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Title: Does perturbation-based balance training prevent falls among individuals with chronic stroke? A randomized controlled trial.

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ABSTRACT (word count: 300; max: 300)

Objectives: No intervention has been shown to prevent falls post-stroke. We aimed to determine if perturbation-based balance training (PBT) can reduce falls in daily life among individuals with chronic stroke.

Design: Assessor-blinded randomized controlled trial.

Setting: Two academic hospitals in an urban area.

Interventions: Participants were allocated using stratified blocked randomization to either 'traditional' balance training (control) or PBT. PBT focused on improving responses to instability, whereas traditional balance training focused on maintaining stability during functional tasks. Training sessions were 1 hour twice/week for 6 weeks. Participants were also invited to complete 2 'booster' training sessions during the follow-up.

Participants: Eighty-eight participants with chronic stroke (>6-months post-stroke) were recruited and randomly allocated one of the two interventions. Five participants withdrew; 42 (control) and 41 (PBT group) were included in the analysis.

Primary and secondary outcome measures: The primary outcome was rate of falls in the 12-months post-training. Negative binomial regression was used to compare fall rates between groups. Secondary outcomes were measures of balance, mobility, balance confidence, physical activity, and social integration.

Results: PBT participants reported 53 falls (1.45 falls/person-year) and control participants reported 64 falls (1.72 falls/person-year; rate ratio: 0.85 [0.42, 1.69]; p=0.63). Per-protocol analysis included 32 PBT and 34 control participants who completed at least 10/12 initial training sessions and 1 booster session. Within this sub-set, PBT participants reported 32 falls (1.07 falls/person-year) and control participants reported 57 falls (1.75 falls/person-year; rate ratio: 0.62 [0.29, 1.30]; p=0.20). PBT participants had greater improvement in reactive balance control than the control group, and these

improvements were sustained 12-months post-training. There were no intervention-related serious adverse effects.

Conclusions: The results are inconclusive. PBT may help to prevent falls in daily life post-stroke, but ongoing training may be required to maintain the benefits.

Trial registration: ISRCTN05434601.

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Key words: Stroke; Rehabilitation; Exercise; Physiotherapy; Accidental Falls; Postural balance

STRENGHTS AND LIMITATIONS OF THE STUDY

- This study employed an assessor-blinded randomized controlled trial. As is typical of exercise studies, participant blinding was not possible.
- Attendance to the intervention was high (mean 87% of sessions attended), and rates of withdrawal from the study were low (<6%).
- The primary outcome (falls in daily life) was collected via self-report, which may have led to under-reporting.
- Inclusion and exclusion criteria were minimal so that results would be generalizable to a broad population of individuals with chronic stroke. However, recruited participants were, on average, high functioning; these results might not apply to more severely-affected individuals with stroke.

INTRODUCTION

People with stroke have increased fall risk compared to age-matched individuals who have not had a stroke.[1] Impaired balance control, low balance confidence, and high rate of falls post-stroke are associated with reduced quality of life and reduced physical activity as a strategy to prevent falls.[2,3] Physical exercise, particularly exercise that includes balance training, can reduce fall rates in older adults.[4] However, studies including individuals with stroke have not demonstrated reduced fall rates following balance training.[5,6]

Balance training programs typically include exercises that aim to improve the ability to maintain balance when keeping still (e.g., standing with reduced base of support) or during voluntary movement (e.g., sit-to-stand or step ups).[7-11] This type of balance training may prevent falls by reducing the risk of losing balance in daily life. However, occasional loss of balance may be an inevitable consequence of mobility, so the ability to react quickly after losing balance is essential to prevent falls.[12] Perturbation-based balance training (PBT) is a type of exercise where participants repeatedly experience loss of balance in order to practice and improve control of balance reactions.[13] A review of small-sample randomized controlled trials suggests that PBT can prevent falls in older adults and individuals with Parkinson's disease.[14]

People with stroke have impaired reactive balance control,[15,16] and impaired control of balance reactions is related to increased fall rates in daily life post-stroke.[17,18] PBT can improve reactive balance control post-stroke.[19] A non-randomized study found that those who completed PBT during in-patient stroke rehabilitation fell less frequently post-discharge than those who did not.[20]

The main purpose of this study was to determine if PBT reduces fall rates in people with chronic stroke. A secondary purpose was to determine the effect of PBT on balance control, balance confidence, mobility, daily physical activity, and social integration. We hypothesized that, compared to a control group who completed 'traditional' balance training, those who completed PBT would

experience fewer falls in the year post-training and would have greater improvements in measures of functional balance and mobility. Additionally, we expected that, due to reduced fall rates and improved balance confidence, participants who completed PBT would be less likely to restrict daily physical activities; therefore, we hypothesized that participants who completed PBT would show increased daily physical activity and improved social integration compared to those in the control group.

METHODS

Trial design

This assessor-blinded pragmatic randomized controlled trial took place at the Toronto Rehabilitation Institute (University Health Network) and Sunnybrook Health Sciences Centre. Individuals with chronic stroke were recruited and randomly assigned to either: 1) PBT or 2) 'traditional' balance training (control group). The full study protocol is available elsewhere;[21] protocol modifications are detailed in the relevant sections below. The protocol and amendments were approved by the University Health Network (study ID: 14-7428) and Sunnybrook Health Sciences Centre (study ID: 134-2014) Research Ethics Boards.

Participants

Community-dwelling adults with chronic stroke (>6 months post-stroke) were recruited from research volunteer databases and advertisements in the community. Participants could stand independently without upper-limb support for >30s and tolerate at least 10 postural perturbations. Exclusion criteria were: >2.1m tall and/or weighing >150kg; other neurological conditions; lower extremity amputation; unable to understand instructions in English; recent (last 6 months) significant illness, injury or surgery; severe osteoporosis (diagnosis of osteoporosis with fracture); poorly controlled diabetes or hypertension; contraindications to physical exercise;[22] receiving physiotherapy or supervised exercise

targeting balance and mobility; and/or received PBT in the year before enrolment. Due to difficulty recruiting, the protocol was amended to allow individuals <50 years old to participate. Volunteers completed telephone screening and subsequently attended an initial assessment where written informed consent was obtained and eligibility was confirmed. To help alleviate barriers to participation, participants were compensated for travel expenses (public transit fare or parking).

Interventions

Participants completed 2 1-hour training sessions per week for 6 weeks, and 2 1-hour 'booster' training sessions 3- and 9-months after the initial training period. Interventions were administered by a physiotherapist (CJD or SK) on a 1:1 basis (i.e., one physiotherapist per participant) in research laboratories in academic hospitals. Both laboratories contained a 2.63 x 2.63m 4-post XY patient lift gantry (Prism Medical Ltd, Concord, ON, Canada), and the Sunnybrook laboratory also contained a 8.5m long ceiling lift track, to which the safety harness was attached during PBT. Physiotherapists were trained in delivering the control intervention by reviewing the intervention developers' documentation,[23] and in delivering the PBT intervention by study investigators (AM and VGD). Interventions followed a general guide, but were tailored to participants' ability and balance impairments. Participants rated perceived level of challenge on a 5-point scale (see Supplementary Material) after completing each exercise set. The physiotherapists documented activities in each session, perceived level of challenge, adverse events, and deviations from prescribed activities.

Control group

The control group completed the Keep Moving with Stroke program.[23] This is an exercise program for community-dwelling individuals with stroke, based on balance and mobility interventions evaluated in clinical trials.[9-11] This program was designed to be delivered in a group, but was delivered 1:1 in this

study to match attention received from the physiotherapist by the PBT group. Each session included a 5-10 minute warm-up, 40 minutes of mobility and balance exercises, and a 5-10 minute cool-down with stretching. Exercises included walking, sit-to-stand, heel raises, walking while carrying an object, tap-ups or step-ups (forward and sideways), reaching and weight shifting, and standing with reduced base of support.

PBT group

PBT sessions included a 5-10 minute warm-up, voluntary tasks intended to induce internal perturbations, voluntary tasks combined with external perturbations, and a 5-10 minute cool-down. Participants were supervised by the physiotherapist and wore a custom safety harness (ABG Concept Médical Inc., Valcourt, QC, Canada) attached to the overhead support. Internal perturbations occurred when participants failed to control balance during voluntary movement; 'agility' tasks, such as kicking a soccer ball, were used to induce internal perturbations. External perturbations were caused by forces outside participants' control (e.g., push or pull from the physiotherapist). We aimed for at least 60 postural perturbations per session, and set the task difficulty such that participants required an upper extremity response, external assistance (i.e., from the overhead harness or physiotherapist), or a multi-step response ~50% of the time. The progression in voluntary tasks occurred on a continuum from stable to mobile, and from predictable to unpredictable.[24] Additionally, progression occurred by increasing the magnitude of external perturbation, or imposing sensory or environmental challenges. The full PBT program is available in the Supplementary Material.

Group allocation

Participants were assigned using blocked stratified randomization with allocation concealment to either the control or PBT group by the principal investigator (AM), who was not involved in recruiting,

assessments, or intervention administration. A variable block size of 4, 6 or 8 was used. There were four strata from two stratification factors: site (two levels), and frequency of 'failures' during baseline reactive balance control assessment[17] (two levels). The random allocation sequence was computer generated and maintained in an electronic file by the principal investigator.

Outcomes

Cohort descriptors

Demographic and stroke information were recorded at study enrolment: age, sex, time since stroke, lesion location, falls history, National Institutes of Health Stroke Scale (NIH-SS[25]), and Chedoke-McMaster Stroke Assessment (CMSA) foot and leg scores.[26] Demographics and medical history were obtained by self-report and, when possible, verified from participants' hospital charts.

Primary outcome – falls

A fall was defined as "an event that results in a person coming to rest unintentionally on the ground or other lower level".[27] Participants completed 12-months of falls reporting after the initial 6-week training period. Participants were provided stamped addressed postcards containing a 2-week calendar to record falls, which they completed daily, and returned to the research team fortnightly. If a postcard was not returned within 2 weeks the research assistant called the participant to ascertain if they fell. Participants who fell completed a short telephone questionnaire regarding the cause, circumstances, and consequences of the fall. Falls were excluded from analysis, by unanimous decision of two blinded research assistants, if they were caused by loss of consciousness or an overwhelming external force (i.e., if anyone would fall in that situation). If the research assistants could not agree that a fall should be excluded, that fall was included in the analysis.

Secondary outcomes

Balance and mobility and balance confidence were assessed immediately before, immediately after, and 6- and 12-months after the end of the initial training period. Functional balance and mobility were assessed using the Berg balance scale (BBS[28]), the mini-Balance Evaluation Systems test (mini-BEST[29]), and the Timed Up & Go (TUG[30]). The Activities-specific Balance Confidence (ABC) questionnaire[31] was used to assess balance confidence in daily activities.

Physical activity and social integration were evaluated with the Physical Activity Scale for Individuals with Physical Disabilities (PASIPD[32]) and the Subjective Index of Physical and Social Outcome (SIPSO[33]), respectively, at baseline and every 2 months during the 12-month follow-up.

Blinding

The research assistants (AA and AC) were blinded to group allocation and were responsible for screening, recruiting, and collecting data. At the post-training, 6-month, and 12-month assessments, the research assistants guessed group allocation for each participant, rated their confidence in their guess of group allocation, and noted if they had received any information to violate blinding. In cases where blinding was violated, the balance measures were re-coded from video footage by another blinded research assistant.

Sample size

The target sample size was estimated for the primary outcome (fall rate in the year post-training) using a formula for negative binomial regression.[34] Assuming the control group would report 1.75 per person-year,[17] a rate ratio of 0.54,[14] mean follow-up time of 11 months per person, level of significance of 0.05, and power of 0.8, we estimated that 37 participants per group would be required to show a statistically significant between-group difference in fall rates.

Statistical analysis

Wilcoxon-Mann-Whitney test (continuous/ordinal variables) and Fisher's exact test (categorical/frequency variables) were used to compare the two groups at baseline. Negative binomial regression was used to compare fall rates and logistic regression was used to compare the proportion of fallers between the two groups. Intent-to-treat analysis was used; all participants with some falls-monitoring data were included in the analyses. To account for variable falls-monitoring duration between participants (e.g., due to premature withdrawal from the study) the natural log of the monitoring duration was included as an offset variable in negative binomial regression, and as a covariate in logistic regression. Exploratory per-protocol analysis was also conducted, comparing proportion of fallers and fall rates between the two groups, including only those participants who attended at least 10/12 of the initial training sessions and 1 booster session. We initially planned to conduct repeated-measures analysis of variance, with group-by-time interaction, to evaluate the effect of the interventions on secondary outcome measures.[21] However, because the variables were not normally distributed we conducted analysis of co-variance (ANCOVA), comparing BBS, mini-BEST, mini-BEST subscale scores, TUG, ABC, PASIPD, and SIPSO at each time point between groups, controlling for the value at baseline. Dependent variables were rank transformed prior to entry into the ANCOVA to allow for non-parametric analysis. Alpha was 0.05 for all analyses.

RESULTS

Recruitment

Recruiting occurred between 24 April 2014 and 29 June 2016. Initially, we planned to recruit 46 participants per group to account for a 20% withdrawal rate.[21] However, recruiting was stopped when we had at least 37 participants per group who had returned at least one fall-reporting postcard. Any

participants who had started the intervention at this point continued with the study until they either withdrew or completed all study elements. The trial ended when data collection for all recruited participants was complete (August 2017). Forty-four participants were assigned to each group, with 42 (control) and 41 (PBT) returning at least 1 fall-reporting postcard (Figure 1); thus 42 control and 41 PBT participants were included in analysis of the primary outcome (falls in daily life). Baseline characteristics for these participants are in Table 1; there were no significant differences between groups on any baseline characteristics.

Intervention adherence

During the initial 6-week training program, PBT participants attended a mean 10.5 sessions, with 34/41 participants attending at least 10 sessions (out of the prescribed 12). Participants experienced a mean of 577 perturbations during all sessions (standard deviation: 195 perturbations; minimum: 42 perturbations), or a mean of 55 perturbations per session (standard deviation: 9 perturbations). For all PBT sessions combined, mean rate of balance recovery 'failures' was 57%, and mean rate of perceived challenge was 2.4 (on a five-point scale). In the initial 6-week training phase, control participants attended a mean of 11 sessions, with 38/42 participants attending at least 10 sessions (out of the prescribed 12). On average, control participants completed 87% of the prescribed exercises (standard deviation: 18%). For all control training sessions combined, mean rate of perceived challenge was 2.4.

Outcomes and estimation

Blinding

Blinding was violated for 9 participants (7 PBT and 2 control), who revealed their group allocation in conversation with the research assistant. The BBS and mini-BEST scores for these participants were re-coded from video recordings by another blinded research assistant who had no interaction with

participants. For the remaining participants, the research assistants correctly guessed group allocation 56% of the time; i.e., guesses were not correct more often than would be expected by random chance.

Missing data

Data were missing at assessment time points because participants: declined to complete the assessment (15 PBT and 21 control assessments); were unavailable due to acute illness (3 control assessments); were unavailable due vacation or other personal commitments (3 control assessments); or could not be contacted at the time of the assessment (6 control assessments). Some participants declined to come to the laboratories for the 6- and 12-month assessments, but were willing to complete the questionnaires (ABC, SIPSO, and PASIPD) over the telephone. Even when participants attended a study appointment, some declined to complete individual tests; the number of individuals included in analysis of each variable at each time point is detailed in the Tables.

Falls

In the year post-training, 46% (19/41) of PBT participants and 55% (23/42) of control participants reported at least one fall; the between-group difference in odds of being a 'faller' was not statistically significant (odds ratio: 0.71 [0.30, 1.70]; p=0.44). PBT participants reported 53 falls (1.45 falls per person-year) and control participants reported 64 falls (1.72 falls per person-year); the between-group difference in fall rates was not statistically significant (rate ratio: 0.85 [0.42, 1.69]; p=0.63).

Thirty-two PBT participants and 34 control participants completed at least 10/12 of the initial training sessions and 1 booster session, and were included in per-protocol analysis. Within this sub-set, 44% (14/32) of PBT participants and 59% (20/34) of control participants reported at least one fall in the year after training. The between group difference in odds of being a 'faller' was not statistically significant (odds ratio: 0.56 [0.21, 1.50]; p=0.25). PBT participants reported 32 falls (1.07 falls per

person-year) and control participants reported 57 falls (1.75 falls per person-year). The between-group difference in fall rates was not statistically significant (rate ratio: 0.62 [0.29, 1.30]; p=0.20).

Balance confidence, balance, mobility, physical activity, and social integration

Post-training, the PBT group had higher scores than the control group for the reactive sub-scale of the mini-BEST ($F_{1,74}$=7.33, p=0.0084; Table 2), whereas the control group had higher scores than the PBT group for the sensory subscale ($F_{1,74}$=4.19, p=0.044). Scores for the reactive sub-scale of the mini-BEST were higher for the PBT group than the control group at 6-months ($F_{1,57}$=8.32, p=0.0055) and 12-months ($F_{1,53}$=11.59, p=0.0013). Likewise, at 12-months, the PBT group had a higher score on the total mini-BEST than the control group ($F_{1,53}$=4.04, p=0.049). There were no other statistically significant between-group differences for balance and mobility measures at any time point.

There were no significant between-group differences for the PASIPD at any time point (Table 3). SIPSO scores were significantly higher for the control group compared to the PBT group at 6-months ($F_{1,59}$=6.73, p=0.012), 8-months ($F_{1,54}$=4.25, p=0.044), 10-months ($F_{1,61}$=4.89, p=0.031), and 12-months ($F_{1,59}$=4.13, p=0.047).

Data showing change in secondary outcomes over time are presented in the supplementary data (Supplementary Tables S1 and S2). No analyses were conducted on these data.

