective of our efforts, if indeed balance training was found to be effective, was to offer practical recommendations for exercise prescription of such programs. To this end, the results of different exercise dosing patterns (frequency, duration, intensity) were evaluated.

METHODS

Search Strategy

A systematic search was performed in 3 electronic databases: PubMed, CINAHL, and PEDro. In PubMed and CINAHL, the following MeSH headings were used: Stroke AND proprioception (OR balance) AND exercise (OR exercise therapy). In PEDro, a simple search was performed with every possible combination among the following key words: (1) Intervention (training, activity, exercise therapy, rehabilitation); (2) Population (stroke, cerebral vascular accident); (3) Outcome (balance, postural stability, postural control, body sway). Each search contained 1 word from each group of terms. Bibliographies of the identified studies were also manually searched.

Inclusion and Exclusion Criteria

To be included in this review studies had to meet the following criteria:

1. The study population was adults (≥18 years of age) at any stage along the continuum of poststroke recovery,
2. The study included at least 1 standing balance exercise in the intervention, either for the experimental group or for the control group,
3. At least 1 of the study outcomes evaluated balance or postural challenge (static or dynamic, laboratory tested or functional) using methods that were validated and found to be reliable for individuals with stroke,
4. The study was published in English,
5. The study was a clinical trial including randomized trials, pilot studies, and case series, and
6. The study was published from January 2006 through February 2010.

Studies were excluded from review if: (1) The study evaluated instrumented neurological treatment approaches applying gait manipulations, such as body weight–supported training, robotic devices, virtual reality, constraint-induce therapy, or electrical stimulation (unless balance training was the intervention applied with the control group), (2) The study was a secondary analysis of data published prior to January 2006, or (3) The study was a case study (ie, with N = 1).

Evidence Rating System

To rate the level of evidence, we used a scale described by the American Academy of Cerebral Palsy and Developmental Medicine.[10] Studies were ranked on a 5-point scale from Level I (systematic reviews or large randomized clinical trials [n > 100]) to Level V (expert opinion). Within each level, quality was assessed based on 7 internal and external validity characteristics, and 1 point was assigned for the presence of each component. Examples of these components included well-defined inclusion/exclusion criteria and appropriate measures that were valid and reliable. A full description of the American Academy of Cerebral Palsy and Developmental Medicine scale is available in Appendices A and B. To improve the sensitivity of the scale, we awarded one-half point if we determined that only part of the characteristic was present, for example, if dropout rate was reported but was greater than 20%. To fully capture the effect of balance training on balance performance, studies of Levels I through IV were reviewed. We considered only those studies that scored 4 and above in quality rating (ie, at least moderate quality). Rating of the evidence was done by the 2 authors independently. If a discrepancy in rating was found, we obtained agreement through a repeat reading of the article and discussion.

Data Extraction

The following headings were used to extract the data into tables of evidence: study design, inclusion and exclusion criteria, participant age, time since stroke, severity of stroke, initial sample size and sample size available for analysis, details of intervention (for experimental and control group including pattern, progress and adherence), balance outcome (type, test description, trials allowed, reliability and validity), additional outcomes, results (including main statistical test, effect size, if reported, and statistical significance), clinical importance, study conclusions, and special comments. Extracted data were organized by "time since stroke" (acute, subacute, chronic).

RESULTS

The article selection process is illustrated in Figure 1. The complete quality assessment of the 22 included studies is presented in Table 1.

Participants in the Acute Stage Poststroke

Six studies,*[11-17] evaluated balance exercise programs for 388 participants in the acute stage poststroke (0-6 months), of whom 189 were assigned to an experimental group. The age range was 30 to 92 years. Descriptive data from these studies appear in Table 2.

Interventions

The diversity among the balance rehabilitation programs made comparison among studies challenging. Included among the balance programs were standing balance practice,[11] group therapy,[12] "patient-centered approach" (wherein participants chose the treatment method),[13] "motor relearning program" (intended to reinforce the relationship between training and

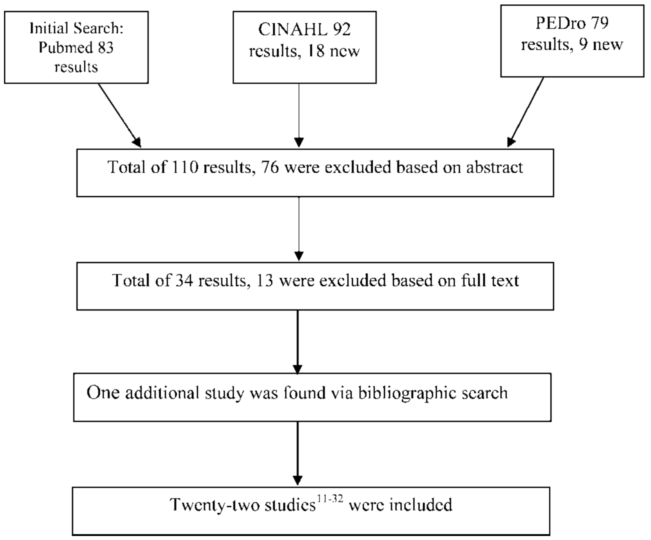
*Langhammer et al reported their outcomes in two separate publications.[14,15]

functional performance),[17] intensive training versus patient-initiated training,[14,15] and conventional gait and balance training versus body weight–supported training.[16]

Progression

Four studies described some form of exercise progression in the program. In the standing balance program,[11] participants progressed from supported standing to free standing, and were encouraged to be active while standing (eg, reaching, sit-to-stand). Exercises in the group therapy class were gradually increased in level of difficulty, complexity, or number of repetitions.[12] The motor relearning program progressed from sitting to standing, and from static to dynamic tasks.[17] The conventional gait training program[16] progressed participants in this group to more challenging balance and gait tasks such as increased walking speed and stair climbing as performance improved.

Figure 1. Article selection flowchart.



Follow-up

Four studies had a long-term follow-up for either 6 months[12] or 12 months.[13-16] The 2 remaining studies evaluated their participants either immediately after the end of a 6-week program[17] or 12 weeks postadmission to a rehabilitation facility.[11]

Training Dosage and Attrition

Studies that demanded high frequency and duration of training (eg, 5 times per week, ≥90 min/session) reported high attrition rates (ie, from 26% for 90-min/d sessions[11] to 43% for 180-min/d sessions[12]), mostly attributed to fatigue[11] or medical reasons[12] such as acute illness requiring readmission to an acute hospital. The following training patterns resulted in less than 20% attrition: 5 times per week for 45- to 60-minute sessions (0%[11] and 10%[12] for control groups), 2 to 3 times per week for 40- to 60-minute sessions[14,15] (8.5% and 17.5% for the intensive and self-initiated groups, respectively), 2 to 3 times per week for 120-minute sessions[17] (10% for both experimental and control groups, only 2 participants for dropped out for medical reasons), 3 times per week for 90-minute sessions[16]

Table 1. Levels of Evidence and Quality Ratings of Extracted Studies

Study	Level of Evidence	Quality Rating (Out of 7)[a,b]	Main Missing Criteria
Allison and Dennett[11]	II	5.5	Intervention details, power calculation
English et al[12]	III	6.5	Dropout > 20%
Pyoria et al[13]	III	5.5	Blind assessment, power calculation
Langhammer et al[14,15]	II	7	
Hidler et al[16]	II	5.5	Blind assessment, power calculation
Chan et al[17]	II	5	Intervention details, power calculation, dropout > 20%
Eser et al[18,19]	II	5.75	Power calculation, adherence report
Yelnik et al[20]	II	6.5	Power calculation
Srivastava et al[21]	IV	5	Blind assessment, intervention details, power calculation
Olawale and Ogunmakin[22]	IV	5	Blind assessment, power calculation
Fritz et al[23]	IV	5	Blind assessment
Yen et al[24]	II	5.25	Blind assessment, power calculation, control intervention details
Gok et al[25]	II	6	Power calculation
Bayouk et al[26]	II	5.5	Blind assessment, power calculation
Leroux et al[27]	IV	5	Blind assessment
Macko et al[28]	IV	6	Blind assessment
Huijbregts et al[29]	III	4.5	Exclusion criteria, intervention details, power calculation
Huijbregts et al[30]	III	5	Blind assessment, dropout = 20%
Michael et al[31]	IV	5	Blind assessment, dropout > 20%
Stuart et al[32]	III	5.5	Blind assessment

[a]For quality assessment we examined the dropout rates at the end of treatment (and not the follow-up).
[b]If the study was a pilot study to calculate power for a future study, we awarded it credit for power calculation.

Table 2. Extracted Research Evidence for Participants in the Acute Stage

Study	Sample Size (Exp/Con) Initial to Final	Age Mean ± SD (Range)	Days Since Stroke, Mean ± SD (Range)	Severity	Balance Test	Control Activities	Balance Results
Allison and Dennett[11]	7/10 to 4/10	Exp: 72.4 ± 17.9 (55-88) Con: 78 ± 7.9 (65-92)	Exp: 15.1 ± 16.0 (6-58) Con: 20.6 ± 20.5 (9-57) Inpatients	Discharged after 2 to 4 wk	BBS	Conventional physical therapy 45 min, 5 d/ wk	12 of 14 participants improved BBS: Difference Con 20.5 (1.5-31) Difference Exp: 37 (6.5-42) $P < 0.05$ (Exp group started lower)
English et al[12]	38/40 to 28/34 to 22/21 on follow-up	Circuit: 61.6 ± 11.8, Individual: 68.9 ± 11.8	Circuit: 29.7 ± 15.5 Individual: 24.4 ± 12.4 Inpatient	High functional level	BBS	One-on-one PT, up to 60 min/d, 5/wk + usual care	BBS: Con: 28.2 ± 17.7 to 46.7 ± 7.9 (at discharge) to 50.8 ± 4.9 (follow-up) Circuit: 32.2 ± 15.5 to 48 ± 7.4 to 49.1 ± 8.5 No significant difference between groups
Pyoria et al[13]	40/40 to 33/35	Activating:72 (51-89) Traditional: 72 (47-85)	Activating: 25 (12-59) Traditional: 28 (10-57) Started inpatient	Barthel index: 9.1/9.2 ± 4.4/4.2	Postural control and balance for stroke	Therapist-centered approach, normal movement, preventing spasticity, manual	Both groups have improved on the postural control and balance for stroke scale Activating group: from 42 (18) to 63 (95% CI 16-25) after 12 mo Traditional group: from 42 (19) to 59 (95% CI 10-24)
Langhammer et al[14,15]	32/35 to 32/33 (3 mo) to 32/31 (12 mo)	Exp: 76 ± 12.7 Con: 72 ± 13.6	Program started right after discharge from hospital (<1 mo)	Mixed (subgroup analysis)	BBS	Standard care, interdisciplinary No contact after discharge	Both groups improved in all criteria (average of 14/15 points on BBS for both) Improvement remained stable after 6 mo, slight decrease after 12 Participants who started with BBS < 32 showed larger improvement
Hidler et al[16]	36/36 to 33/30	Lokomat: 59.9 (30-79) Con: 54.6 (36-78)	Exp: 110.9 ± 62.5 Con: 138.9 ± 60.9 Outpatients	Stratified by walking speed	BBS	Conventional gait training	BBS: Both groups improved by 6 or 7 points on average (at 3 mo) Conventional gait group improved more in walking speed and 6-min walking distance ($P < 0.05$)
Chan et al[17]	33/33 to 26/26	Exp: 53.8 ± 15.4 Con: 54.4 ± 13.7 All less than 65	Mean Exp: 117.7 Mean Con: 88.8 Could be up to 12 mo poststroke Outpatients	BBS: Low starting point (mean < 30)	BBS	Therapy is not participant specific, participant is not involved in developing program, no practice-function correlation	Significant between-group differences on the BBS Motor Relearning group: 28.2 (8)-35.3 (7.7)-41.1 (6)-45.8 (3.7) Con: 27.9 (7.8)-30.0 (10.4)-30.1 (6.9)-37.4 (17.5) $P <$ 0.015