Ancillary analysis

Additional exploratory analysis compared causes, circumstances, and consequences of falls in daily life between groups (Table 4). There was a significant between-group difference in motor activity at the time of the fall (p=0.010). Falls in control participants were more likely to occur during transfers than falls in PBT participants, whereas falls in PBT participants were more likely to occur during reaching/bending than falls in control participants. Participants had something in their hands at the time

of 45% of control-group falls, compared to 23% of PBT-group falls (p=0.023). PBT participants attempted to stop themselves from falling by using a step response for 21%, or a grasping response for 18% of falls, whereas control participants tried to prevent the fall by stepping for only 9% of falls, and grasping for 30% of falls; however, this difference was not statistically significant (p=0.18). PBT participants required assistance to get up after 48% of falls, compared to just 27% of falls for control participants (p=0.040). Injuries resulted from 18 falls (39% of falls) in the PBT group and 20 falls (34% of falls) in the control group (p=0.68). Most injuries were minor (e.g., cuts and bruises). Participants sought medical attention after 3 falls (all control): visit to emergency room (2 falls), and treatment from an unspecified healthcare professional (1 fall).

Harms

Forty-eight adverse events were possibly, probably, or definitely related to study procedures or interventions among the 88 randomized participants. Events were: fatigue with training (3 PBT, 1 control); joint pain during or soon after training (14 PBT, 11 control); delayed onset muscle soreness (5 PBT, 8 control); seizure during training (1 PBT participant, with history of frequent seizures); abnormally elevated heart rate and low blood pressure during training (1 control; this participant was withdrawn from the study). For all but this last event, medical attention was not necessary to treat adverse events. In the case of fatigue or joint/muscle pain, the intensity and/or duration of training was reduced until the issue resolved. Additionally, four falls that occurred during the training portion of the study were considered related to study procedures or interventions. In one case (control) the participant fell outside the hospital while on the way to a study appointment. The other three falls were reported by a single PBT participant who noted that he felt more confident, and may have increased risk-taking behaviour, as a result of the intervention. Eight participants experienced serious adverse events

unrelated to study procedures, but that resulted in study withdrawal: prolonged hospitalization (1 PBT, 1 control); another stroke (2 PBT, 3 control); death (1 control); and cancer diagnosis (1 control).

DISCUSSION

We hypothesized that PBT would reduce fall rates among individuals with stroke; this hypothesis was not supported. While the rate ratio comparing falls rates between the PBT and control groups was 0.85, this was not statistically significant. The pooled rate ratio estimating the effect of exercise on fall rates in community-dwelling older adults is 0.80,[4] which is similar to that observed in the current study. Our sample size was based on a rate ratio of 0.54, which was estimated from a meta-analysis of PBT,[14] that included studies among older adults and individuals with Parkinson's disease. Another non-randomized study reported a fall rate ratio of 0.32 when comparing individuals with sub-acute stroke who completed PBT during in-patient rehabilitation to those who did not.[20] The effect of PBT on fall rates in chronic stroke may be much lower than in other patient populations or individuals with sub-acute stroke and, therefore, the current study may not have had sufficient power to detect the true effect. Conversely, the between-group difference in fall rates was much greater when only individuals who completed at least 80% of initial training sessions and 1 booster session were included in the analysis. The booster sessions may have helped participants to retain the training benefits.[35,36]

Importantly, the control group also completed balance training; previous studies using similar exercise programs found no effect of balance training on fall rates in people with chronic stroke when compared to a sham intervention[7] or 'usual care'.[37] Thus, we expect that control participants did not have reduced fall risk as a result of completing this program. However, both groups improved balance and mobility following training, and it is possible that improved balance and mobility led to reduced fall risk in the control group.

Consistent with specificity of training, the PBT group improved reactive balance control (reactive sub-scale of the mini-BEST), but the control group did not;[38] these improvements were retained at 6- and 12-months. This finding agrees with those of Bhatt *et al*., who found that resistance to falling following a slip was retained up to 6-months after a single PBT session.[36] Despite these retained improvements in reactive balance control, PBT participants did not have a significantly reduced fall risk than control participants. Falls occur when there is a loss of balance and subsequent failure to recover.[39] Improved reactive balance control following PBT should help to prevent falls by improving the ability to recover from a loss of balance. Loss of balance can occur due to an external force or failure of anticipatory balance control. Thus, it is possible that effective fall prevention post-stroke requires sustained improvements in both anticipatory and reactive balance control; home exercise may help participants to retain improvements in anticipatory balance control.[37]

Contrary to our hypothesis, control participants reported greater social integration 6-12 months post-training than the PBT group. Individual-item SIPSO scores suggest that this finding was primarily driven by control participants reporting increased independence in moving around their local neighbourhoods. The control training program included walking practice during every session, whereas the PBT program only included short bouts of walking in later sessions. This walking practice may have increased control participants' confidence with community mobility. While increased social integration at 6-12 months was not associated with improved physical function, it is likely that the tests used in the current study do not correlate highly with community mobility.[40] Training-related improvements in balance and mobility in both groups, and increased self-reported participation in the control group, were not associated with increased physical activity post-training. While impaired balance and mobility post-stroke may be a barrier to physical activity,[41] improved balance and mobility alone is not sufficient to increase activity.[7,42] It is likely that an intervention that combines behaviour

change techniques with physical exercise is required to increase long-term participation in physical activity.[43]

Examining fall characteristics can provide further insight into intervention effects on falls.[20] Individuals with stroke seem to be reliant upon upper-extremity reactions to prevent falls in daily life.[27] In the current study, participants had something in their hands at the time of the fall for more control group falls than PBT falls, which may have prevented these individuals from using an upper-extremity reaction to prevent the fall.[44] Conversely, training, with a specific focus on reactive stepping, may have made PBT participants less reliant on upper extremity reactions to prevent falls. Participants required assistance to get up from the ground after more PBT group than control group falls; this finding could suggest that those PBT participants who fell were more impaired than PBT participants who did not fall or than those in the control group who fell.

Limitations

The primary outcome (falls in daily life) was obtained via self-report. While the method of prospective falls reporting used in the current study is the best available,[45] falls may have been under-reported. The cohort was, on average, relatively high functioning (e.g., median BBS score ~50/56), but had a wide range of physical function (minimum scores for CMSA leg: 3, CMSA foot: 2, BBS: 23, mini-BEST: 5; maximum NIH-SS score: 13; highest TUG time: 119s). This study's findings apply to community-dwelling individuals with chronic stroke who can stand independently for at least 30s. Group allocation blinding was violated for 9 participants. Balance measures for these participants were re-scored by a truly blinded research assistant; however, knowledge of group allocation may have sub-consciously influenced how other data were collected for these participants.

PASIPD scores were higher at the time points when the questionnaire was administered in-person compared to over the telephone. Physical activity questionnaires, including the PASIPD,[32] are

often designed to have several methods of administration (e.g., self-administered via in-person or telephone interview).[46] When used in practice, investigators seem to treat administration methods as equivalent; for example, in a multi-site validation study of the International Physical Activity Questionnaire, some sites administered the questionnaire via telephone interview and others via in-person interview.[47] We are not aware of any study that directly compared scores from the PASIPD or any other physical activity questionnaire when administered using different methods. It is possible that scores are higher when administered in-person versus over the telephone as participants' desire for social acceptance was higher when they interacted directly with the research assistant. Alternatively, in-person administration may have led to more accurate scores than telephone administration within this population, who may have subtle cognitive-communication deficits, as the research assistant and participant could avail of non-verbal communication to facilitate completing the questionnaire. However, SIPSO scores did not differ between telephone versus in-person administration. Finally, participants in the current study may have truly been more active in the week prior to the in-person interview compared to the telephone interview to prepare for the tests of physical function. Future studies should investigate the potential influence of administration methods on physical activity questionnaire scores.

Clinical implications

While this study found that PBT did not reduce fall rates among the entire cohort, PBT participants improved reactive balance control and retained these improvements up to 12-months post-training. Combined with results of previous studies reporting reduced fall rates following PBT among individuals with sub-acute stroke,[20] chronic stroke with a history of falling,[48] and without stroke,[14] these results suggest that PBT may be a useful addition to existing balance training post-stroke. Joint pain was the most common adverse event related to PBT, which appeared to be most prevalent among

those with lower-extremity arthritis; these participants were able to complete training with modifications to avoid exacerbating pain (e.g., temporarily reducing perturbation intensity). Therefore, modifications to PBT may be required for those with lower-extremity arthritis. Regular 'booster' PBT training sessions may be necessary to prevent falls long-term.

Contributorship statement: AM conceived of the study, is the grant holder, performed statistical analysis and drafted the manuscript. AM, VGD, ASI, DB, ELI, and GM developed the study protocol. AM and GM led implementation of the study at each site. AM, VGD, and ELI developed the intervention. AA, AC and ASI collected data. CJD and SK delivered the interventions. All authors approved the final manuscript.

Competing interests statement: The authors declare that they have no competing interests.

Data sharing statement: Due to research ethics and privacy restrictions, raw data for this study are currently not available publically.

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TABLES

Table 1: Participant characteristics at study enrolment. Values presented are medians with interquartile range in parentheses (for continuous/ordinal variables) or number with percentage in parentheses (for count/frequency variables). The p-value is for the Wilcoxon-Mann-Whitney test (continuous/ordinal variables) or Fisher's exact test (count/frequency variables).

	PBT (n=41)	**Control (n=42)**	***p-value***
Age (years)	66 (17)	67 (13)	*0.84*
Sex (number, %)			
Female	15 (36.6)	12 (28.6)	*0.49*
Male	26 (63.4)	30 (71.4)	
Time post-stroke (years)	2.0 (3.3)	3.2 (4.5)	*0.086*
More affected side (number, %)			
Left	22 (53.7)	22 (52.4)	*>0.99*
Right	19 (46.3)	20 (47.6)	
NIH-SS (score)	3 (4)	3 (5)	*0.57*
CMSA leg (score)	5 (1)	5 (1)	*0.54*
CMSA foot (score)	5 (3)	5 (1)	*0.45*
ABC scale (%)	65.6 (26.3)	79.1 (33.8)	*0.42*
BBS (score)	50 (10)	51 (7)	*0.94*
Mini-BEST (score)	18 (7)	18 (5)	*0.95*
TUG (s)	14.4 (12.3)	13.0 (7.6)	*0.62*
PASIPD (score)	8.4 (9.5)	11.6 (10.9)	*0.48*
SIPSO (score)	30 (9)	31 (13)	*0.74*
Fall in the past year (number, %)			
Yes	17 (41.5)	18 (42.9)	*>0.99*
No	24 (58.5)	24 (57.1)	

ABC=Activities-specific Balance Confidence scale, BBS=Berg Balance Scale, mini-BEST=mini-Balance Evaluation Systems Test, CMSA=Chedoke-McMaster Stroke Assessment, NIH-SS=National Institutes of Health Stroke Scale; PASIPD=Physical Activity Scale for Individuals with Physical Disabilities, SIPSO=Subjective Index of Physical and Social Outcome.

Table 2: Balance and mobility measures between groups. Values presented are least-square means with 95% confidence intervals in brackets. The p-value is for the ANCOVA comparing groups at each time point, controlling for the baseline value.

	PBT	Control	*p-value*
Post-training			
N	39	38	
ABC (%)	75.6 [71.6, 79.7]	78.2 [74.1, 82.2]	*0.97*
BBS (score)	50.8 [50.0, 51.7]	51.2 [50.3, 52.1]	*0.99*
Mini-BEST (score)	20.3 [19.6, 21.0]	20.1 [19.3, 20.8]	*0.96*
BEST-anticipatory (score)	4.4 [4.2, 4.6]	4.4 [4.2, 4.6]	*0.94*
BEST-reactive (score)	4.2 [3.7, 4.7]	3.6 [3.0, 4.1]	*0.044*
BEST-sensory (score)	5.3 [5.2, 5.5]	5.6 [5.4, 5.7]	*0.0084*
BEST-gait (score)	6.4 [6.0, 6.7]	6.6 [6.2, 7.0]	*0.44*
TUG (s)	17.5 [15.8, 19.2]	17.4 [15.7, 19.1]	*0.30*
6-month follow-up			
N	30*	30*	
ABC (%)	75.4 [70.1, 80.8]	74.1 [68.6, 79.5]	*0.70*
BBS (score)	50.2 [49.2, 51.2]	51.3 [50.3, 52.4]	*0.11*
Mini-BEST (score)	19.8 [18.9, 20.7]	19.1 [18.2, 20.0]	*0.81*
BEST-anticipatory (score)	4.3 [4.0, 4.6]	4.3 [4.0, 4.6]	*0.99*
BEST-reactive (score)	4.0 [3.4, 4.5]	2.9 [2.3, 3.4]	*0.0055*
BEST-sensory (score)	5.4 [5.1, 5.7]	5.4 [5.2, 5.7]	*0.44*
BEST-gait (score)	6.2 [5.6, 6.7]	6.5 [6.0, 7.1]	*0.25*
TUG (s)	16.8 [15.3, 18.2]	15.4 [13.9, 16.9]	*0.32*
12-month follow-up			
N	27†	29†	
ABC (%)	75.2 [69.3, 81.1]	78.1 [72.1, 84.0]	*0.95*
BBS (score)	50.6 [49.5, 51.6]	51.1 [50.0, 52.1]	*0.27*
Mini-BEST (score)	20.6 [19.4, 21.8]	18.7 [17.5, 19.8]	*0.049*
BEST-anticipatory (score)	4.3 [4.0, 4.6]	4.3 [3.9, 4.6]	*0.45*
BEST-reactive (score)	4.2 [3.6, 4.9]	2.6 [2.0, 3.2]	*0.0013*
BEST-sensory (score)	5.4 [5.1, 5.7]	5.4 [5.1. 5.6]	*0.64*
BEST-gait (score)	6.6 [6.0, 7.3]	6.5 [5.9, 7.1]	*0.90*
TUG (s)	15.7 [14.3, 17.2]	17.3 [15.9, 18.7]	*0.79*

ABC=activities-specific balance confidence scale; BBS=Berg balance scale; BEST=balance evaluation systems test.

*N=32 PBT and 31 control for the ABC at 6-month follow-up. †N=31 PBT and 31 control for the ABC at 12-month follow-up.

Table 3: Physical activity and social integration between groups. Values presented are least-square means with 95% confidence intervals in brackets The p-value is for the ANCOVA comparing groups at each time point, controlling for the baseline value.

	PBT	Control	*p-value*
Post-training			
N	39	38	
PASIPD (score)	12.3 [10.0, 14.6]	11.2 [8.8, 13.6]	*0.92*
SIPSO (score)	29.8 [28.1, 31.4]	31.2 [29.5, 32.9]	*0.29*
2-month follow-up			
N	38	31	
PASIPD (score)	8.6 [6.4, 10.8]	9.5 [7.1, 11.9]	*0.51*
SIPSO (score)	29.7 [28.2, 31.2]	31.5 [29.8, 33.21]	*0.23*
4-month follow-up			
N	33	34	
PASIPD (score)	9.2 [7.3, 11.2]	7.8 [5.9, 9.8]	*0.34*
SIPSO (score)	30.0 [28.2, 31.9]	30.2 [28.4, 32.0]	*0.62*
6-month follow-up			
N	32	31*	
PASIPD (score)	11.3 [7.3, 15.3]	10.9 [6.8, 15.0]	*0.21*
SIPSO (score)	30.3 [29.0, 31.6]	32.6 [31.3, 33.9]	*0.012*
8-month follow-up			
N	31	26	
PASIPD (score)	7.0 [5.6, 8.4]	6.9 [5.4, 8.5]	*0.61*
SIPSO (score)	30.5 [29.3, 31.7]	32.3 [31.0, 33.6]	*0.037*
10-month follow-up			
N	32	32	
PASIPD (score)	7.0 [5.5, 8.5]	8.2 [6.7, 9.7]	*0.16*
SIPSO (score)	29.9 [28.4, 31.3]	32.3 [30.9, 33.8]	*0.031*
12-month follow-up			
N	31	31	
PASIPD (score)	11.1 [7.4, 14.8]	10.1 [6.4, 13.9]	*0.27*
SIPSO (score)	30.6 [29.1, 32.0]	32.6 [31.1, 34.0]	*0.047*

PASIPD=physical activity scale for individuals with physical disabilities; SIPSO=subjective index of physical and social outcome

*N=30 control for the SIPSO

Table 4: Between-group comparison of fall circumstances. Values are the number of falls in each category, with the percentage of falls in parentheses. The percentage was calculated from the total number of falls for which information was available (i.e., "do not recall" responses were excluded from the denominator). Percentages might not sum to 100 due to rounding error. The p-value is for Fisher's exact test comparing the two groups, excluding "do not recall" responses from analysis.