Abbreviations: BBS, Berg Balance Scale; Con, control group; Exp, Experimental group.

(8% and 16% for the experimental and control groups, respectively, due to poor attendance or decline in health). Mean attrition rate per total weekly training duration across studies and groups is presented in Figure 2.

Results

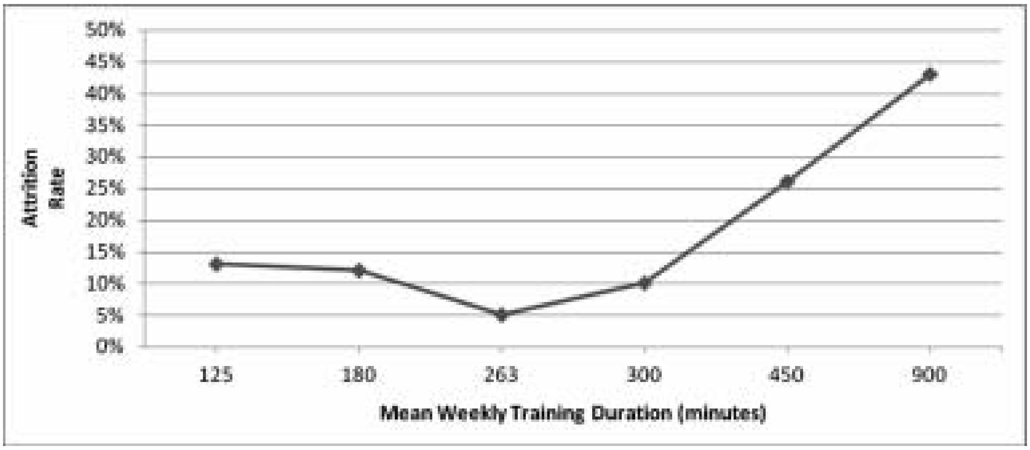
Most studies reported similar findings. Both experimental and control groups demonstrated significant improvement in the balance test scores with no significant between-groups differences. An exception was the study by Chan et al[17] wherein the group that participated in the "motor relearning program" demonstrated a significantly larger ($P < 0.015$) improvement on the Berg Balance Scale (BBS) following 6 weeks of intervention compared with the control group.

Participants in the Subacute Stage Poststroke

Three studies evaluated participants from a wide range of "time since stroke" with the range approximating the subacute stage of stroke.*[18-21] These studies included a

*Eser and Yavuzer et al reported their outcomes in two separate publications.[18,19]

Figure 2. Mean attrition rate per weekly training duration in acute stage (the ordering of data points corresponds to the following references, respectively: [14/15,16,17,11] control/[12] control, [11,12])



total of 167 participants, of whom 106 were assigned to an experimental group. Data from these studies appear in Table 3. In 2 studies,[18,19,21] balance training sessions were performed daily for 15 to 20 minutes, 5 d/wk for 3 to 4 weeks with a portable balance trainer (Nor-Am device, Nor-Am Patient Products, Oakville, Ontario, Canada)[18,19] or a force platform with visual feedback (Biodex Balance Master, Biodex Corporation, Shirley, NY, USA).[21] Participants also received daily in-patient "conventional stroke rehabilitation."[18,19,21] In the third study, a 4-week, outpatient multisensorial program incorporated visual deprivation, head movements, and unstable surfaces in addition to walking and stepping for 60 to 70 minutes, 5 d/wk.[20] All 3 programs had excellent adherence with relatively low attrition rates (6%-18%). In each of the randomized controlled trials,[18,20] participants in all groups showed statistically significant improvement in balance parameters ($P < 0.001$ for BBS,[20] $P < 0.025$ for Brunnstrom stage[18]), with no demonstrable advantage of the specific balance intervention. Moreover, the findings for functional tests and instrumented measures were contradictory. For instance, while Yavuzer et al[18] identified improvement in postural control and weight bearing on the paretic limb while walking, in another report of the same study Eser et al[19] found no benefits related to lower extremity motor recovery (as measured by Brunnstorm's stages of recovery). Likewise, while Yelnik et al[20] found significant improvement on the BBS for both experimental and control groups, there was no change recorded on the force platform measures. Conversely, in a noncontrolled study, Srivastava et al[21] showed significant improvements on both functional and instrumented measures including the BBS ($P < 0.0001$) and force platform measures of balance index ($P < 0.0001$) and dynamic limits of stability ($P < 0.0001$), with partial retention of improvements at the 3-month follow-up assessment.