	PBT (53 falls)	**Control (64 falls)**	***p-value***
Cause of fall			
Do not recall	8	6	
Slip	16 (35.6)	22 (37.9)	*0.26*
Trip	11 (24.4)	6 (10.3)	
Push/external force	1 (2.2)	3 (5.2)	
Incorrect weight transfer[49]	17 (37.8)	13 (46.6)	
Posture at the time of the fall			
Do not recall	7	4	
Lying	1 (2.2)	0 (0)	*0.33*
Sitting	4 (8.9)	7 (12.1)	
Standing	9 (20.0)	6 (10.3)	
Walking	32 (68.9)	47 (77.6)	
Motor activity at the time of the fall			
Do not recall	7	4	
Not moving	4 (8.9)	2 (3.5)	*0.010*
Transferring	2 (4.4)	12 (20.7)	
Turning/reaching/bending	10 (22.2)	3 (5.2)	
Walking on level surface	18 (37.8)	20 (34.5)	
Walking on ramp/stairs/uneven surface	12 (26.7)	21 (36.2)	
Cognitive activity at the time of the fall			
Do not recall	10	9	
None	34 (78.6)	44 (81.1)	*0.80*
Distracted	9 (21.4)	11 (18.9)	
Where did the fall occur			
Outdoors	19 (35.8)	22 (34.4)	*>0.99*
Indoors	34 (64.2)	12 (65.6)	
Using an assistive device			
Do not recall	7	5	
Never use one	11	21	
No	16 (45.7)	24 (66.7)	*0.096*
Yes	19 (54.3)	12 (33.3)	
Holding onto a handrail			
Do not recall	7	6	
No	41 (89.1)	48 (82.8)	*0.41*
Yes	5 (10.9)	10 (17.2)	

	PBT (53 falls)	Control (64 falls)	*p-value*
Anything in hands			
Do not recall	9	6	
No	34 (77.3)	32 (55.2)	*0.023*
Yes (one or both hands)	10 (22.7)	26 (44.8)	
Action to try to prevent the fall			
Do not recall	9	18	
None	27 (61.4)	28 (60.9)	*0.18*
Grasp	8 (18.2)	14 (30.4)	
Step or step + grasp	9 (20.5)	4 (8.7)	
Length of lie on floor or ground			
Do not recall	7	4	
A few minutes or less	39 (84.8)	57 (95.0)	*0.098*
More than a few minutes but less than an hour	7 (15.2)	3 (5.0)	
Assistance required to get up from fall			
Do not recall	7	4	
No	24 (52.2)	44 (73.3)	*0.040*
Yes	22 (47.8)	16 (26.7)	
Injuries			
Do not recall	7	5	
None	28 (60.9)	39 (66.1)	*0.68*[*]
Cuts or bruises	17 (37.0)	19 (32.2)	
Joint sprain or dislocation	1 (2.2)	1 (1.7)	
Medical assistance required after fall			
Do not recall	7	5	
No injuries	30	42	
Injured but did not seek treatment	16 (100)	14 (82.4)	*0.23*[†]
Saw other healthcare professional	0 (0)	1 (5.9)	
Treated in hospital emergency room	0 (0)	2 (11.8)	

[*]Analysis compared injury vs no injury

[†]Analysis compared sought treatment vs did not seek treatment

FIGURE CAPTIONS

Figure 1: Participant flow through the study. Eight participants who consented to participate in the study were excluded on the initial assessment because they could not tolerate the lean-and-release postural perturbations. Participants were withdrawn after randomization because it became apparent that they did not meet the study criteria (1 PBT participant had osteoporosis with history of fracture, and 1 control participant had uncontrolled hypertension), or because they had a significant decline in health during the training portion of the study (1 PBT and 1 control participant). One PBT participant was withdrew from the study because she did not like the group allocation. Therefore, there were 42 control participants and 41 PBT participants available for analysis of the primary outcome (falls in daily life). Participants withdrew during the 12-month follow-up period because they: no longer wished to be in the study (2 PBT, 1 control); experienced a serious adverse event (2 PBT, 5 control); were lost to follow-up (2 PBT, 3 control); or enrolled in a conflicting study (2 PBT).

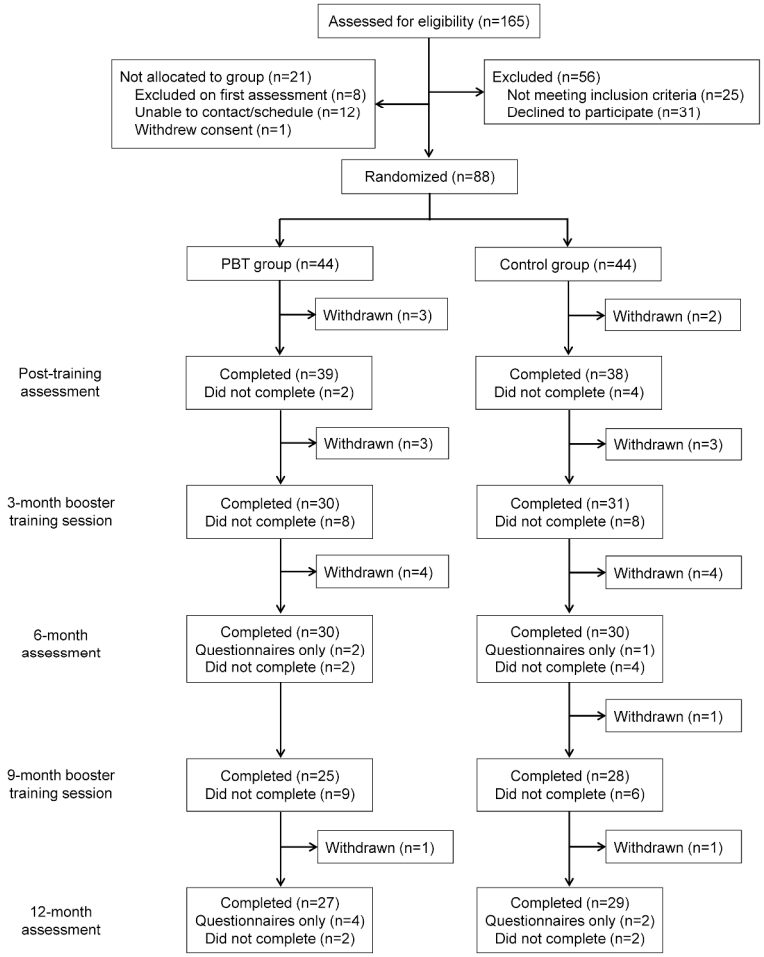

Figure 1: Participant flow through the study. Eight participants who consented to participate in the study were excluded on the initial assessment because they could not tolerate the lean-and-release postural perturbations. Participants were withdrawn after randomization because it became apparent that they did not meet the study criteria (1 PBT participant had osteoporosis with history of fracture, and 1 control participant had uncontrolled hypertension), or because they had a significant decline in health during the training portion of the study (1 PBT and 1 control participant). One PBT participant was withdrew from the study because she did not like the group allocation. Therefore, there were 42 control participants and 41 PBT participants available for analysis of the primary outcome (falls in daily life). Participants withdrew during the 12-month follow-up period because they: no longer wished to be in the study (2 PBT, 1 control); experienced a serious adverse event (2 PBT, 5 control); were lost to follow-up (2 PBT, 3 control); or enrolled in a conflicting study (2 PBT).

300x400mm (300 x 300 DPI)

SUPPLEMENTARY TABLES

Table S1: Balance and mobility measures, change over time. Values presented are the differences from pre-training with 95% confidence intervals in brackets. A positive difference value indicates an improvement for all variables except the TUG, where a negative value indicates an improvement (i.e., faster TUG time compared to baseline).

	PBT	Control
Post-training		
N	39	38
ABC (%)	5.2 [0.7, 9.8]	6.6 [1.5, 11.6]
BBS (score)	1.8 [0.7, 2.9]	1.9 [1.0, 2.9]
Mini-BEST (score)	2.6 [1.8, 3.4]	2.2 [1.5, 3.0]
BEST-anticipatory (score)	0.5 [0.2, 0.8]	0.5 [0.2, 0.8]
BEST-reactive (score)	1.5 [0.9, 2.1]	0.8 [0.3, 1.2]
BEST-sensory (score)	0 [-0.2, 0.2]	0.3 [0.0, 0.5]
BEST-gait (score)	0.6 [0.1, 1.0]	0.7 [0.3, 1.1]
TUG (s)	-1.0 [-2.9, 0.8]	-1.1 [-2.8, 0.5]
6-month follow-up		
N	30*	30*
ABC (%)	3.5 [-2.3, 9.2]	0.6 [-5.2, 6.3]
BBS (score)	0.3 [-0.8, 1.4]	1.3 [0.2, 2.4]
Mini-BEST (score)	1.6 [0.6, 2.6]	0.8 [-0.1, 1.7]
BEST-anticipatory (score)	0.3 [-0.1, 0.6]	0.3 [-0.1, 0.7]
BEST-reactive (score)	1.2 [0.5, 1.8]	0.0 [-0.5, 0.5]
BEST-sensory (score)	0.1 [-0.2, 0.3]	0.2 [-0.1, 0.5]
BEST-gait (score)	0.1 [-0.6, 0.8]	0.3 [-0.1, 0.8]
TUG (s)	1.0 [-1.0, 2.9]	-0.5 [-1.4, 0.5]
12-month follow-up		
N	27†	29†
ABC (%)	3.5 [-3.1, 10.2]	3.8 [-2.7, 10.3]
BBS (score)	0.6 [-0.7, 1.8]	0.8 [-0.3, 2.0]
Mini-BEST (score)	2.2 [0.9, 3.4]	0.1 [-1.1, 1.4]
BEST-anticipatory (score)	0.2 [-0.1, 0.5]	0.2 [-0.2, 0.7]
BEST-reactive (score)	1.4 [0.5, 2.3]	-0.4 [-1.0, 0.2]
BEST-sensory (score)	0.1 [-0.2, 0.4]	0.1 [-0.1, 0.4]
BEST-gait (score)	0.4 [-0.3, 1.2]	0.2 [-0.4, 0.8]
TUG (s)	0.1 [-1.0, 1.2]	1.6 [-0.4, 3.6]

ABC=activities-specific balance confidence scale; BBS=Berg balance scale; BEST=balance evaluation systems test.

*N=32 PBT and 31 control for the ABC at 6-month follow-up. †N=31 PBT and 31 control for the ABC at 12-month follow-up.

Table S2: Physical activity and social integration, change over time. Values presented are the difference from pre-training with 95% confidence intervals in brackets. A positive difference value indicates an improvement.

	PBT	Control
Post-training		
N	39	38
PASIPD (score)	1.1 [-2.0, 4.2]	-1.0 [-3.1, 1.0]
SIPSO (score)	0.5 [-1.4, 2.5]	1.8 [0.0, 3.7]
2-month follow-up		
N	38	31
PASIPD (score)	-2.1 [-5.1, 0.8]	-2.8 [-5.8, 0.3]
SIPSO (score)	-0.1 [-1.7, 1.6]	1.5 [-0.4, 3.4]
4-month follow-up		
N	33	34
PASIPD (score)	-1.7 [-4.2, 0.8]	-4.1 [-6.6, -1.5]
SIPSO (score)	0.5 [-1.2, 2.2]	0.7 [-1.3, 2.7]
6-month follow-up		
N	32	31*
PASIPD (score)	0.4 [-5.3, 6.2]	-2.2 [-5.6, 1.1]
SIPSO (score)	0.3 [-1.0, 1.7]	2.5 [0.8, 4.2]
8-month follow-up		
N	31	26
PASIPD (score)	-4.5 [-7.3, -1.6]	-5.7 [-9.7, -1.6]
SIPSO (score)	0.2 [-1.1, 1.5]	1.8 [0.4, 3.3]
10-month follow-up		
N	32	32
PASIPD (score)	-4.1 [-6.6, -1.7]	-3.5 [-6.7, -0.4]
SIPSO (score)	-0.3 [-1.6, 1.0]	2.2 [0.4, 3.9]
12-month follow-up		
N	31	31
PASIPD (score)	0.4 [-4.6, 5.4]	-2.9 [-6.0, 0.2]
SIPSO (score)	0.8 [-0.7, 2.3]	2.7 [0.9, 4.4]

PASIPD=physical activity scale for individuals with physical disabilities; SIPSO=subjective index of physical and social outcome

*N=30 control for the SIPSO

Toronto Perturbation-Based Balance Training

Program Manual

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LIST OF ABBREVIATIONS

AFO = ankle-foot orthosis
BOS = base of support
BP = blood pressure
CMSA = Chedoke-McMaster Stroke Assessment
DF = dorsiflexion
EV = eversion
HR = heart rate
INV = inversion
Mini-BES = Mini Balance Evaluation Systems (test)
PBT = perturbation-based balance training
PF = plantarflexion
RPC = rating of perceived challenge
TUG = timed-up and go

INTRODUCTION

The **goal of PBT** is to improve reactive balance control in order to optimize safe independent mobility. The program requires that individuals repeatedly experience loss of balance (i.e., internal or manual postural perturbations) and are provided the opportunity to practice stepping reactions to regain balance following this instability. As participants adapt to the challenge and improve their balance control, the challenge should be increased. Challenge can be increased by increasing the magnitude of the manual perturbation, adding more challenging secondary movement and cognitive tasks, removing or altering sensory feedback, and changing the environment.

Note, for convenience and clarity of expression in this document, we use feminine pronouns to refer to the treating physiotherapist, and masculine pronouns to refer to the participant.

1. SCREENING AND ASSESSMENT

1.1 An initial assessment is required to inform and guide treatment, and ensure patient safety.

Information regarding significant medical history is obtained; specifically, does the participant:

- Have arthritis in the lower extremities or any other joint pain;
- Normally wear glasses or contact lenses;
- Normally use a cane, a rollator, or any other mobility aid;
- Normally wear an orthotic (brace) around the ankle and/or knee;
- Normally wear a sling around the arm/shoulder;
- Have diabetes;
- Take any medication on an "as needed" basis (i.e., PRN medication);
- Report any recent falls; and
- Have fear of falling?

Modifications to the manner in which the program is provided may be made based on responses to the questions above. For example, some activities might be avoided to prevent exacerbation of a previous injury.

The initial assessment includes:

- Assessment of reactive stepping using
    - Forward-fall lean-and-release perturbations under two conditions: usual response and encouraged use (5 trials per condition); and
    - Observation of reactions in the 'Reactive' component of the mini-Balance Evaluation Systems (mini-BES) test.
- Consideration of some of the contributors to impaired reactive stepping:
    - Stroke severity/stroke symptoms – e.g., using the National Institutes of Health Stroke Scale;
    - Stage of motor recovery – e.g., using the Chedoke McMaster Stroke Assessment (CMSA);
    - Balance confidence – e.g., using the Activity-specific Balance Confidence scale; and
    - Sensation (see Sections 1.4 and 1.5).

1.2 Lean and release assessment instructions.

Control of reactive stepping following a postural perturbation is assessed using a lean-and-release system. Participants wear a safety harness attached to an overhead support system. The harness is also connected at the back to a beam via a quick-release mechanism (i.e., a modified crossbow trigger). The participant must lean forward from the ankles far such that approximately 10% of his body weight supported by the cable. Once achieved, the cable is released creating a forward fall from which the participant needs to recover. He is instructed step as quickly as possible to regain balance and come to stable stance. If he cannot regain stability independently, then the assessor can aid in the recovery and prevent a 'fall' (i.e., being caught by the safety harness).

Two conditions are assessed and recorded on the score sheet (see Section 1.3) – the 'usual response' and the 'encouraged use'. The first five trials are completed as described above and the limb that

responds first to the release is recorded. This is the **'usual response'**. If the same limb responds ≥4/5 times, this is considered to be the 'preferred limb'. In the **'encouraged use'** condition, five trials are completed with the preferred limb blocked and the participant is instructed to attempt to react with the non-preferred limb. The blocking is accomplished with the hand or foot of the physiotherapist/assessor. If it appears that the participant is going to step with the blocked limb, the hand/foot can be removed quickly, but the participant is not told that the block will be removed. If there is no obvious preferred limb (i.e., participant stepped 3 times with one leg and 2 with the other), then the limb that is blocked should alternate 2 times for one limb and 3 for the other.

The lean-and-release assessment is video-recorded and the video is reviewed later to observe any participant-specific impairments in reactive stepping (see also Section 4). While it might be possible to observe some obvious impairments in 'real time', often the reaction happens so quickly that this is not possible.

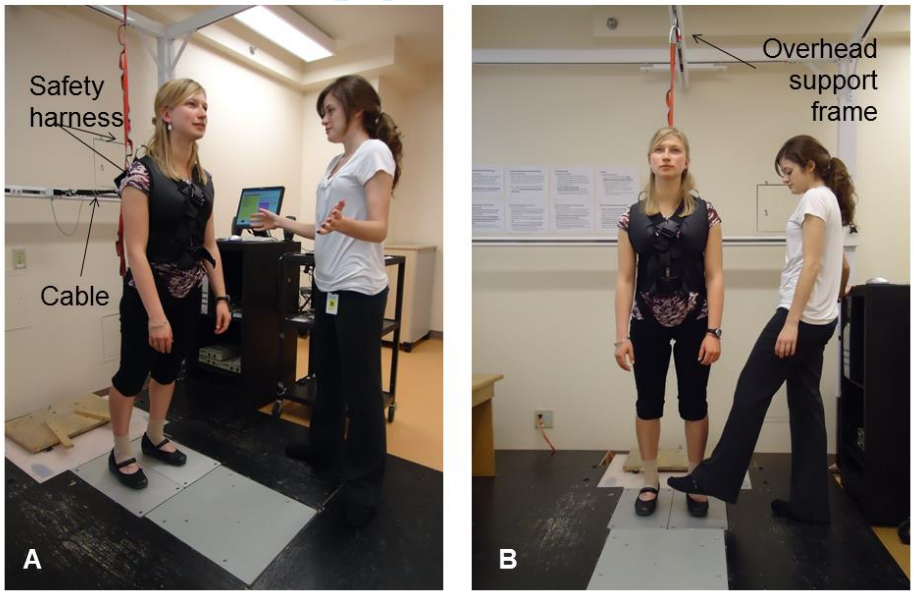

Figure 1.1: The lean-and-release system. Panel A (left) shows the usual response condition. Panel B (right) shows the encouraged-use condition. Figure taken from Mansfield et al., BMC Neurol. 2015;15:87

1.3 Lean and release collection sheet.

Usual response

- ❑ Participant wearing harness
- ❑ Aim for 10% body weight on the cable
- ❑ Random delay between 'ready' signal and perturbation
- ❑ Review video to determine preferred limb & assists (if not clear during testing)
- ❑ Record limb for first step

Test	Trial #	Comments	Limb	Assist
1			❑ Right ❑ Left	❑ No ❑ Yes
2			❑ Right ❑ Left	❑ No ❑ Yes
3			❑ Right ❑ Left	❑ No ❑ Yes
4			❑ Right ❑ Left	❑ No ❑ Yes
5			❑ Right ❑ Left	❑ No ❑ Yes

Preferred limb (initiated stepping in ≥4/5 trials with this limb):

- ❑ Right
- ❑ Left
- ❑ No clear preference

Encouraged use

- ❑ Block preferred limb with researchers hand/foot; if no limb preference do two trials blocking one limb and three blocking the other
- ❑ Aim for 10% body weight on the cable
- ❑ Random delay between 'ready' signal and perturbation
- ❑ Review video to determine preferred limb & assists (if not clear during testing)
- ❑ Record limb for first step

Test	Trial #	Comments	Limb	Assist
6			❑ Right ❑ Left	❑ No ❑ Yes
7			❑ Right ❑ Left	❑ No ❑ Yes
8			❑ Right ❑ Left	❑ No ❑ Yes
9			❑ Right ❑ Left	❑ No ❑ Yes
10			❑ Right ❑ Left	❑ No ❑ Yes

1.4 Sensation assessment instructions.

Exteroceptive and proprioceptive sensation are assessed in the affected foot and ankle. It is necessary to know if the participant appreciates light touch and movement of the ankle and foot. If these are absent or decreased, steps should be taken to accommodate the deficits in order to minimize potential injury due to PBT.