Participants in the Chronic Stage

Balance rehabilitation of individuals in the chronic stage poststroke (>12 months) was the focus of 11 studies,[22-32] which evaluated a total of 274 participants of whom 180 were assigned to an experimental group. The age range was 36 to 85 years, with the mean age approximately 60 years. On average, the studies' samples reflected moderate severity. Description of these studies can be found in Table 4.

Interventions

Seven studies examined group exercise therapy[26-32] that focused on static and dynamic balance as well as fostered continued exercise involvement and goal achievement.[29,30] The remaining 4 studies[22,23,25] investigated the effect of balance exercise in one-on-one sessions. One-on-one programs emphasized different components of balance training such as sitting, standing, walking, and stair climbing exercises while reaching and with altering base of support[22]; intense mobility training[23]; or using the Kinesthetic Ability Trainer (KAT; LLC, Vista, CA, USA) to alter surface and sensory conditions while standing.[25]

Progression

Seven studies reported some form of exercise progression. For group therapy, the number of repetitions, the height of the exercise step, and the ankle weights were gradually increased in 2 studies.[26,27] Other forms of progression included increased intensity and duration of exercise[31,32] as well as increased complexity.[31] As for the one-on-one programs, in 1 study, training progressed from sitting, to standing, to walking while altering the base of support and using tilt boards.[22] Alternatively, complexity and difficulty of tasks were increased as participants improved.[23] The Kinesthetic Ability Trainer was introduced with a high level of stability that was gradually reduced as participants progressed.[25]

Follow-up

Two programs provided 3-month follow-up after that intervention.[23,29] In the remaining studies, participants were assessed at the end of the intervention program, which lasted 4 weeks,[24,25] 8 weeks,[22,26-29] 9 weeks,[30] or 6 months.[31,32]

Table 3. Extracted Research Evidence for Participants in the Subacute Stage

Study	Sample size (Exp/Con) Initial to Final	Age mean ± SD (Range)	Time Since Stroke mean ± SD (Range)	Severity	Balance Test	Control Activities	Balance Results
Eser et al[18,19]	25/25 to 22/19 (due to early discharge)	60.9 ± 11.7 (before randomization)	Exp: median 6 mo (2-120) Con: median 5 mo (2-18) Inpatients	Moderate (able to take at least 1 step with or without assistance)	Kinematic and kinetic gait parame- ters/Brunnstorm's stages	Both groups: usual rehabilitation: 5 d/ wk, 2-5 h/d, 8 wk Includes balance exercises	2006: Exp improved significantly in pelvic excursion in the frontal plane ($P = 0.021$) and in vertical ground reaction force on the paretic leg ($P = 0.03$) in walking 2008: Both groups significantly improved in all parameters ($P < 0.05$)
Yelnik et al[20]	36/36 to 35/33	Exp: 55.5 (32.5-78.3) Con: 54.9 (26.5-77.3)	Exp: 217 ± 92.9, in days Con: 218 ± 93.4, in days Outpatients	High functional level (able to walk independently)	BBS, number of falls, stability limits on a platform	Neurodevelopmental based treatment Includes weight shift, pelvic control, sitting on the edge of a platform, walking	Both groups improved in most criteria BBS: Con: 47 (39-53) to 53 (43-55) to 51 (44-55) Multisensorial: 49 (42-53) to 53 (48-55) to 53 (49-55) No improvement on platform No difference in number of falls
Srivastava et al[21]	45 to 40	45.51 ± 11.24 (24-65)	16.51 ± 15.14 (3-59) in mo Inpatients	Moderate (able to walk independently or with 1 person's support)	BBS; Balance Index (BI) and dynamic limits of stability (DLS) scores produced by the Biodex Balance Master™	NA	BBS: 34.93 ± 11.45 to 46.85 ± 8.39, $P <$ 0.000; to 48.44 ± 8.76 at follow-up BI: 3.84 ± 1.27 to 2.16 ± 0.96 to 2.37 ± 0.86 at follow-up, $P <$ 0.000, lower is better DLS: 7.44 ± 7.28 to 16.00 ± 9.94 to 14.15 ± 9.18 at follow- up, $P < 000$, higher is better

Abbreviations: BBS, Berg Balance Scale; Con, control group; Exp, experimental group.[a]

Program Dosage and Attrition

Most group programs met 2 times per week for 1-hour exercise sessions over 8 to 9 weeks.[30] Three studies reported no attrition (100% adherence),[26,27,29] Macko et al[28] reported 9% attrition (for nonmedical reasons), and Huijbregts et al[30] reported 20% attrition (2 of 10 participants left the study, 1 for health reasons). In 2 studies, participants met for 6 months either 2 times per week[32] or 3 times per week[31] for a 1-hour training session. Eighteen percent of the participants dropped out of the intervention in a study by Stuart et al,[32] mostly due to transportation problems. However, in a study by Michael et al,[31] 3 of 10 participants left the study, all for medical reasons. Other studies assessed outcomes of one-on-one training programs provided for either 45- to 60-minute sessions 2 times per week for 8 weeks[22] or for 50-minute sessions 2 to 5 times per week for 4 weeks.[24] The programs by Fritz et al[23] and Gok et al[25] were especially intense and involved daily 3-hour sessions for 10 days[23] or 5-d/wk sessions (20 minute per session) for 4 weeks[25] in addition to 2 to 3 hours of conventional rehabilitation daily. All one-on-one programs reported no attrition.

Results

These findings suggest that important changes in balance performance can be achieved in participants in the chronic stage poststroke even participants are more than 10 years after stroke. The training program could be one-on-one, short and intense (10 days), or in a group format, for a longer period of time (from 8 weeks up to 6 months) at a lower intensity. Two nonrandomized controlled trials also suggest that balance performance of these patients can deteriorate with usual care for 6 months[32] or no care for 9 weeks.[30]

DISCUSSION

Previous reviews[5,8] have shown the positive effect of balance training on balance performance of individuals poststroke based on a small body of literature published prior to 2006. With a large number of recent studies investigating balance training from 2006 till present, our systematic review confirms the importance of specificity of training and supports the use of balance exercises to improve balance performance for individuals with moderately severe stroke, at least in the short

Table 4. Extracted Research Evidence for Participants in the Chronic Stage

Study	Sample Size (Exp/Con) Initial to Final	Age Mean ± SD (Range)	Time Since Stroke Mean ± SD (Range)	Severity	Balance Test	Control Activities	Balance Results
"One-on-One" Interventions							
Olawale and Ogunmakin[22]	23 no attrition	57.56 ± 10.40 (43-78)	28.8 ± 21.64 mo	Range of pretraining BBS:41-52	BBS	NA	Pretraining: 41-52 (mean = 47.13, SD = 4.09) Posttraining: 49-55 (mean = 52.63, SD = 2.45) $P = 0.012$ Falls: 17 before, 9 falls along
Fritz et al[23]	8 no attrition	62 ± 21 (17-80)	2 y + 10 mo (10 mo-6 y)	In the community, BBS < 45	BBS, Dynamic Gait Index (DGI), Falls Efficacy Scale (FES)	Measured 2 wk prior to program and right before	Effect size: BBS: 1.37 Falls Efficacy Scale: 0.7 Dynamic Gait Index: 2.04 A very small effect on gait parameters
Yen et al[24]	7/7 no attrition	Exp: 57.3 ± 16.44 Con: 56.05 ± 12.69	Exp: 1.97 y (1.5-2.9) Con: 1.96 y (0.5-7.1)	Brunnstrom stage 4 in both groups	BBS	General PT sessions including balance exercises	BBS: General physical therapy: 50.57 ± 3.55 to 51.57 ± 3.1 (P = 0.102) BWSTT: 50.29 ± 3.25 to 52.43 ± 2.88, $P = 0.016$
Gok et al[25]	15/15 no attrition	Exp: 55.1 ± 11.4 Con: 59.7 ± 4.8	Exp: 460 d ± 90.4 Con: 630.3 d ± 109.3	FIM motor: Exp: 64 Con: 56	The balance subscale of the Fugl-Meyer; Balance Index on the KAT	Positioning, balance, ROM, resistance and gait training	Exp improved more in static ($P = 0.045$) and dynamic ($P = 0.001$) balance indices, and Fugl-Meyer Stroke Assessment (P = 0.001) Both groups improved other motor scores
Group therapy							
Bayouk et al[26]	8/8 no attrition	Exp: 68.4 ± 7.1 Con: 62.0 ± 4.6	Exp: 7.1 ± 12.5 y Con: 5.7 ± 6.9 y	Average 5/7 on Chedoke-McMaster Stroke Assess	Center of pressure displacement during double-legged stance (10 s) and sit to stand (eyes open/ closed, firm/foam	Same program with eyes open and on a hard regular surface	Exp (and not Con) significantly reduced their center of pressure (COP) variability in eyes open+ firm surface M/L axis and in eyes open + soft surface A/P axis In the sitting to standing task both groups significantly improved: reduced COP excursion in "eyes open, soft surface," walking speed ↑ by 12%
Leroux et al[27]	10 no attrition	63.9 ± 10.3 (51-82)	9.9 ± 11.1 (1.1-37.1) y	Mean 13/25 on Stroke Impairment Asses (4-22)	BBS; ground reaction force and COP for double-legged (20 s) and tandem stance (10 s), stool touch, sit-to-stand	Healthy individual for comparison of laboratory measures	BBS: 9 of 10 increased their score Range: −3 to +5, a significant 5.8% improvement in the mean (48.3 ± 5.9 to 51.1 ± 5.1) Lab: A significant improvement in postural steadiness for the tandem position and the stool touch and in the peak vertical ground reaction force from the paretic leg during sit to stand

(*continues*)

Table 4. Extracted Research Evidence for Participants in the Chronic Stage *(Continued)*