Sensation is assessed with the participant sitting on a raised plinth, feet dangling, with shoes and socks removed. Demonstration of the test should be done with the participant's eyes open and administered to the less-affected foot/ankle. The actual test should be administered to the more-affected foot/ankle following the demonstration with the participant's eyes closed.

Light touch is assessed using a cotton ball; the cotton ball should lightly touch but not brush the sole of the participant's foot. The foot is touched 5 times and the participant is instructed to respond when the touch is felt. Responses are recorded on the score sheet (see Section 1.5). If there is no response (and you are certain that the participant understood the instructions) this is recorded as a negative response.

The **perception of joint movement** is assessed in the ankle (dorsiflexion and plantar flexion) and in the foot (inversion and eversion). The participant's foot is held in two places: the bony prominences of the first and fifth meta-tarsal phalangeal joints and at the medial and lateral malleoli. Movements of the ankle should be demonstrated on the less-affected side as "up" for dorsiflexion and "down" for plantar flexion and, of the foot, as "in" for inversion and "out" for eversion. Care should be taken not to change the pressure of the hold during the movement. When being tested, movements should be through small ranges and time should be allowed for the participant to respond. If the participant is unsure of the direction of the movement, the range should be increased. If the participant is still unsure, then this is a negative response for the test. Five movements should be tested at the ankle and five at the foot.

Each correct, incorrect, or absent response is recorded on the score sheet (Section 1.5). If the participant scores <4/5 for light touch appreciation, and/or <8/10 for joint movement perception, then consideration is made for use of an Aircast Airsport Ankle Brace during training.

1.5 Sensation assessment collection sheet.

Position recognition

Position	Correct response?
Dorsiflexion	❑ Yes ❑ No
Plantarflexion	❑ Yes ❑ No
Dorsiflexion	❑ Yes ❑ No
Dorsiflexion	❑ Yes ❑ No
Plantarflexion	❑ Yes ❑ No
Number correct	

Position	Correct response?
Inversion	❑ Yes ❑ No
Eversion	❑ Yes ❑ No
Inversion	❑ Yes ❑ No
Eversion	❑ Yes ❑ No
Eversion	❑ Yes ❑ No
Number correct	

If number correct is <8/10, an AirSport ankle brace should be used to prevent injury during PBT.

Light touch sensation

Trial	Correct response?
Trial 1	❑ Yes ❑ No
Trial 2	❑ Yes ❑ No
Trial 3	❑ Yes ❑ No
Trial 4	❑ Yes ❑ No
Trial 5	❑ Yes ❑ No
Number correct	

If number correct is <4/5, an AirSport ankle brace should be used to prevent injury during PBT.

2. PLANNING THE PROGRAM

2.1 The program is individualized to the participant's specific impairments in reactive balance control

In order to create an effective training program, consideration is made of the participant's unique areas of dyscontrol (identified on initial assessment; see Section 1). Section 4 (Perturbation Training Log) outlines areas of dyscontrol and suggested treatment approaches for each problem. The principle of individual differences considers an individual's response to exercise. Therefore, progression should be gradual and systematic and occur at the individual participant's rate of improvement. Task difficulty is not absolute and could vary from participant-to-participant depending on specific control problems and other deficits.

2.2 List of equipment

The following equipment is required for this specific program:

- Overhead harness support track;
- Fall-arrest approved safety harness;
- Equipment for task-specific activities:
    - Thin foam mat (e.g., thickness of yoga mat or 2.5 cm gym mat);
    - Thick foam pad (dense blue foam);
    - Hand ball (2 sizes; e.g., 10 cm diameter and tennis ball);
    - Soccer ball;
    - Steps (10 cm and 20 cm high);
    - Stop watch;
    - Unstable 'step' (if an unstable step is not available, place a regular step on a thin foam mat);
    - Cross marked out in tape on the floor (2 pieces of tape each at least 60 cm long placed to intersect at right angles (see Figure 6.24);
    - Set of 6 – 23 cm diameter multi-colored Agility Dots;
    - Foam obstacles (e.g., pool noodles or half-round foam rollers); and
- Participant-specific equipment (e.g., walking aid, ankle brace/orthosis, helmet, arm sling).

2.3 Ensuring safety during training

2.3.1 Safety harness

Participants wear a safety harness attached to an overhead track at all times to prevent a fall to the ground. However, the harness system should be used as a back-up; the supervising physiotherapist still intervenes and provides physical assistance to 'brake the fall' when she feels the individual will not be able to recover balance. (Note, to allow participants the opportunity to practice stepping reactions, the physiotherapist ***only*** provides hands-on assistance if the participant is unable to regain stability alone.) The harness can prevent a fall to the floor but cannot prevent all possible injuries. Appropriate selection of participants, consideration of their underlying impairments, and appropriate supervision is still required. For example, it is possible that an individual could experience an ankle sprain while stepping in response to a perturbation (see Section 2.3.2). It is also possible that a frail individual who falls completely into the harness will experience an injury (e.g., bruise) because he is caught by the safety harness; a fracture could also be possible with a participant who has very low

bone mineral density. Participants should not be left 'dangling' in the safety harness as the straps can restrict circulation.

2.3.2 Protective equipment for ankle

An ankle-foot orthosis (AFO; if prescribed) or an Aircast AirSport Ankle Brace is used during PBT if the participant meets one or more of the following criteria:

- Participant typically uses an AFO during home and/or community walking;
- CMSA foot score is stage 3 or lower;
- Ankle joint position sense score is <8/10 (see Section 1.4 and 1.5);
- Light touch sensation of the plantar surface of the foot score is <4/5 (see Section 1.4 and 1.5); and/or
- The treating physiotherapist feels this is necessary to preserve stability of the ankle joint and prevent injury.

Use of the AirSport Ankle Brace, AFO, or any other assistive devices should be documented in the Perturbation Training Log (Section 4).

2.3.3 Monitoring heart rate and blood pressure

Heart rate (HR) and blood pressure (BP) are taken from the less affected arm using an automatic BP cuff. The less-affected arm is repositioned in an extended position resting on a table slightly below the level of the heart. If BP and/or HR fall outside of an 'acceptable' range (systolic BP is outside 90-140 mmHg; diastolic BP is outside 60-90 mmHg; or, HR is outside 60-100 bpm), a second measure is obtained. If the values continue to be outside of the range, the participant is asked to sit quietly for 5 minutes and perhaps, take a few deep breaths or drink a glass of water, before taking a third measurement. Participants with HR/BP measurements outside of the acceptable range are also questioned regarding recent medications (what they have taken and when, or if they have not taken their usual medications), when they last had something to eat/drink, and if the recently took caffeine, exercised, or smoked. The decision to continue or terminate the session is made by the physiotherapist considering factors such as the participants' usual resting HR/BP, how far the measured values are outside of the acceptable range, the participants' usual medication (e.g., beta-blockers), and the participants' perception of how they are feeling. If the visit is terminated, the physiotherapist may advise that the participant follow-up with his primary care physician. If the visit continues, the physiotherapist may choose to monitor HR and BP regularly throughout the visit and observe cardiovascular responses to exercise.

3. THE PROGRAM

3.1 Overview

The PBT program involves 12 1-hour training sessions provided 2 times per week for 6 weeks. Each session is 60 minutes in length and is provided in a one-to-one format. This core program is modified to fit with delivery of in-patient rehabilitation to allow for evaluation among individuals with sub-acute stroke.

Sessions begin with a 10-minute warm-up and end with a 10-minute cool-down following the warm-up and cool-down from the Keep Moving with Stroke program. Each session involves a minimum of ten 'voluntary' tasks that are each practiced for about 2 minutes. Once the participant is comfortable doing the task, the physiotherapist provides a manual perturbation to cause the participant to lose balance with the intent of evoking a reactive step (see Section 3.3). Six external perturbations are provided per task such that there are 60 external perturbations per session; however, fewer perturbations may be performed if participant tolerance is low. Participants might also experience a loss of balance (i.e., internal perturbation) due to failure to properly control balance during the voluntary task. Intensity of the session is determined by participant response; the participant should successfully regain stability with 1 or 2 steps and no assistance from the physiotherapist or safety harness 50% of the time. If the participant is too 'successful', the level of challenge is increased, or vice versa.

3.2 Voluntary Tasks

Each session involves 'voluntary' tasks that progress along a mobility continuum to evoke internal perturbations (i.e., loss of balance or self-destabilization):

a) 'Stable' – the voluntary task is to maintain a static base of support;
b) 'Quasi-mobile' – the voluntary task is to move the feet (e.g., stepping forward with alternate feet); however, the participant remains in place;
c) 'Mobile' – the voluntary task is to move from one location to another (e.g., walking, side-stepping); and
d) 'Unpredictably mobile' – the voluntary task is to move from one location to another in an unpredictable manner (e.g., kicking a soccer ball).

The challenge of each voluntary task can be influenced by manipulating other factors, such as:

a) The sensory condition (e.g., firm to compliant surfaces, eyes open to eyes closed).
b) The cognitive requirements (e.g. single task to multi-task, counting backwards, moving on cue).
c) The environment (e.g., walking on even surface to walking over obstacles).

See "Description of Voluntary Tasks" in Section 5 for further information.

3.3 Methods of Perturbation

Internal perturbations are evoked when the participant attempts to perform a task that causes instability. Various voluntary tasks, including rapid 'agility' tasks (e.g., rapid step-ups) are used to evoke internal perturbations. A task that appears as easy as standing with eyes closed may cause an internal perturbation for a participant with poor balance control. However, some participants do not put themselves in situations causing a loss of balance or necessitating a stepping reaction (i.e., they will

perform agility tasks slowly); therefore, external perturbations are also included in every session to ensure a sufficient training dose.

External perturbations are caused by a force outside of the participant's control. Small-magnitude external perturbations may be used with participants who have lower functional abilities. It is usually easiest to start with perturbations that cause a fall towards the physiotherapist (i.e., pull or lean-and-release) so that the physiotherapist can control the outcome and alleviate participants' anxiety and facilitate participants' perceptions of safety. There are three methods for evoking external perturbations: 1) lean-and-release (predictable direction/magnitude; 2) push/pull (can be unpredictable in terms of direction and magnitude; or 3) trip during walking (see Section 5 for details).

3.4 Measurement

Measures are taken throughout the training to ensure: 1) focus on participant-specific problems; 2) ongoing progression; and 3) participant safety. The Perturbation Training Log (Section 4) is used to document the following:

- Performance on reactive stepping linked to key areas of focus (e.g., if a goal is to reduce frequency of multiple stepping then frequency of multiple stepping should be documented);
- Number of repetitions (i.e., number of times the participant experiences a loss of balance): '0' = balance recovered using 2 steps or fewer; '1' = balance recovered using more than 2 steps; and, 'X' = assistance provided by the safety harness or physiotherapist to recover balance;
- Additional tasks/conditions;
- Number of rest breaks;
- 'Rating of perceived challenge' (RPC) (Section 6);
- HR and/or BP (if indicated);

3.5 Format of training session

1) Participant arrives.
2) HR and BP are taken.
3) Warm-up is completed.
4) Harness is donned.
5) Tasks, as outlined in the Perturbation Training Log (Section 4), are performed for that particular session. Detailed descriptions of each task can be found in Section 5.
6) Documentation about and scoring of each task are completed before moving on to the next task.
7) Rest is taken as required, or after each task.
8) Cool-down and stretching are completed.

4. PERTURBATION TRAINING LOG

Participant ID: _____

Affected side of body: _____ **Does HR &/or BP need monitoring through session?** Y N

Harness size: _____ **Participant Equipment:** AFO AirsSport Arm Sling Other

Participant Goal(s):

_____

_____

Highlights of Assessment Findings:

CMSA stage (/7): Leg _____ Foot _____

Position Recognition (#correct/5): DF/PF _____ INV/EV _____

Light touch (#correct/5): _____

Berg balance scale (/56): _____

Mini-BES - Reactive Postural Control (/12): _____

TUG (sec): _____

Lean & Release – Preferred trials (#): Right _____ Left _____

Lean & Release – Encouraged use trials (#): Right _____ Left _____

Comments:

_____

Participant ID: _____ Date: _____

Treatment planning:

Area of dyscontrol	Treatment suggestions	Additional treatment strategies/comments
❑ Requires external assist to regain stability	❑ Start with low-magnitude perturbation, increase magnitude as tolerated ❑ Consider other problems that contribute, like delayed stepping or no stepping	
❑ Does not step when magnitude of perturbation requires a step	❑ Instruct participant to step when s/he feels unstable ❑ Start with low-magnitude perturbations ❑ Start with predictable time/direction of perturbation ❑ Practice the step prior to perturbation ❑ Consider other problems that contribute, like unwillingness to step with paretic limb	
❑ Has low foot clearance during step: foot 'slides', or shuffles	❑ Use obstacles to 'force' a step-over	
❑ Demonstrates delayed stepping reaction	❑ Instruct participant to step as quickly as possible ❑ Start with predictable time/direction of perturbation ❑ If delay is with non-paretic limb, have participant weight-shift to paretic limb prior to perturbation	

Area of dyscontrol	Treatment suggestions	Additional treatment strategies/comments
❑ Is unwilling to step with paretic limb	❑ Block the non-paretic limb with obstacles, or hand/ foot of physiotherapist ❑ Instruct participant to step with paretic limb ❑ Start with predictable time/direction of perturbation ❑ Time perturbation to coincide with paretic leg/foot being un-weighted	
❑ Demonstrates multi-step reactions	❑ Instruct participant to take as few steps as possible ❑ Instruct participant to take long(er) steps	
❑ Stands asymmetrically prior to perturbation	❑ Instruct participant to increase loading on the less-loaded limb ❑ Consider using video or feedback of stance symmetry	
❑ Takes short steps	❑ Instruct participant to take longer steps ❑ Step to targets ❑ Step over obstacles	
❑ Attempts to use upper extremity to regain stability	❑ Physiotherapist should stand as far away as safely possible ❑ Instruct to not use reach-to-grasp reactions ❑ Have participant hold object to prevent grasping	

Area of dyscontrol	Treatment suggestions	Additional treatment strategies/comments
❑ Falls laterally on step termination	❑ Instruct participant to take as few steps as possible ❑ Start with low-magnitude perturbation ❑ Try forward/backward perturbations initially with a narrow base of support	
❑ Uses 'crossover' steps to respond to lateral perturbations	❑ Instruct participant to use side-stepping strategy ❑ Place large obstacles in front and behind participant to deter cross-overs	
❑ Is unable to step equally well in all directions	❑ Use multi-directional perturbations ❑ Do more perturbations in the most challenging direction	

'Stable' tasks*: *session 1

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Standing still with feet hip-width apart	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, eyes closed	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, on a thin foam mat	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, on a thick foam pad	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, turning head left and right	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, looking up and down	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing with feet hip-width apart, counting backwards by 3's	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Standing with feet hip-width apart, eyes closed & counting backwards by 3's	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing with feet hip-width apart, rapid weight-shifting left and right	❑ Wide BOS	❑ Feet together	6 multi-directional push/pull				
Standing with feet hip-width apart, or in stride position, rapid weight-shifting forward and backward	❑ Wide BOS	❑ Feet together	6 multi-directional push/pull				
Standing with feet hip-width apart, throwing & catching a ball	❑ Wide BOS	❑ Feet together	internal				
Standing with feet hip-width apart, rapid arm raises forward and to the sides	❑ Wide BOS	❑ Feet together	internal				

HR: _____ BP: _____ ***Overall rating of perceived challenge:*** _____

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

_____

_____

_____

'Stable' tasks*: *Session 2

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Standing still with feet hip-width apart	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, eyes closed	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, on a thin foam mat	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, on a thick foam pad	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, turning head left and right	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, looking up and down	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing with feet hip-width apart, counting backwards by 3's	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing with feet hip-width apart, eyes closed & counting backwards by 3's	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing with feet hip-width apart, rapid weight-shifting left and right	❑ Wide BOS	❑ Feet together	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests During task	Rest After task (Y/N)
Standing with feet hip-width apart, or in stride position, rapid weight-shifting forward and backward	❑ Wide BOS	❑ Feet together	6 multi-directional push/pull				
Standing with feet hip-width apart, throwing & catching a ball	❑ Wide BOS	❑ Feet together	internal				
Standing with feet hip-width apart, rapid arm raises forward and to the sides	❑ Wide BOS	❑ Feet together	internal				
Rapid stepping forward with alternate feet	❑ Short steps	❑ Long steps	internal				
Rapid stepping backward with alternate feet	❑ Short steps	❑ Long steps	internal				
Rapid stepping to the right (right foot)	❑ Short steps	❑ Long steps	internal				
Rapid stepping to the left (left foot)	❑ Short steps	❑ Long steps	internal				

HR: _____ BP: _____ ***Overall rating of perceived challenge:*** _____

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Quasi-mobile' tasks: Session 3

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Rapid stepping forward with alternate feet	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid stepping backward with alternate feet	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid stepping to alternate sides	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid tap-ups forward with alternate feet	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				
Walking in place	❑ Feet barely off floor	❑ Knees to hip-height	6 multi-directional push/pull				
Rapid stepping forward with alternate feet, on a thin foam mat	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid stepping backward with alternate feet, on a thin foam mat	❑ Short steps	❑ Long steps	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Rapid stepping to alternate sides, on a thin foam mat	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid tap-ups forward with alternate feet, on a thin foam mat	❑ Low step Step Height: ____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				
Walking in place, on a thin foam mat	❑ Feet barely off floor	❑ Knees to hip-height	6 multi-directional push/pull				

HR: _____ BP: _____ ***Overall rating of perceived challenge*: _____**

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Quasi-mobile' tasks: Session 4