Study	Sample Size (Exp/Con) Initial to Final	Age Mean ± SD (Range)	Time Since Stroke Mean ± SD (Range)	Severity	Balance Test	Control Activities	Balance Results
Macko et al[28]	22 (2 drop outs)	70 ± 1.7 (55-85)	56 ± 19 (9-306) mo	Baseline BBS: 34.0 ± 2, 79% had depressive symptoms	BBS	Participants were measured 1 mo prior to program and right before program	BBS Baseline 1: 34.0 ± 2 Baseline 2: 35.0 ± 1.7 Post-APA: 45.0 ± 1.6 ($P = 0.001$)
Huijbregts et al[29]	18/12 no attrition	Exp: 71 ± 7.6 (56-82) Con: 68 ± 10.5 (42-82)	Exp: 30 ± 26 (6-83) Con: 24 ± 26 (3-86) mo	Chedoke-Mcmaster Stroke Assess: Moderate	The Activity Specific Balance Scale (ABC)	LWS: Living With Stroke, "standard care" across Canada	Only MOST participants improved significantly on the ABC scale ($P < 0.005$) Effect size: 0.76 (first measure to second) and 0.9 (second to third) Significant difference in exercise enrollment on the third evaluation
Michael et al[31]	10 to 7	71 (61-79)	7.5 y (4-22)	Mild to moderate	BBS, DGI, Falls Efficacy Scale (FES)	NA	All subjects improved BBS scores Mean baseline 33.9 ± 8.5 to 46.0 ± 6.7 ($P = 0.005$) at 6 mo DGI score increased from 13.7 ± 3.0 to 16.3 ± 4.3 at 3 mo and 19 ± 3.5 at 6 mo ($P = 0.006$) No change on FES
Stuart et al[32]	49/44 to 40/38	Exp: 66.8 ± 1.4 Con: 70.0 ± 1.7	Exp: 4.2 ± 0.8 Con: 3.5 ± 0.5	Mild-to-moderate hemiparetic gait deficits	BBS	Usual care Consisted of medical care as needed, but no additional exercise program	Mean BBS declined for the control group by 1.5 and increased by 5.1 in the APA group A significant postintervention between-group difference ($P < 0.00004$)
Huijbregts et al[30]	10/8 to 8/8	Exp: 61.8 (9.8) Con: 65.6 (4.7) Exp group significantly younger	Exp: 4.1 (3.4) Con: 3.2 (3.0) in years	No details Relatively high start on BBS (50.88 exp and 49.00 con)	BBS	Waiting to participate in MOST Didn't receive any formal intervention but could have been active in the community (fitness, swimming and/or support groups)	BBS MOST: T1: mean 50.88 (95% CI 46.37, 55.39) T2: 53.00 (49.96, 56.04) ⇒ nonsignificant improvements Con: T1: 49.00 (95% CI 40.26, 57.74) T2: 46.86 (37.52, 56.20)⇒ nonsignificant deterioration T1-T2 between-group difference was significant −4.27 (95% CI −6.66, −1.87)

Abbreviations: APA, Adaptive Physical Activity; BBS, Berg Balance Scale; BWSTT: body weight-supported treadmill training; CI, Confidence Interval; Con: control group; DGI, Dynamic Gait Index; Exp: experimental group; mo, months; MOST, Moving On after Stroke.
[a]All participants were outpatients.

term. Based on this evidence, it is possible to provide practical recommendations for exercise prescription of balance training programs for individuals poststroke across the continuum of recovery.

How Much Do We Train Balance?

For participants in the acute stage, studies that demanded high frequency and duration of training also had a high dropout rate, mostly due to medical reasons or fatigue.[11,12] These findings suggest that daily training sessions lasting 90 minutes or more for 5 times per week may be excessive for an individual in the acute stage of stroke. On the other hand, evidence supports an exercise pattern of 2 to 3 sessions per week for 40 to 120 minutes per session[14-17] or 5 sessions per week for 45 to 60 minutes per session.[11,12] Not only were the attrition rates of these groups much lower and mostly for nonmedical reasons, but the improvements in the adherent participants were very similar to those seen with more intensive approaches. According to the National Institute of Neurological Disorders and Stroke, in-patient rehabilitation programs often involve at least 3 hours of active therapy per day, 5 or 6 days per week.[33] Our findings suggest that improvement can be achieved with less rigorous programs in the acute stage. In the chronic stage, however, intense programs were feasible, demonstrated excellent adherence, and remained partially effective after 3 months.[23,25] Despite these promising results, the optimal intensity for training is still unknown. It is yet to be established what would be more efficient: a relatively long but less frequent program[22,26-32] or short intense interventions.[23,25]

Questions remain regarding whether training is optimally accomplished in groups or using a one-on-one approach. While one-on-one programs had 100% adherence,[22-25] drop-out rates in group interventions in those in the chronic stage were generally higher,[28,30] especially in the longer programs.[31,32] Eight studies implemented group therapy interventions and showed improved balance as well as patient satisfaction in patients in both the acute and chronic stages. No study has directly compared outcomes associated with group versus one-on-one training. For participants in the chronic stage, some studies had no control groups[27,28,31]; in other studies, both groups received group therapy.[26,29] For participants in the acute stage, group exercises were compared with individual training that a control group received, and both groups improved.[12] Two studies showed the advantage of group therapy over usual care[32] or no care[30]; the difference in balance performance between groups was significant postintervention not only because participants in the exercise groups improved but also because performance of the control group deteriorated over time. These findings suggest that in order to obtain maximal benefits of group therapy, close monitoring of class participants and careful selection of inclusion criteria are necessary.

How Do We Measure Balance?

Fifteen studies used the BBS as their balance outcome measure.[11,12,14,16,17,20-24,27,28,30-32] This consistency is particularly interesting in light of findings from a recent systematic review that identified a total of 68 balance tests in the 29 studies reviewed.[6] Findings from our review provide strong evidence that the BBS is very sensitive to changes in the acute stage[11,12,16,17] or in the chronic stage for individuals who started with a low BBS score (ie $\leq$35).[21,23,28,31] Conversely, the value of using the BBS for individuals with higher scores is questionable. For participants with higher scores, it is unclear whether little improvement was made or whether the test was not sufficiently sensitive to demonstrate change.[20,24,27,30] Another consideration related to the BBS is that the test does not consider the extent to which an individual relies on vision to maintain balance; hence, it may not be appropriate to demonstrate a change as a result of multisensorial training with visual deprivation.[20]

Limitations of This Review

This review was limited to studies published in English and found in 3 databases. The strength of the recommendations made in this systematic review is only as strong as the published research. No level I randomized controlled studies were found, 5 studies were categorized as level III, and 6 as level IV. In addition, most studies did not have adequate follow-up and some had very small samples. More often than not, participants were exposed to several treatments in addition to the balance exercises, making it difficult to attribute improvement to one specific intervention. Lastly, this review examined only balance outcomes. As important as balance performance is for individuals poststroke, it is only one factor among many that should be considered in interdisciplinary rehabilitation.

CONCLUSIONS

There is moderate evidence to suggest that balance performance can be improved with balance training for individuals in the acute stage poststroke. Although 5 studies[11,13,14,16,17] support this conclusion, in all those studies both the control and the experimental groups improved; hence, this recommendation should be taken in caution. For individuals in the acute stage, moderate evidence also suggests the following: First, exercising for 90 minutes or more for 5 sessions per week may be excessive and may be more likely to cause adverse effects compared with less demanding training patterns.[11,12] Second, intensive balance training performed 2 or 3 times per week may be sufficient to improve balance performance.[14,16,17] As for individuals in the subacute and chronic stages, moderate evidence suggests that balance performance can be improved with intensive individualized balance training programs,[22,23,25] as well as with group exercise programs performed 2 times per week.[26-30,32] Finally, limited evidence indicates that balance performance of individuals late after stroke might deteriorate in the absence of an intervention.[30,32]

Our understanding of the effects of balance training poststroke will be enhanced if studies include individuals with different levels of severity (especially high severity), additional complications, or specific anatomical balance lesions (eg, cerebellar or vestibular lesions). More high-quality randomized controlled studies, wherein examiners are blinded to group assignment, are needed in order to determine a feasible and effective training dosage (frequency, duration, intensity) for individuals poststroke. In addition, there is a need for tools to assess changes in balance performance in higher-functioning individuals, as well as to identify the specific system underlying balance impairment. Finally, studies with long-term follow-up poststroke are needed to measure the effect of specific balance training on individuals' participation in the community and fall prevention.

REFERENCES

1. Wolfe CDA. The impact of stroke. *Br Med Bull.* 2000;56(2):275-286.
2. Tyson SF, Hanley M, Chillala J, Selley AB, Tallis RC. The relationship between balance, disability, and recovery after stroke: predictive validity of the Brunel Balance Assessment. *Neurorehabil Neural Repair.* 2007;21(4):341-346.