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Rapid stepping forward and backward with right foot	❑ Short steps; rest in stance	❑ Long steps	6 multi-directional push/pull				
Rapid stepping forward and backward with left foot	❑ Short steps; rest in stance	❑ Long steps	6 multi-directional push/pull				
Rapid tap-ups forward with alternate feet	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				
Rapid step-ups with alternate feet	❑ Low step Step Height: _____	❑ Unstable surface (e.g. dense foam)	6 multi-directional push/pull				
Rapid tap-ups to alternate sides	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				
Rapid stepping forward and backward with right foot, on a thin foam mat	❑ Short steps; rest in stance	❑ Long steps	6 multi-directional push/pull				
Rapid stepping forward and backward with left foot, on a thin foam mat	❑ Short steps; rest in stance	❑ Long steps	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Rapid tap-ups forward with alternate feet, on a thin foam mat	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				
Rapid step-ups with alternate feet, on a thin foam mat	❑ Low step Step Height: _____	❑ Unstable surface (e.g. dense foam)	6 multi-directional push/pull				
Rapid tap-ups to alternate sides, on a thin foam mat	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				

HR: _____ BP: _____ ***Overall rating of perceived challenge*: _____**

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Quasi-mobile' tasks: Session 5

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Rapid stepping forward and backward with right foot	❑ Short steps; rest in stance	❑ Long steps	6 multi-directional push/pull				
Rapid stepping forward and backward with left foot	❑ Short steps; rest in stance	❑ Long steps	6 multi-directional push/pull				
Rapid stepping to alternate sides	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid diagonal forward stepping with alternate feet	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Walking in place	❑ Feet barely off floor	❑ Knees to hip-height	6 multi-directional push/pull				
Walking in place, eyes closed	❑ Feet barely off floor	❑ Knees to hip-height	6 multi-directional push/pull				
Rapid stepping with alternate feet in random cued direction	❑ Short steps	❑ Long steps	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Rapid step-ups with alternate feet	❑ Low step Step Height: _____	❑ Unstable surface (e.g. dense foam)	6 multi-directional push/pull				
Rapid tap-ups forward with alternate feet	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				
Rapid tap-ups to alternate sides	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				

HR: _____ BP: _____ ***Overall rating of perceived challenge*: _____**

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Quasi-mobile' tasks: Session 6

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Rapid stepping forward with alternate feet	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid stepping backward with alternate feet	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid stepping to alternate sides	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Walking in place, eyes closed	❑ Feet barely off floor	❑ Knees to hip-height	6 multi-directional push/pull				
'Jogging' (or fast walking) in place	❑ Feet barely off floor	❑ Knees to hip-height	6 multi-directional push/pull				
Rapid diagonal forward stepping with alternate feet	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid stepping with alternate feet in random cued direction	❑ Short steps	❑ Long steps	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
'Jogging' (or fast walking) in place, on a thin foam mat	❑ Feet barely off floor	❑ Knees to hip-height	6 multi-directional push/pull				
Rapid diagonal forward stepping with alternate feet, on a thin foam mat	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid stepping with alternate feet in random cued direction, on a thin foam mat	❑ Short steps	❑ Long steps	6 multi-directional push/pull				

HR: _____ BP: _____ ***Overall rating of perceived challenge*: _____**

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Mobile' tasks: Session 7

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Walking forward	❑ Short steps; walk slowly	❑ Long steps; traffic light	6 multi-directional push/pull				
Walking forward, turning head left and right	❑ Short steps; walk slowly	❑ Long steps; traffic light	6 multi-directional push/pull				
Walking forward, looking up and down	❑ Short steps; walk slowly	❑ Long steps; traffic light	6 multi-directional push/pull				
Walking and stepping over obstacles	❑ Low/short obstacles Define: _____	❑ High/long obstacles Define: _____	6 multi-directional push/pull				
Forward braiding	❑ Walk on the line	❑ Step further across; long steps; traffic light	6 multi-directional push/pull				
Side stepping	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Turning on the spot (alternate between turning to the left and to the right)	❑ Turn slowly	❑ Turn quickly	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Turning on the spot with eyes closed (alternate between turning to the left and to the right)	❑ Turn slowly	❑ Turn quickly	6 multi-directional push/pull				
Turning on the spot, in cued direction	❑ Turn slowly	❑ Turn quickly	6 multi-directional push/pull				
Four square stepping	❑ Short steps	❑ Long steps	6 multi-directional push/pull				

HR: _____ BP: _____ ***Overall rating of perceived challenge*: _____**

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Mobile' tasks: Session 8

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Walking forward	❑ Short steps; walk slowly	❑ Long steps; traffic light	6 multi-directional push/pull				
Walking backward	❑ Short steps; walk slowly	❑ Long steps; traffic light	6 multi-directional push/pull				
Walking forward with eyes closed	❑ Short steps; walk slowly	❑ Long steps; walk quickly	6 multi-directional push/pull				
Tandem walking forward	❑ Not heel-toe; steps close to line	❑ Traffic light	6 multi-directional push/pull				
Side stepping	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Sideways braiding	❑ Steps not fully crossed	❑ Traffic light	6 multi-directional push/pull				
Side stepping over obstacles	❑ Low/short obstacles Define: _____	❑ High/long obstacles Define: _____	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Turning on the spot (alternate between turning to the left and to the right)	❑ Turn slowly	❑ Turn quickly	6 multi-directional push/pull				
Turning on the spot in cued direction	❑ Turn slowly	❑ Turn quickly	6 multi-directional push/pull				
Four square stepping	❑ Short steps	❑ Long steps	6 multi-directional push/pull				

HR: _____ BP: _____ ***Overall rating of perceived challenge*: _____**

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Mobile' Tasks: Session 9

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Walking forward on a thin foam mat	❑ Short steps; walk slowly	❑ Long steps; traffic light	6 multi-directional push/pull				
Walking backward on a thin foam mat	❑ Short steps; walk slowly	❑ Long steps; traffic light	6 multi-directional push/pull				
Side stepping on a thin foam mat	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Four square stepping on a thin foam mat	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Tandem walking forward	❑ Not heel-toe; steps close to line	❑ Traffic light	6 multi-directional push/pull				
Tandem walking backward	❑ Not heel-toe; steps close to line	❑ Traffic light	6 multi-directional push/pull				
Sideways braiding	❑ Steps not fully crossed	❑ Traffic light	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Turning on the spot with eyes closed (alternate between turning to the left and to the right)	❑ Turn slowly	❑ Turn quickly	6 multi-directional push/pull				
Forward braiding	❑ Walk on the line	❑ Step further across; long steps; traffic light	6 multi-directional push/pull				
Walking forward with eyes closed	❑ Short steps; walk slowly	❑ Long steps; walk quickly	6 multi-directional push/pull				

HR: _____ BP: _____ ***Overall rating of perceived challenge:*** _____

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Mobile' tasks: Session 10

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Tandem walking forward	❑ Not heel-toe; steps close to line	❑ Traffic light	6 multi-directional push/pull				
Tandem walking backward	❑ Not heel-toe; steps close to line	❑ Traffic light	6 multi-directional push/pull				
Forward braiding	❑ Walk on the line	❑ Step further across; long steps; traffic light	6 multi-directional push/pull				
Backward braiding	❑ Walk on the line	❑ Step further across; long steps; traffic light	6 multi-directional push/pull				
Tandem walking forward on a thin foam mat	❑ Not heel-toe; steps close to line	❑ Traffic light	6 multi-directional push/pull				
Tandem walking backward on a thin foam mat	❑ Not heel-toe; steps close to line	❑ Traffic light	6 multi-directional push/pull				
Forward braiding on a thin foam mat	❑ Walk on the line	❑ Step further across; long steps; traffic light	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Backward braiding on a thin foam mat	❑ Walk on the line	❑ Step further across; long steps; traffic light	6 multi-directional push/pull				
Sideways braiding on a thin foam mat	❑ Steps not fully crossed	❑ Traffic light	6 multi-directional push/pull				
Turning on the spot with eyes closed in cued direction	❑ Turn slowly	❑ Turn quickly	6 multi-directional push/pull				

HR: _____ BP: _____ ***Overall rating of perceived challenge*: _____**

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Mobile & Unpredictable' Tasks: Session 11

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Kicking soccer ball against wall	[none]	❑ Stand further from wall; kick outside BOS; kick with each leg	6 perturbations: PT attempts to take ball, nudges participant				
Throwing hand ball against a wall	❑ Large ball	❑ Small ball; stand further from wall; throw with each arm	6 perturbations: PT attempts to take ball, nudges participant				
Kicking soccer ball against wall, standing on a thin foam mat	[none]	❑ Stand further from wall; kick outside BOS; kick with each leg	6 perturbations: PT attempts to take ball, nudges participant				
Throwing hand ball against a wall, standing on a thin foam mat	❑ Large ball	❑ Small ball; stand further from wall; throw with each arm	6 perturbations: PT attempts to take ball, nudges participant				
Walking with sudden stops and changes in direction	❑ Walk slowly	❑ Walk quickly	6 multi-directional push/pull/trip				
Move to different corners of the room	❑ Walk slowly	❑ Walk quickly	6 multi-directional push/pull/trip				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Walking with sudden stops and changes in direction, obstacles around the room	❑ Walk slowly	❑ Walk quickly	6 multi-directional push/pull/trip				
Move to different corners of the room, obstacles around the room	❑ Walk slowly	❑ Walk quickly	6 multi-directional push/pull/trip				
Four square stepping to unpredictable cued direction	❑ Short steps	❑ Long steps	12 multi-directional push/pull/trip				
'Dodgeball'	❑ Ball thrown at upper body	❑ Ball thrown rapidly at feet	internal				

HR: _____ BP: _____ ***Overall rating of perceived challenge:*** _____

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Mobile & unpredictable' tasks: Session 12

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Kicking soccer ball back and forth with physiotherapist	❑ Within reach; kicked slowly	❑ Step to reach; kicked quickly	internal				
Throwing ball back and forth with physiotherapist	❑ Large ball; within reach	❑ Small ball; step to reach	internal				
Kicking soccer ball with physiotherapist, standing on a thin foam mat	❑ Within reach; kicked slowly	❑ Step to reach; kicked quickly	internal				
Throwing ball with physiotherapist, standing on a thin foam mat	❑ Large ball; within reach	❑ Small ball; step to reach	internal				
Walking with sudden stops and changes in direction	❑ Walk slowly	❑ Walk quickly	12 multi-directional push/pull/trip				
Move to different corners of the room	❑ Walk slowly	❑ Walk quickly	12 multi-directional push/pull/trip				
Walking with sudden stops and changes in direction, obstacles around the room	❑ Walk slowly	❑ Walk quickly	12 multi-directional push/pull/trip				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Move to different corners of the room, obstacles around the room	❑ Walk slowly	❑ Walk quickly	12 multi-directional push/pull/trip				
Four square stepping to unpredictable cued direction	❑ Short steps	❑ Long steps	12 multi-directional push/pull/trip				
'Dodgeball'	❑ Ball thrown at upper body	❑ Ball thrown rapidly at feet	internal				

HR: _____ BP: _____ ***Overall rating of perceived challenge:*** _____

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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Booster sessions

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Standing still with feet hip-width apart, eyes closed	❑ Wide base of support	❑ Feet together	6 multi-directional lean-and-release				
Rapid tap-ups forward with alternate feet	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				
Rapid tap-ups to alternate sides	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				
Rapid stepping with alternate feet in random cued direction	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Turning on the spot, in cued direction	❑ Turn slowly	❑ Turn quickly; eyes closed	6 multi-directional push/pull				
Side stepping/braiding	❑ Short steps	❑ Long steps; thin foam mat	6 multi-directional push/pull/trip				
Forward tandem/braiding	❑ Steps close to line	❑ Long steps; thin foam mat	6 multi-directional push/pull/trip				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Backward tandem/braiding	❑ Steps close to line	❑ Long steps; thin foam mat	6 multi-directional push/pull/trip				
Walking with sudden stops and changes in direction, obstacles around the room	❑ Walk slowly	❑ Walk quickly	6 multi-directional push/pull/trip				
Kicking soccer ball against wall	[none]	❑ Kick outside BOS; on thin foam mat	6 perturbations: PT attempts to take ball, nudges participant				

HR: _____ BP: _____ ***Overall rating of perceived challenge:*** _____

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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5. TASK DESCRIPTIONS

Types of external perturbations

1) Lean and release

a. Forward-directed lean-and-release perturbation. The participant stands facing the physiotherapist, leaning forward with some of his body weight supported by the physiotherapist. He should be leaning far enough forward that his shoulders and hips are ahead of his toes; however, smaller lean angles can be used with more impaired individuals. The physiotherapist's hands are on the participants' shoulders. At an unexpected time, the physiotherapist releases her hands and the participant starts to fall forward, requiring a step to regain stability. The goal is for the participant to take as few steps as possible to recover.

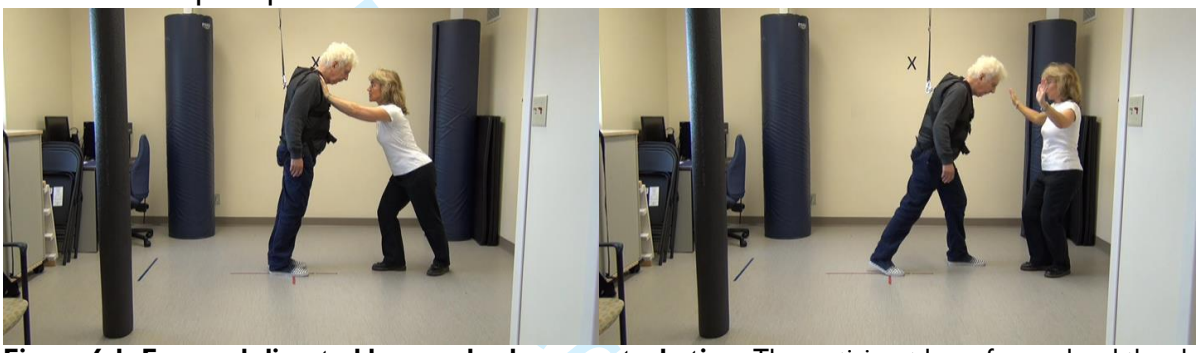


Figure 6.1. Forward-directed lean-and-release perturbation. The participant leans forward and the physiotherapist supports his weight (left). The physiotherapist releases her support and the participant steps to recover his balance (right).

b. Backward-directed lean-and-release perturbation. The participant stands in front of and facing away from the physiotherapist, leaning backward with some of his body weight supported by the physiotherapist. He should be leaning far enough backward that his shoulders and hips are behind his heels; however, smaller lean angles can be used with more impaired individuals. The physiotherapist's hands are on the participants' shoulders. At an unexpected time, the physiotherapist releases her hands and the participant starts to fall backward, requiring a step to regain stability. The goal is for the participant to take as few steps as possible to recover upright standing balance.

Figure 6.2. Backward-directed lean-and-release perturbation. The participant leans backward and the physiotherapist supports his weight (left). The physiotherapist releases her support and the participant steps to recover his balance (right).

c. Lateral-directed lean-and-release perturbation. The participant stands with his feet close together, leaning to the right (or left) with some of his body weight supported by the physiotherapist's hands. He should be leaning far enough to the right (or left) that the midline of the pelvis is aligned over the right (or left) foot; however, smaller lean angles can be used with more impaired individuals. The physiotherapist's hands are on the participant's right (or left) shoulder and

right (or left) hip. At an unexpected time, the physiotherapist releases her hands and the participant starts to fall to the right (or left), requiring a step to regain stability. The goal is for the participant to take as few steps as possible to recover balance.

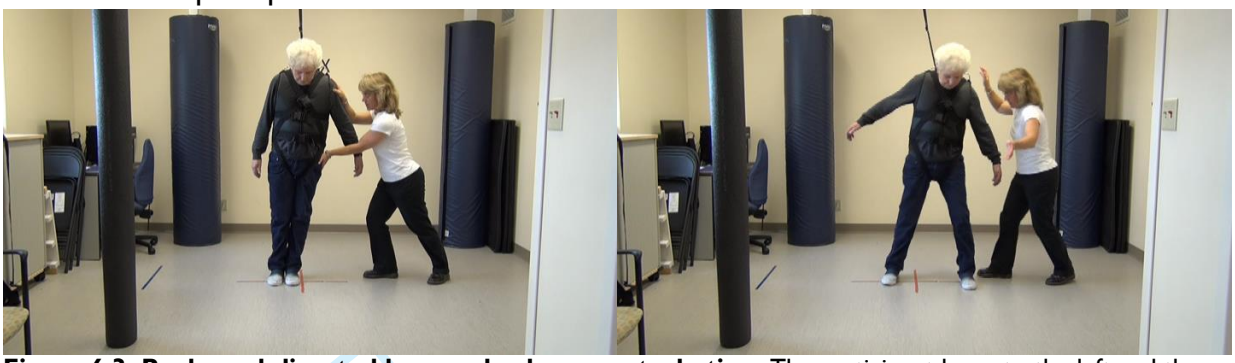


Figure 6.3. Backward-directed lean-and-release perturbation. The participant leans to the left and the physiotherapist supports his weight (left). The physiotherapist releases her support and the participant steps to recover his balance (right).

2) Multi-directional push/pull/trip

a. Multidirectional push. The physiotherapist places her hands on the participant's hips or shoulders and pushes him forward, requiring a reactive step to regain stability. Alternatively, one of the physiotherapist's hands could be on the hip and the other on the shoulder; a push forward at the level of one scapula would facilitate a diagonal reactive step. In all scenarios, the physiotherapist should be ready to assist with the recovery, if necessary, by having a light hold of the safety harness. The physiotherapist should only provide assistance if the participant is unable to regain stability independently; this is true with every reaction. Note that backward-directed pushes are not performed.

Figure 6.4. Forward-directed push perturbation. The physiotherapists' hands may be placed at the hips (top images) or with one hand on the hips and one on the shoulders.

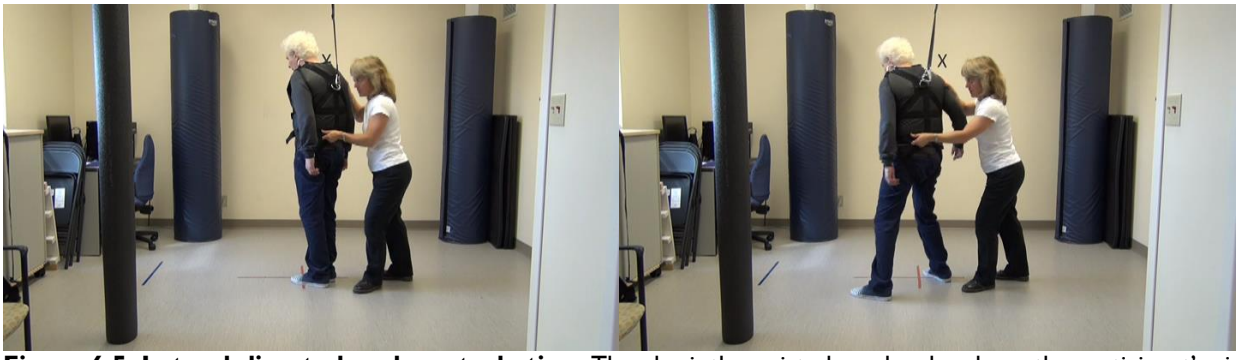


Figure 6.5. Lateral-directed push perturbation. The physiotherapist places her hands on the participant's right (or left) hip or shoulder and pushes him to the left (or right), requiring a reactive step to regain stability.

b. Multi-directional pull perturbation. The physiotherapist may pull the participant's shoulders or pull on the harness to cause the participant to start to fall forward, requiring a reactive step to regain stability.

Figure 6.6. Forward-directed pull perturbation. The physiotherapist places her hands on the participant's shoulders (top) or pulls on the harness (bottom).

Figure 6.7. Backward-directed pull perturbation. The physiotherapist uses the shoulders, hips, or harness to pull the participant backward, requiring a reactive step to regain stability.

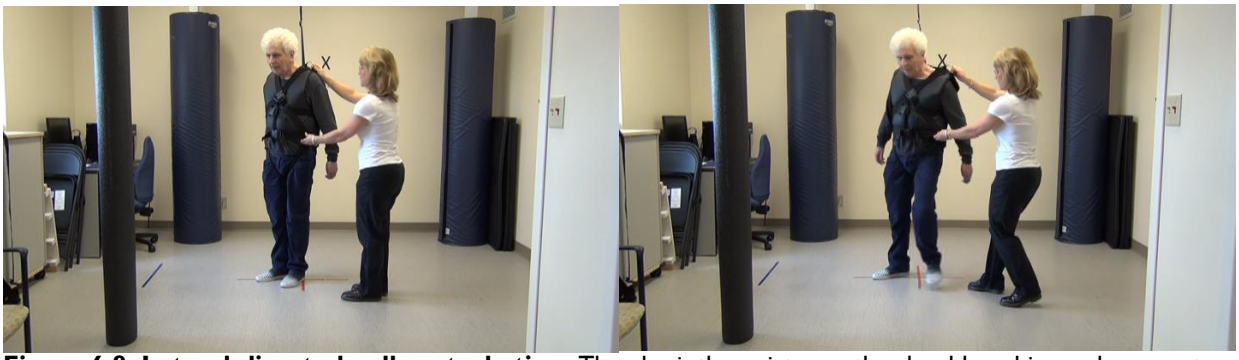


Figure 6.8. Lateral-directed pull perturbation. The physiotherapist uses the shoulders, hips or harness, to pull the participant to the right (or left), requiring a reactive step to regain stability.

c. Trip perturbation while walking. As the participant walks (forward, backward, sideways), the physiotherapist places her foot in the path of the swing limb causing a trip. A reactive step is required to regain stability. A second person is recommended in this scenario as it is difficult for the physiotherapist doing the tripping to be in a place to provide support should it be needed.

Figure 6.9. Trip perturbation. The physiotherapist catches the participants' limb with her foot while walking.

Descriptions of voluntary tasks

Standing still with feet hip-width apart – participant stands unassisted with the eyes open and the feet positioned as wide as the hips. The lean-and-release perturbations are performed in random directions (forward, backward and lateral).

Adaptation to reduce difficulty – have participant adopt a wider base of support (BOS)
Adaptation to increase difficulty – have participant stand with the feet together
Progressions of this task:
Eyes closed – if participant is unable, the lights in the room should be dimmed (alternatively, dark sunglasses may be worn)
Standing on a thin foam mat
Standing on a thick foam mat
Turning head to the right and left – to spot a target
Looking up and down – to spot a target
Counting backwards by 3's – from a random number given by physiotherapist
Eyes closed and counting backwards – as written above, but combined

Rapid weight-shifting left and right – participant shifts his body weight from one foot to the other as quickly as possible, and the feet remain in contact with the floor. The task is repeated until all perturbations are accomplished.

Adaptation to reduce difficulty – have participant adopt a wider BOS

Adaptation to increase difficulty – have participant stand with the feet together

Rapid weight-shifting forward and backward –participant stands with feet either 'side-by-side' or in a 'stride position' and shifts his body weight forward and backward; if feet are 'side-by-side' then body weight rocks from toes to heels and back; if feet are in stride then body weight transfers from one foot to the other as quickly as possible; part of each foot always remains in contact with the floor. The task is repeated until all perturbations are accomplished.

Adaptation to reduce difficulty –have participant adopt a wider BOS, with the feet either side-by-side or in stride

Adaptation to increase difficulty – have participant stand with the feet together (if side-by-side) or with the feet in tandem (if in stride position)

Throwing and catching a ball – if the participant has use of both arms he should catch and throw a ball back and forth with the physiotherapist; if the participant has functional use of only one arm he should hit a ball back that has been thrown by the physiotherapist.

Adaptation to reduce difficulty – have participant adopt a wider BOS

Adaptation to increase difficulty – have participant stand with the feet together

Rapid arm raises forward and to the sides – participant raises one arm, then both arms, to 90 degrees of shoulder flexion as quickly as possible and stops as quickly as possible; participant raises two arms, then one arm at a time, to 90 degrees of shoulder abduction as quickly as possible and stops as quickly as possible.

Adaptation to reduce difficulty – have participant adopt a wider BOS

Adaptation to increase difficulty – have participant stand with the feet together

Rapid stepping forward with alternate feet – participant steps forward as quickly as possible with the right foot then returns it to the starting position, then steps forward as quickly as possible with the left foot, and then returns it to the starting position; there should be a transfer of body weight to the stepping foot once it touches down in the forward position. The task is repeated until all perturbations are accomplished.

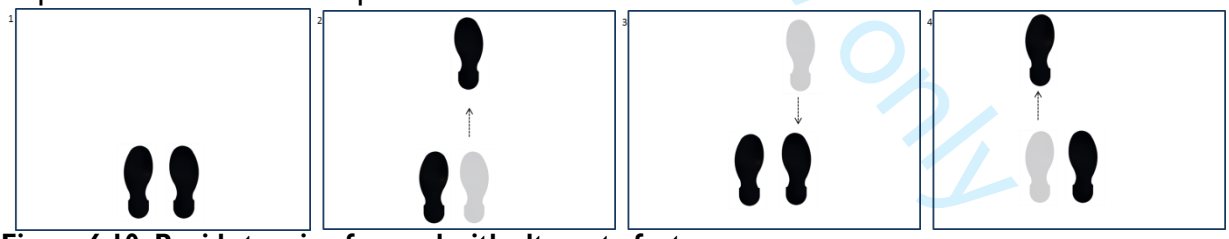


Figure 6.10. Rapid stepping forward with alternate feet

Adaptation to reduce difficulty – have participant take short steps

Adaptation to increase difficulty – have participant take long steps

Progressions of this task:

Standing on a thin foam mat

Rapid stepping backward with alternate feet – participant steps backward as quickly as possible with the right foot, then returns it to the starting position, then steps backward as quickly as possible with the left foot, and then returns it to the starting position; there should be a transfer of body weight to the stepping foot once it touches down in the backward position. The task is repeated until all perturbations are accomplished.

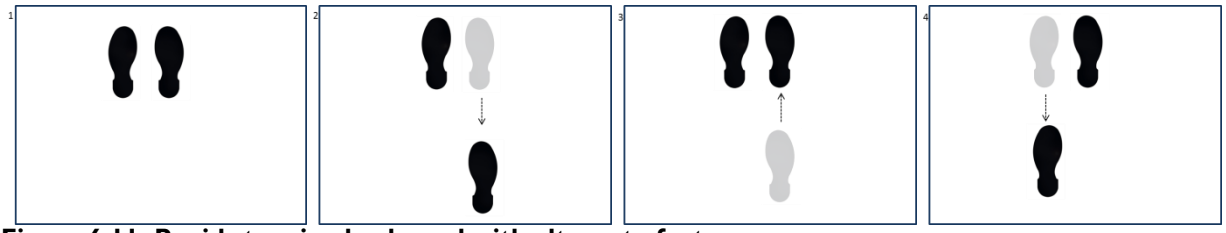


Figure 6.11. Rapid stepping backward with alternate feet

Adaptation to reduce difficulty – have participant take short steps
Adaptation to increase difficulty – have participant take long steps
Progressions of this task:
Standing on a thin foam mat

Rapid stepping to the right (right foot) – participant steps with the right foot to the right as quickly as possible, then back to the starting position; there should be transfer of body weight to the right foot once it touches down in the lateral position. The task is repeated until all perturbations are accomplished.

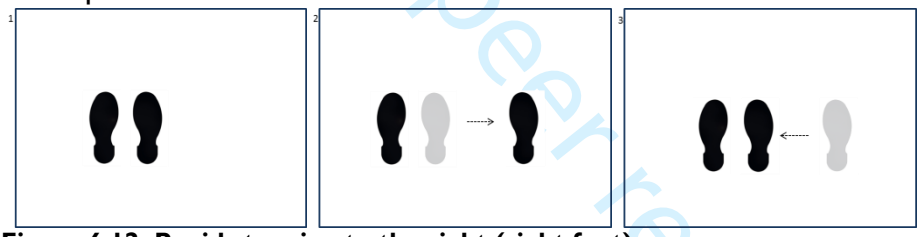


Figure 6.12. Rapid stepping to the right (right foot)

Adaptation to reduce difficulty – have participant take short steps
Adaptation to increase difficulty – have participant take long steps

Rapid stepping to the left (left foot) – participant steps with the left foot to the left as quickly as possible, then back to the starting position; there should be transfer of body weight to the left foot once it touches down in the lateral position. The task is repeated until all perturbations are accomplished.

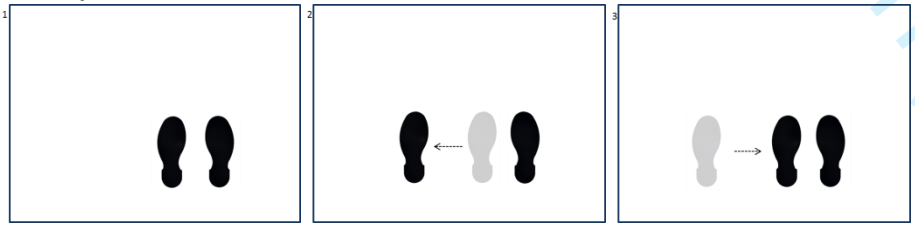


Figure 6.13. Rapid stepping to the left (left foot)

Adaptation to reduce difficulty – have participant take short steps
Adaptation to increase difficulty – have participant take long steps

Rapid stepping to alternate sides– participant steps with the right foot to the right as quickly as possible (including body weight transfer), then back to the starting position; then he steps with the left foot to the left as quickly as possible (including body weight transfer), then back to the starting position. The task is repeated until all perturbations are accomplished.

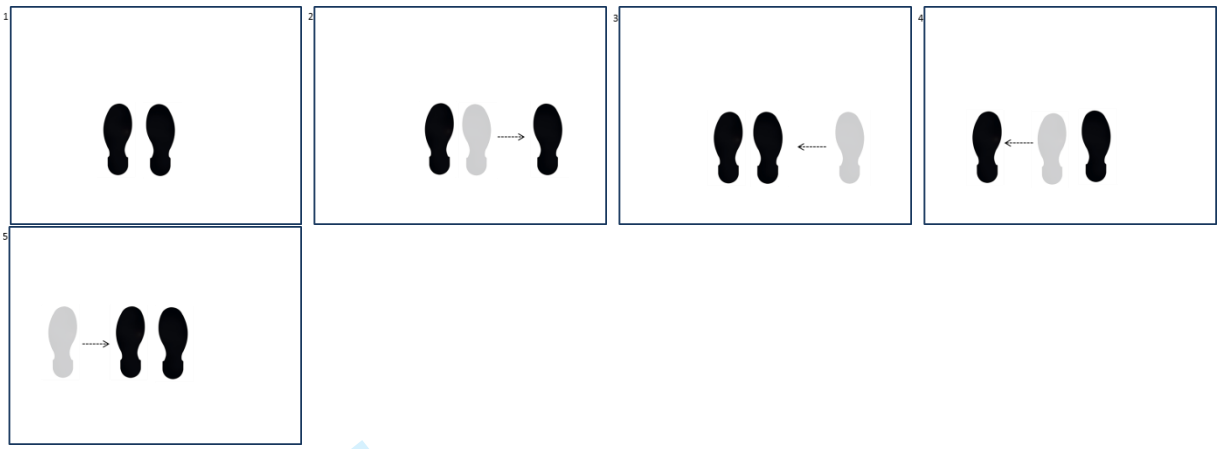


Figure 6.14. Rapid stepping to alternate sides

Adaptation to reduce difficulty – have participant take short steps
Adaptation to increase difficulty – have participant take long steps
Progressions of this task:
Standing on a thin foam mat

Rapid tap-ups forward with alternate feet – participant stands with a step in front of his feet; he lifts up the right foot and lightly touches the step, then places it back on the floor; then he lifts up the left foot and lightly touches the step, then places it back on the floor. The goal is to maintain the body weight over the stance limb, i.e. no transfer of body weight forward. The task is repeated until all perturbations are accomplished.

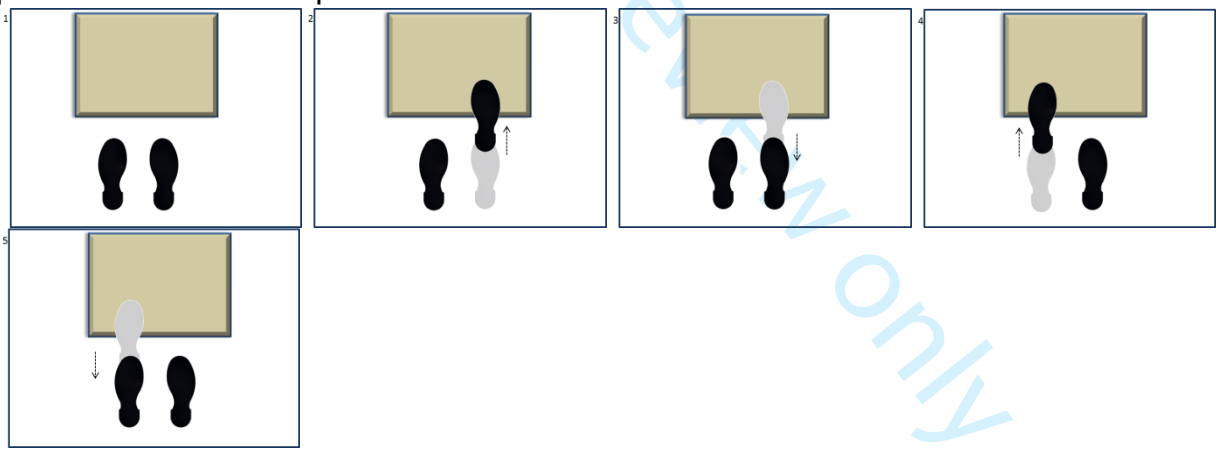


Figure 6.15. Rapid tap-ups forward with alternate feet

Adaptation to reduce difficulty – have participant tap-up to a low step
Adaptation to increase difficulty – have participant tap-up to an unstable surface, e.g. a soccer ball
Progressions of this task:
Standing on a thin foam mat

Walking in place – participant alternates stepping with the right and the left foot. The participant should not move from the spot, though a small amount of 'drift' is typical. The task is repeated until all perturbations are accomplished.

Adaptation to reduce difficulty – have participant step with minimal height from floor

Adaptation to increase difficulty – have participant step with maximum height from floor, i.e. knees raised to hip-height

Progressions of this task:

Walking on the spot on a thin foam mat

Eyes closed – if participant is unable, the lights in the room should be dimmed

Increased speed to 'jogging', or fast walking, on the spot

Jogging, or fast walking, on the spot on a thin foam mat

Rapid stepping forward and backward with the right foot – participant shifts his body weight to the left foot and then steps forward with the right foot, shifting some body weight forward but not enough to completely unweight the left; then the participant shifts his body weight back to the left foot in order to take a full step as far backward as possible with the right foot, and accepts some body weight on the right. The task is repeated until all perturbations are accomplished.

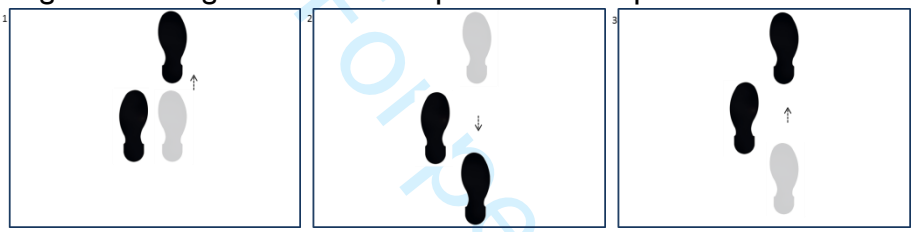


Figure 6.16. Rapid stepping forward and backward with the right foot

Adaptations to reduce difficulty – have participant take short steps; have participant rest momentarily between transitioning from front to back or from back to front

Adaptation to increase difficulty – have participant take long steps

Progressions of this task:

Standing on a thin foam mat

Rapid stepping forward and backward with the left foot – participant shifts his body weight to the right foot and then steps forward with the left foot, shifting some body weight forward but not enough to completely unweight the right; then the participant shifts his body weight back to the right foot in order to take a full step as far backward as possible with the left foot, and accepts some body weight on the left. The task is repeated until all perturbations are accomplished.