3. Lamb SE, Ferrucci L, Volapto S, Fried LP, Guralnik JM, Gustafson Y. Risk factors for falling in home-dwelling older women with stroke: the women's health and aging study. *Stroke.* 2003;34(2):494-501.
4. Belgen B, Beninato M, Sullivan PE, Narielwalla K. The association of balance capacity and falls self-efficacy with history of falling in community-dwelling people with chronic stroke. *Arch Phys Med Rehabil.* 2006;87(4):554-561.
5. Eng JJ, Pang MY, Ashe MC. Balance, falls, and bone health: role of exercise in reducing fracture risk after stroke. *J Rehabil Res Dev.* 2008;45(2):297-313.
6. Orr R, Raymond J, Fiatarone Singh M. Efficacy of progressive resistance training on balance performance in older adults: a systematic review of randomized controlled trials. *Sports Med.* 2008;38(4):317-343.
7. Van de Port IG, Wood-Dauphinee S, Lindeman E, Kwakkel G. Effects of exercise training programs on walking competency after stroke: a systematic review. *Am J Phys Med Rehabil.* 2007;86(11):935-951.
8. Hammer A, Nilsagarad Y, Wallquist M. Balance training in stroke patients—a systematic review of randomized, controlled trials. *Adv Physiother.* 2008;10(4):163-172.
9. Cramer SC. Repairing the human brain after stroke, I: mechanisms of spontaneous recovery. *Ann Neurol.* 2008;63(3):272-287.
10. AACPDM methodology to develop systematic reviews of treatment interventions. Retrieved February 1st 2009, from, http://www.aacpdm.org/resources/systematicReviewsMethodology.pdf. 2008.
11. Allison R, Dennett R. Pilot randomized controlled trial to assess the impact of additional supported standing practice on functional ability post stroke. *Clin Rehabil.* 2007;21(7):614-619.
12. English CK, Hillier SL, Stiller KR, Warden-Flood A. Circuit class therapy versus individual physiotherapy sessions during inpatient stroke rehabilitation: a controlled trial. *Arch Phys Med Rehabil.* 2007;88(8):955-963.
13. Pyoria O, Talvitie U, Nyrkk H, Kautiainen H, Pohjolainen T, Kasper V. The effect of two physiotherapy approaches on physical and cognitive functions and independent coping at home in stroke rehabilitation. A preliminary follow-up study. *Dis Rehabil.* 2007;29(6):503-511.
14. Langhammer B, Stanghelle JK, Lindmark B. Exercise and health-related quality of life during the first year following acute stroke. A randomized controlled trial. *Brain Inj.* 2008;22(2):135-145.
15. Langhammer B, Stanghelle JK, Lindmark B. An evaluation of two different exercise regimes during the first year following stroke: a randomised controlled trial. *Physiother Theory Pract.* 2009;25(2):55-68.
16. Hidler J, Nichols D, Pelliccio M, et al. Multicenter randomized clinical trial evaluating the effectiveness of the Lokomat in subacute stroke. *Neurorehabil Neural Repair.* 2009;23(1):5-13.
17. Chan DY, Chan CC, Au DK. Motor relearning programme for stroke patients: a randomized controlled trial. *Clin Rehabil.* 2006;20(3):191-200.
18. Yavuzer G, Eser F, Karakus D, Karaoglan B, Stam HJ. The effects of balance training on gait late after stroke: a randomized controlled trial. *Clin Rehabil*. 2006;20(11):960-969.
19. Eser F, Yavuzer G, Karakus D, Karaoglan B. The effect of balance training on motor recovery and ambulation after stroke: a randomized controlled trial. *Eur J Phys Rehabil Med.* 2008;44(1):19-25.
20. Yelnik AP, Le Breton F, Colle FM, et al. Rehabilitation of balance after stroke with multisensorial training: a single-blind randomized controlled study. *Neurorehabil Neural Repair.* 2008;22(5):468-476.
21. Srivastava A, Taly AB, Gupta A, Kumar S, Murali T. Post-stroke balance training: role of force platform with visual feedback technique. *J Neurol Sci.* 2009;287(1/2):89-93.
22. Olawale OA, Ogunmakin OS. The effect of exercise training on balance in adult patients with post-stroke hemiplegia. *Int J Ther Rehabil.* 2006;13(7):318-322.
23. Fritz SL, Pittman AL, Robinson AC, Orton SC, Rivers ED. An intense intervention for improving gait, balance, and mobility for individuals with chronic stroke: a pilot study. *J Neurol Phys Ther.* 2007;31(2):71-76.
24. Yen CL, Wang RY, Liao KK, Huang CC, Yang YR. Gait training induced change in corticomotor excitability in patients with chronic stroke. *Neurorehabil Neural Repair*. 2008;22(1):22-30.
25. Gok H, Geler-Kulcu D, Alptekin N, Dincer G. Efficacy of treatment with a kinaesthetic ability training device on balance and mobility after stroke: a randomized controlled study. *Clin Rehabil.* 2008;22(10/11):922-930.
26. Bayouk J, Boucher JP, Leroux A. Balance training following stroke: effects of task-oriented exercises with and without altered sensory input. *Int J Rehabil Res.* 2006;29(1):51-59.
27. Leroux A, Pinet H, Nadeau S. Task-oriented intervention in chronic stroke. *Am J Phys Med Rehabil.* 2006;85(10):820-830.
28. Macko RF, Benvenuti F, Stanhope S, et al. Adaptive physical activity improves mobility function and quality of life in chronic hemiparesis. *J Rehabil Res Dev.* 2008;45(2):323-328.
29. Huijbregts MPJ, Myers AM, Streiner D, Teasell R. Implementation, process, and preliminary outcome evaluation of two community programs for persons with stroke and their care partners.(Grand rounds). *Top Stroke Rehabil.* 2008;15(5):503-518.
30. Huijbregts MPJ, McEwen S, Taylor D. Exploring the feasibility and efficacy of a telehealth stroke self-management programme: a pilot study. *Physiother Can.* 2009;61(4):210-220.
31. Michael K, Goldberg AP, Treuth MS, Beans J, Normandt P, Macko RF. Progressive adaptive physical activity in stroke improves balance, gait, and fitness: preliminary results. *Top Stroke Rehabil.* 2009;16(2):133-139.
32. Stuart M, Benvenuti F, Macko R, et al. Community-based adaptive physical activity program for chronic stroke: feasibility, safety, and efficacy of the Empoli model. *Neurorehabil Neural Repair.* 2009;23(7):726-734.
33. The National Institute of Neurological Disorders and Stroke: post-Stroke rehabilitation fact sheet. Retrieved July 15, 2009, from, http://www.ninds.nih.gov/disorders/stroke/poststrokerehab.htm. 2009.

APPENDIX A:
The American Academy of Cerebral Palsy and Developmental Medicine (AACPDM) Evidence Rating Criteria[10]

Level	Studies
I	Systematic review of randomized controlled trials (RCTs), large RCT (n > 100)
II	Smaller RCTs (n < 100), systematic reviews of cohort studies "Outcomes research"
III	Cohort studies (must have concurrent control group), systematic reviews of case control studies
IV	Case series, cohort study without concurrent control group (eg, with historical control group), case-control study
V	Expert opinion, case study or report, bench research expert opinion based on theory or physiologic research, common sense/anecdotes

APPENDIX B:
Strength of Evidence Synthesis Based on the AACPDM Scale[10]

Strong Evidence	Consistent, statistically significant findings in outcome measures in at least 2 high-quality Level II studies
Moderate Evidence	Provided by consistent statistically significant findings in outcome measures in at least 1 high-quality Level II study and at least 1 moderate quality Level II or III study
Limited Evidence	Provided by consistent, statistically significant findings in at least 1 high-quality Level II study OR Provided by consistent, statistically significant findings in outcome measures in at least 2 high-quality Level III studies (in the absence of high-quality Level II studies)
Indicative Findings	Provided by consistent, statistically significant findings in outcome and or process measures in at least 1 high quality Level III study or moderate quality Level II studies (in the absence of high quality Level II studies)
No or Insufficient Findings	Indicated by conflicting results (statistically significant positive and negative results)