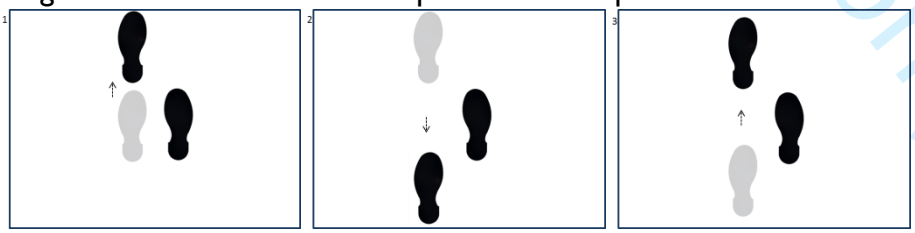


Figure 6.17. Rapid stepping forward and backward with the left foot

Adaptations to reduce difficulty – have participant take short steps; have participant rest momentarily between transitioning from front to back or from back to front

Adaptation to increase difficulty – have participant take long steps

Progressions of this task:

Standing on a thin foam mat

Rapid step-ups with alternate feet - participant stands with a step in front of his feet; he steps up onto the step with the right foot, shifts his body weight forward and steps up with the left foot, placing it on the step in a comfortably-wide position; then he steps down with the right foot, shifts his

body weight back onto the right foot and steps down with the left. The process is repeated with the right foot leading until 3 perturbations are completed; then the left leads until the final 3 perturbations are completed.

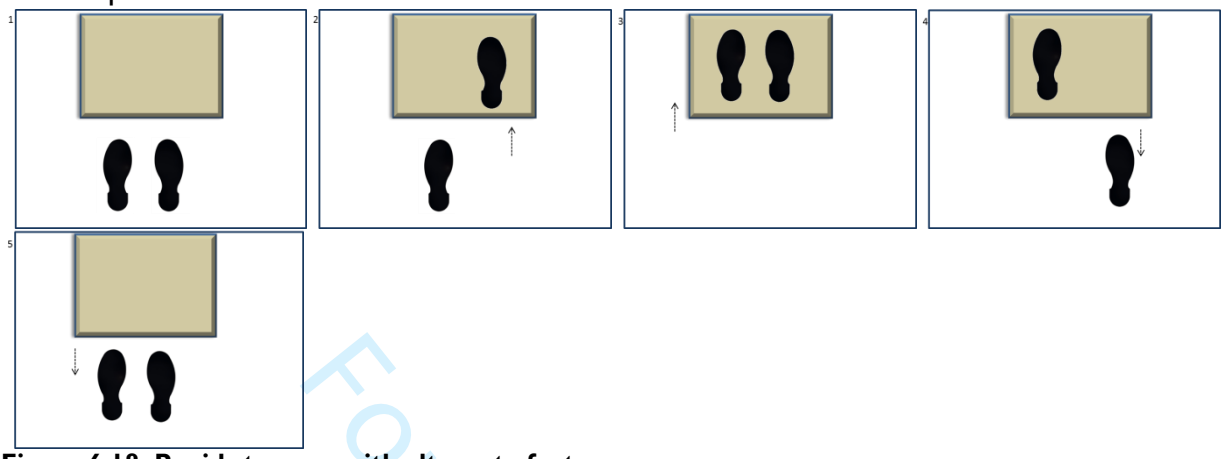


Figure 6.18. Rapid step-ups with alternate feet

Adaptation to reduce difficulty – have participant step-up to a low step
Adaptation to increase difficulty – have participant step-up to an unstable surface, for e.g., a step placed on a thin foam mat, or thick foam pad
Progressions of this task:
Standing on a thin foam mat – i.e. the person is standing on the mat, but the step may be on a hard surface, depending on the adaptation for difficulty

Rapid tap-ups to alternate sides – participant stands with a step lateral to each foot; he lifts up the right foot and lightly touches the step on the right, then places it back on the floor; then lifts up the left foot and lightly touches the step on the left, then places it back on the floor. The goal is to maintain the body weight over the stance limb, i.e., no transfer of body weight to the side tapping-up. The task is repeated until all perturbations are accomplished.

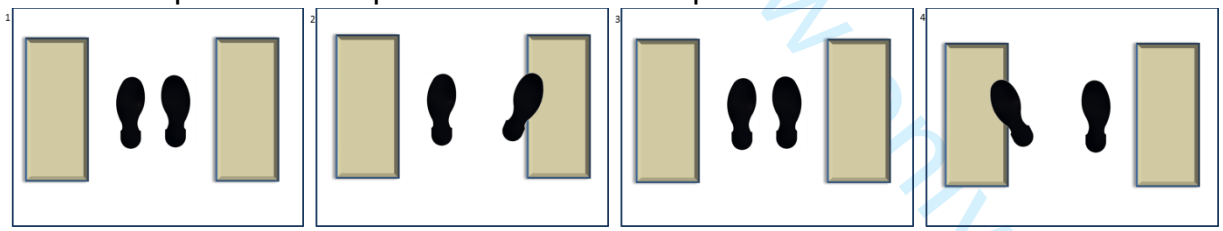


Figure 6.19. Rapid tap-ups to alternate sides

Adaptation to reduce difficulty – have participant tap-up to a low step
Adaptation to increase difficulty – have participant tap-up to an unstable surface, e.g. a soccer ball
Progressions of this task:
Standing on a thin foam mat – i.e. the person is standing on the mat, but the step/obstacle may be on a hard surface, depending on the adaptation for difficulty

Rapid diagonal forward stepping with alternate feet – participant steps diagonally forward (a 45° angle) as quickly as possible with the right foot, then returns it to the starting position, then steps diagonally forward as quickly as possible with the left foot, then returns it to the starting position; there should be a transfer of body weight to the stepping foot once it touches down in the diagonal position. The task is repeated until all perturbations are accomplished.

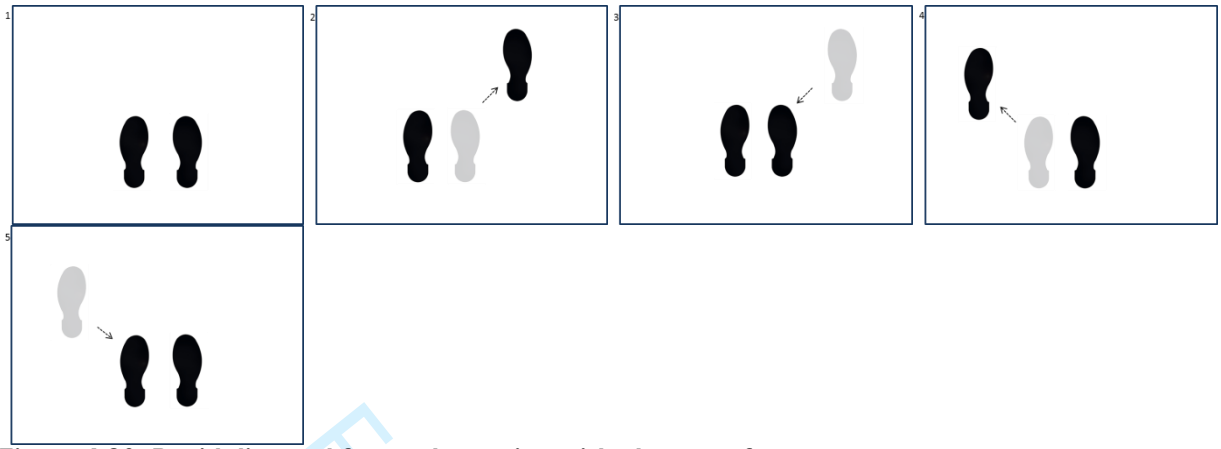


Figure 6.20. Rapid diagonal forward stepping with alternate feet

Adaptation to reduce difficulty – have participant take short steps
Adaptation to increase difficulty – have participant take long steps
Progressions of this task:
Standing on a thin foam mat

Rapid stepping with alternate feet in random physiotherapist-cued directions – participant stands in the centre of 6 targets placed on the floor (e.g., different colored Agility Dots); physiotherapist calls out a color and the participant steps to the colored dot with one foot (transferring some body weight) and then returns that foot to the centre; the process repeats with the next randomly called color. The task is repeated until all perturbations are accomplished.

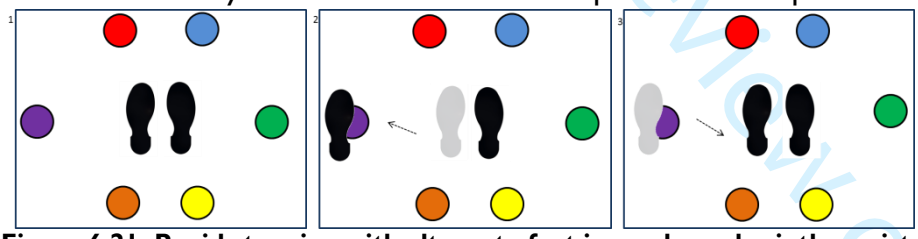


Figure 6.21. Rapid stepping with alternate feet in random physiotherapist-cued directions

Adaptation to reduce difficulty – targets require short steps
Adaptation to increase difficulty – targets require long steps
Progressions of this task:
Standing on a thin foam mat

Walking forward – participant takes steps to travel in a forward direction. Walking continues until all perturbations are accomplished.

Adaptations to reduce difficulty – have participant take short steps, or walk slowly
Adaptation to increase difficulty – have participant take long steps; traffic light*
Progressions of this task:
Turning head to the right and left – to spot a target
Looking up and down – to spot a target
Stepping over obstacles –e.g. pool noodles

* Traffic Light = participant walks at a fast pace like he would if crossing a street; physiotherapist counts down like the traffic light would in the crosswalk

Eyes closed – if participant is unable, the lights in the room should be dimmed
Walking on a thin foam mat

Forward braiding – participant takes a step forward with the right foot that crosses the midline path and lands lateral to, and slightly ahead of, the left foot; then he brings the left foot out and around the right foot, taking a step across the midline path that lands lateral to, and slightly ahead of, the right foot; then the process repeats until all perturbations are accomplished.

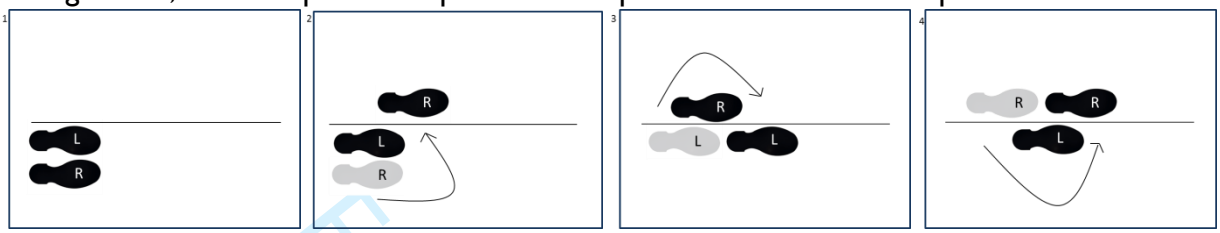


Figure 6.22. Forward braiding

Adaptation to reduce difficulty – walk on the line
Adaptations to increase difficulty - increase distance of step across line; take bigger steps; increase the walking speed
Progressions of this task:
Walking on a thin foam mat

Side stepping – participant stands on left side of room; he takes a step to the right with the right foot, followed by a step to the right (medially) with the left foot; the stepping continues until the edge of the room/available space is reached; then, starting from the right side of the room, he will walk in the opposite direction – left foot steps to left, followed by right foot stepping to left. Stepping continues until all perturbations are accomplished.

Figure 6.23. Side stepping

Adaptation to reduce difficulty – have participant take short steps
Adaptation to increase difficulty – have participant take long steps
Progressions of this task:
Stepping over obstacles –e.g. pool noodles
Walking on a thin foam mat

Turning on the spot, alternating to the right and left – participant takes steps to turn continuously in a clockwise direction. After a few turns (or 3 perturbations) the participant changes direction and turns counter-clockwise (until the final 3 perturbations are completed).

Adaptation to reduce difficulty – have participant turn slowly
Adaptations to increase difficulty – have participant turn quickly
Progressions of this task:
Eyes closed – if participant is unable, the lights in the room should be dimmed
Cued direction – physiotherapist calls out 'right' or 'left' and the participant turns in the direction called; it may be the same direction or a change in direction
Cued and Eyes closed – as written above but combined

Four square stepping – using tape, a cross is marked out on the floor creating 4 squares; participant stands in the bottom right-hand square facing forward; he is asked to step forward over the line with one foot then the other into the top right-hand square; then to step sideways, over the tape with the left foot and then the right into the top left-hand square; then to step backwards with one foot and then the other into the bottom left-hand square; and then finally, to step sideways with the right foot, then the left into the bottom right-hand square. He does that pattern a few times (or 3 perturbations) and then switches directions, moving in a clockwise pattern (until the final 3 perturbations are completed).

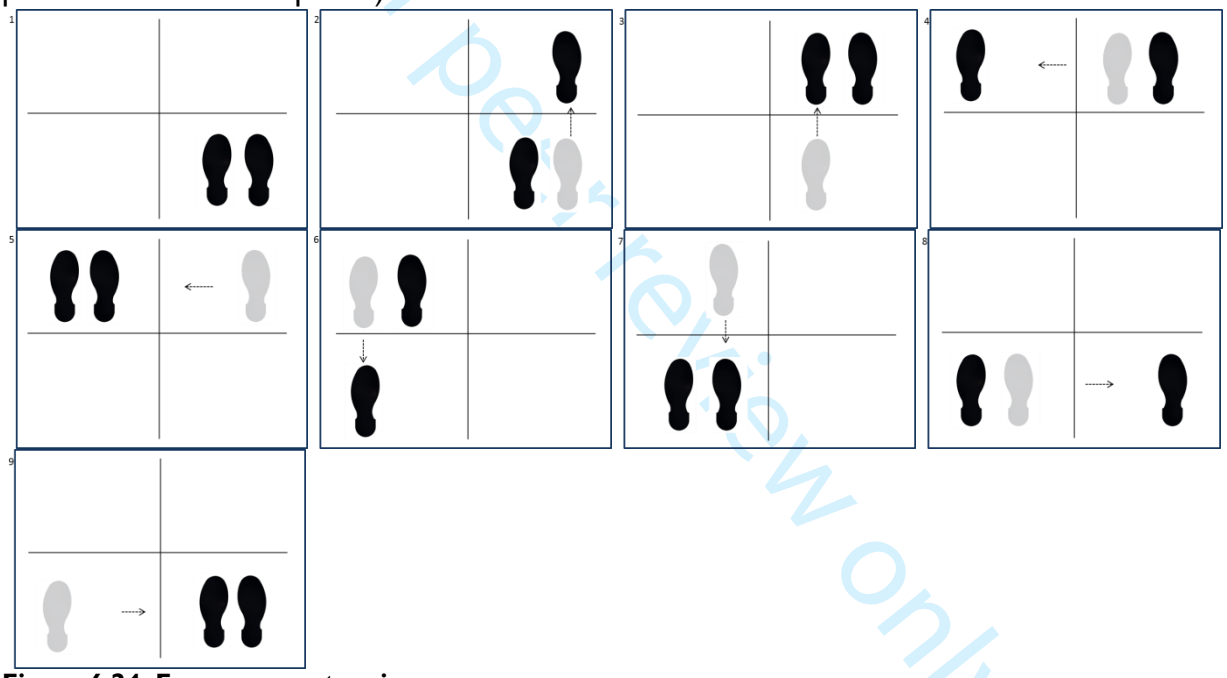


Figure 6.24. Four square stepping

Adaptation to reduce difficulty – have participant take short steps over the lines
Adaptation to increase difficulty – have participant take long steps over the lines
Progressions of this task:
Stepping on a thin foam mat
Cued direction – physiotherapist calls out 'change' or 'switch' and the participant begins moving in the opposite direction

Walking backward – participant takes steps to travel in a backward direction. Walking continues until all perturbations are accomplished.
Adaptation to reduce difficulty – have participant take short steps, or walk slowly
Adaptation to increase difficulty – have participant take long steps; traffic light
Progressions of this task:
Walking on a thin foam mat

Tandem walking forward - participant takes a step forward with the right foot and places the right heel ahead of the left toes; then he brings the left foot out and around the right foot, and places the left heel ahead of the right toes; then the process repeats until all perturbations are completed.

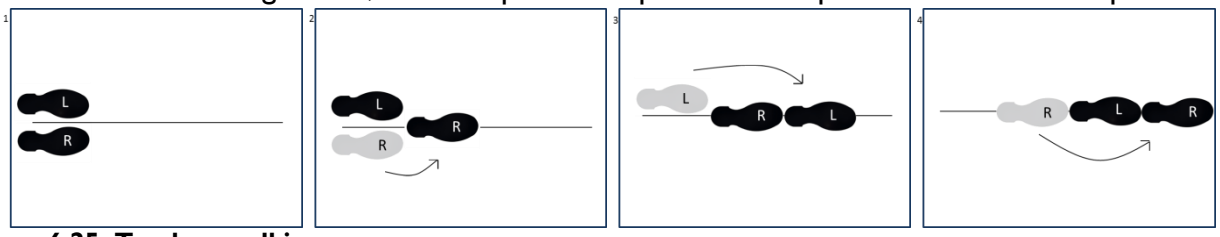


Figure 6.25. Tandem walking

Adaptations to reduce difficulty – participant takes longer steps (i.e. heel and toes don't touch) or participant places feet close to the line but not on the line
Adaptation to increase difficulty – traffic light
Progressions of this task:
Walking on a thin foam mat

Sideways braiding – participant stands at the right edge of the room; he is asked to walk to the left; he takes a step with the right foot that crosses over the left foot and lands lateral to, and slightly ahead of, the left foot, with part of his foot on the midline; then he brings the left foot out from behind the right and steps to the left, landing on the midline; then he takes a step with the right foot that crosses behind the left foot and lands lateral to, and slightly behind, the left foot, with part of his foot on the midline; then he takes the left foot over the right foot and steps to the left; and then the process repeats until he walks as far as he possibly can within the available space. Then he is asked to do the opposite and walk to the right. This pattern continues until all perturbations are accomplished.

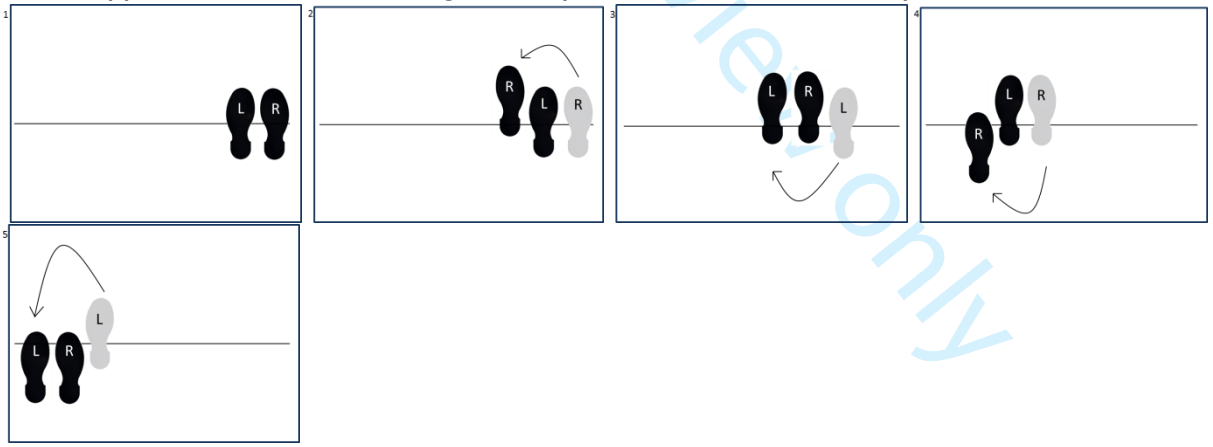


Figure 6.26. Sideways braiding

Adaptations to reduce difficulty – participant's foot does not fully cross over or behind the stance foot; or, participant's foot crosses but does not come into contact with midline
Adaptation to increase difficulty – traffic light
Progressions of this task:
Walking on a thin foam mat

Tandem walking backward - participant takes a step backward with the right foot and places the right toes behind the left heel; then he brings the left foot out and around the right foot, and places the left toes behind the right heel; then the process repeats until all perturbations are completed.

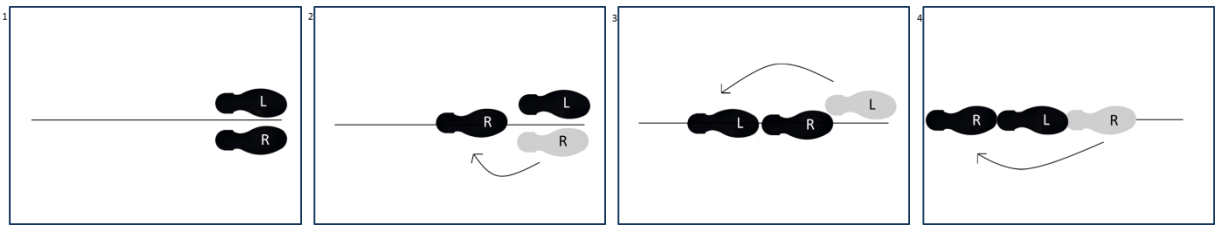


Figure 6.27. Tandem walking backward

Adaptations to reduce difficulty – participant takes longer steps (i.e. heel and toes don't touch) or participant places feet close to the line but not on the line
Adaptation to increase difficulty – traffic light
Progressions of this task:
Walking on a thin foam mat

Backward braiding – participant takes a step backward with the right foot that crosses the midline path and lands lateral to, and slightly behind, the left foot; then he brings the left foot out and around the right foot, taking a step backwards across the midline path that lands lateral to, and slightly behind, the right foot; then the process repeats until all perturbations are accomplished.

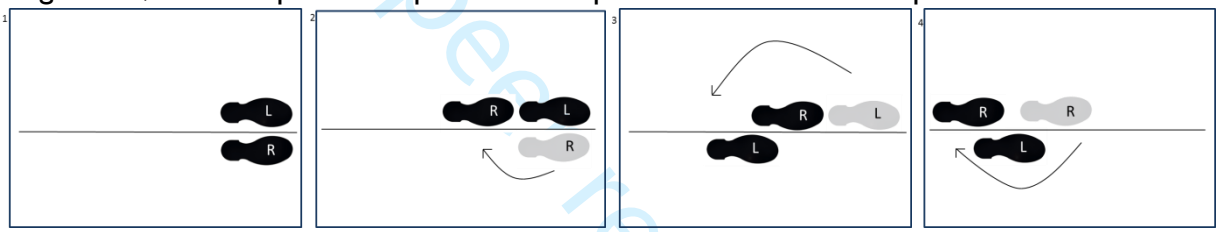


Figure 6.28. Backward braiding

Adaptation to reduce difficulty – walking on the line
Adaptations to increase difficulty - increase distance of step across line; take longer steps; traffic light
Progressions of this task:
Walking on a thin foam mat

Kicking a soccer ball against wall – participant stands at least 1 metre away from a wall; he kicks a soccer ball with enough force that it bounces back to him from the wall; he receives the ball and kicks it again. The task is repeated until all perturbations are accomplished.

Adaptation to reduce difficulty – none
Adaptations to increase difficulty – have participant stand further away from the wall; have participant kick it outside of his base of support; have participant alternate kicking with each foot
Progressions of this task:
Standing on a thin foam mat
Kicking the ball to the physiotherapist and receiving it back; this may require moving to reach the ball
Kicking the ball with the physiotherapist while standing on a thin foam mat

Throwing a handball against the wall – participant stands at least 1 metre away from a wall; he throws a hand ball with enough force that it bounces back to him from the wall; he receives the ball and throws it again. The task is repeated until all perturbations are accomplished.

Adaptation to reduce difficulty – have participant throw a large ball

Adaptations to increase difficulty – have participant throw a small ball; have participant stand further away from the wall; have participant throw the ball with each arm

Progressions of this task:

Standing on a thin foam mat

Throwing the ball to the physiotherapist and receiving it back; this may require moving to catch it

Throwing the ball with the physiotherapist while standing on a thin foam mat

Walking with sudden stops and changes in direction – participant walks forward and at any time, the physiotherapist says 'stop', and the participant has to stop walking quickly, or says 'right' ('left'), and the participant has to turn to the right (left) and continue walking. The task continues until all perturbations are accomplished.

Adaptation to reduce difficulty – have participant walk slowly

Adaptation to increase difficulty – have participant walk quickly

Progressions of this task:

Stepping over obstacles, e.g. pool noodles or steps – the participant has to walk in the frame and manage the obstacles while also stopping or changing direction on command

Move to different corners of the room – participant stands in the centre of the room facing forward; he is asked to move to one corner of the room (marked with different colored Agility Dots or numbers); he walks forward to the corners in front of him, then backward to return to the start position, or he walks backward to the corners behind him, then forward to return to the start position. The task continues until all perturbations are accomplished.

Adaptation to reduce difficulty – have participant walk slowly

Adaptation to increase difficulty – have participant walk quickly

Progressions of this task:

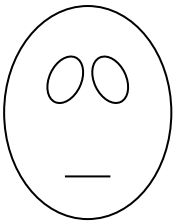
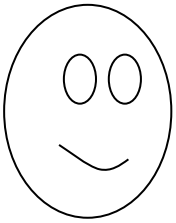
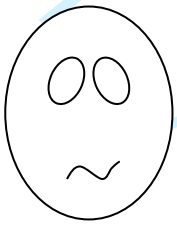
Stepping over obstacles, e.g. pool noodles or steps – the participant has to walk in the frame and manage the obstacles while making his way to the correct pole

Dodgeball – the participant must avoid being hit by the ball that is being thrown at him by the physiotherapist. This requires transfer of weight and reactive stepping.

Adaptation to reduce difficulty – physiotherapist throws ball at upper body

Adaptation to increase difficulty – physiotherapist throws ball rapidly at participant's feet

6. RATING OF PERCEIVED CHALLENGE SCALE

NO CHALLENGE AT ALL		1
A LITTLE BIT OF CHALLENGE		2
SOME CHALLENGE		3
MUCH CHALLENGE		4
CAN NOT DO		5

ADAPTED FROM: DARTHMOUTH COOP FUNCTIONAL ASSESSMENT CHARTS / WONCO (World Organization of Family Doctors) 1995

CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	
	2b	Specific objectives or hypotheses	
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	
Participants	4a	Eligibility criteria for participants	
	4b	Settings and locations where the data were collected	
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	
	6b	Any changes to trial outcomes after the trial commenced, with reasons	
Sample size	7a	How sample size was determined	
	7b	When applicable, explanation of any interim analyses and stopping guidelines	
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those	

		assessing outcomes) and how	
	11b	If relevant, description of the similarity of interventions	
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	
	13b	For each group, losses and exclusions after randomisation, together with reasons	
Recruitment	14a	Dates defining the periods of recruitment and follow-up	
	14b	Why the trial ended or was stopped	
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	
Other information			
Registration	23	Registration number and name of trial registry	
Protocol	24	Where the full trial protocol can be accessed, if available	
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.

TIDieR Template for Intervention Description and Replication

The TIDieR (Template for Intervention Description and Replication) Checklist*:

Information to include when describing an intervention and the location of the information

Item number	Item	Where located **	
		Primary paper (page or appendix number)	Other † (details)
	BRIEF NAME		
1.	Provide the name or a phrase that describes the intervention.		
	WHY		
2.	Describe any rationale, theory, or goal of the elements essential to the intervention.		
	WHAT		
3.	Materials: Describe any physical or informational materials used in the intervention, including those provided to participants or used in intervention delivery or in training of intervention providers. Provide information on where the materials can be accessed (e.g. online appendix, URL).		
4.	Procedures: Describe each of the procedures, activities, and/or processes used in the intervention, including any enabling or support activities.		
	WHO PROVIDED		
5.	For each category of intervention provider (e.g. psychologist, nursing assistant), describe their expertise, background and any specific training given.	∞	
	HOW		
6.	Describe the modes of delivery (e.g. face-to-face or by some other mechanism, such as internet or telephone) of the intervention and whether it was provided individually or in a group.	∞	
	WHERE		
7.	Describe the type(s) of location(s) where the intervention occurred, including any necessary infrastructure or relevant features.	∞	

	WHEN and HOW MUCH		
8.	Describe the number of times the intervention was delivered and over what period of time including the number of sessions, their schedule, and their duration, intensity or dose.		
	TAILORING		
9.	If the intervention was planned to be personalised, titrated or adapted, then describe what, why, when, and how.		
	MODIFICATIONS		
10.‡	If the intervention was modified during the course of the study, describe the changes (what, why, when, and how).	n/a	
	HOW WELL		
11.	Planned: If intervention adherence or fidelity was assessed, describe how and by whom, and if any strategies were used to maintain or improve fidelity, describe them.	8, 13	
12.‡	Actual: If intervention adherence or fidelity was assessed, describe the extent to which the intervention was delivered as planned.	13	

** **Authors** - use N/A if an item is not applicable for the intervention being described. **Reviewers** – use '?' if information about the element is not reported/not sufficiently reported.

† If the information is not provided in the primary paper, give details of where this information is available. This may include locations such as a published protocol or other published papers (provide citation details) or a website (provide the URL).

‡ If completing the TIDieR checklist for a protocol, these items are not relevant to the protocol and cannot be described until the study is complete.

* We strongly recommend using this checklist in conjunction with the TIDieR guide (see *BMJ* 2014;348:g1687) which contains an explanation and elaboration for each item.

* The focus of TIDieR is on reporting details of the intervention elements (and where relevant, comparison elements) of a study. Other elements and methodological features of studies are covered by other reporting statements and checklists and have not been duplicated as part of the TIDieR checklist. When a **randomised trial** is being reported, the TIDieR checklist should be used in conjunction with the CONSORT statement (see www.consort-statement.org) as an extension of **Item 5 of the CONSORT 2010 Statement.** When a **clinical trial protocol** is being reported, the TIDieR checklist should be used in conjunction with the SPIRIT statement as an extension of **Item 11 of the SPIRIT 2013 Statement** (see www.spirit-statement.org). For alternate study designs, TIDieR can be used in conjunction with the appropriate checklist for that study design (see www.equator-network.org).

BMJ Open

Does perturbation-based balance training prevent falls among individuals with chronic stroke? A randomized controlled trial.

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Manuscript ID	bmjopen-2018-021510.R1
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Date Submitted by the Author:	06-Jun-2018
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Primary Subject Heading:	Rehabilitation medicine
Secondary Subject Heading:	Sports and exercise medicine, Cardiovascular medicine, Geriatric medicine, Neurology
Keywords:	Stroke < NEUROLOGY, REHABILITATION MEDICINE, Exercise, Physiotherapy, Accidentaly falls, Postural balance

Title: Does perturbation-based balance training prevent falls among individuals with chronic stroke? A randomized controlled trial.

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Word count: 4,365

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Mann and Andrew Huntley for assistance with data processing, and Cynthia Campos for assistance with creating the training manual.

ABSTRACT (word count: 300; max: 300)

Objectives: No intervention has been shown to prevent falls post-stroke. We aimed to determine if perturbation-based balance training (PBT) can reduce falls in daily life among individuals with chronic stroke.

Design: Assessor-blinded randomized controlled trial.

Setting: Two academic hospitals in an urban area.

Interventions: Participants were allocated using stratified blocked randomization to either 'traditional' balance training (control) or PBT. PBT focused on improving responses to instability, whereas traditional balance training focused on maintaining stability during functional tasks. Training sessions were 1 hour twice/week for 6 weeks. Participants were also invited to complete 2 'booster' training sessions during the follow-up.

Participants: Eighty-eight participants with chronic stroke (>6-months post-stroke) were recruited and randomly allocated one of the two interventions. Five participants withdrew; 42 (control) and 41 (PBT group) were included in the analysis.

Primary and secondary outcome measures: The primary outcome was rate of falls in the 12-months post-training. Negative binomial regression was used to compare fall rates between groups. Secondary outcomes were measures of balance, mobility, balance confidence, physical activity, and social integration.

Results: PBT participants reported 53 falls (1.45 falls/person-year) and control participants reported 64 falls (1.72 falls/person-year; rate ratio: 0.85 [0.42, 1.69]; p=0.63). Per-protocol analysis included 32 PBT and 34 control participants who completed at least 10/12 initial training sessions and 1 booster session. Within this sub-set, PBT participants reported 32 falls (1.07 falls/person-year) and control participants reported 57 falls (1.75 falls/person-year; rate ratio: 0.62 [0.29, 1.30]; p=0.20). PBT participants had greater improvement in reactive balance control than the control group, and these

improvements were sustained 12-months post-training. There were no intervention-related serious adverse effects.

Conclusions: The results are inconclusive. PBT may help to prevent falls in daily life post-stroke, but ongoing training may be required to maintain the benefits.

Trial registration: ISRCTN05434601.

Funding: Canadian Institutes of Health Research.

Key words: Stroke; Rehabilitation; Exercise; Physiotherapy; Accidental Falls; Postural balance

STRENGHTS AND LIMITATIONS OF THE STUDY

- This study employed an assessor-blinded randomized controlled trial. As is typical of exercise studies, participant blinding was not possible.
- Attendance to the intervention was high (mean 87% of sessions attended), and rates of withdrawal from the study were low (<6%).
- The primary outcome (falls in daily life) was collected via self-report, which may have led to under-reporting.
- Inclusion and exclusion criteria were minimal so that results would be generalizable to a broad population of individuals with chronic stroke. However, recruited participants were, on average, high functioning; these results might not apply to more severely-affected individuals with stroke.

INTRODUCTION

People with stroke have increased fall risk compared to age-matched individuals who have not had a stroke.[1] Impaired balance control, low balance confidence, and high rate of falls post-stroke are associated with reduced quality of life and reduced physical activity as a strategy to prevent falls.[2,3] Physical exercise, particularly exercise that includes balance training, can reduce fall rates in older adults.[4] However, studies including individuals with stroke have not demonstrated reduced fall rates following balance training.[5,6]

Balance training programs typically include exercises that aim to improve the ability to maintain balance when keeping still (e.g., standing with reduced base of support) or during voluntary movement (e.g., sit-to-stand or step ups).[7-11] This type of balance training may prevent falls by reducing the risk of losing balance in daily life. However, occasional loss of balance may be an inevitable consequence of mobility, so the ability to react quickly after losing balance (i.e., reactive balance control) is essential to prevent falls.[12] Perturbation-based balance training (PBT) is a type of exercise where participants repeatedly experience loss of balance in order to practice and improve control of balance reactions.[13] A review of small-sample randomized controlled trials suggests that PBT can prevent falls in older adults and individuals with Parkinson's disease.[14]

People with stroke have impaired reactive balance control,[15,16] and impaired control of balance reactions is related to increased fall rates in daily life post-stroke.[17,18] PBT can improve reactive balance control post-stroke.[19] A non-randomized study found that those who completed PBT during in-patient stroke rehabilitation fell less frequently post-discharge than those who did not.[20]

The main purpose of this study was to determine if PBT reduces fall rates in people with chronic stroke. A secondary purpose was to determine the effect of PBT on balance control, balance confidence, mobility, daily physical activity, and social integration. We hypothesized that, compared to a control group who completed 'traditional' balance training, those who completed PBT would

experience fewer falls in the year post-training and would have greater improvements in measures of functional balance and mobility. Additionally, we expected that, due to reduced fall rates and improved balance confidence, participants who completed PBT would be less likely to restrict daily physical activities; therefore, we hypothesized that participants who completed PBT would show increased daily physical activity and improved social integration compared to those in the control group.

METHODS

Trial design

This assessor-blinded pragmatic randomized controlled trial took place at the Toronto Rehabilitation Institute (University Health Network) and Sunnybrook Health Sciences Centre. Individuals with chronic stroke were recruited and randomly assigned to either: 1) PBT or 2) 'traditional' balance training (control group). The full study protocol is available elsewhere;[21] protocol modifications are detailed in the relevant sections below. The protocol and amendments were approved by the University Health Network (study ID: 14-7428) and Sunnybrook Health Sciences Centre (study ID: 134-2014) Research Ethics Boards. This manuscript was prepared following the CONSORT[22] and TIDieR[23] checklists.

Participants

Community-dwelling adults with chronic stroke (>6 months post-stroke) were recruited from research volunteer databases and advertisements in the community. Participants could stand independently without upper-limb support for >30s and tolerate at least 10 postural perturbations. Exclusion criteria were: >2.1m tall and/or weighing >150kg; other neurological conditions; lower extremity amputation; unable to understand instructions in English; recent (last 6 months) significant illness, injury or surgery; severe osteoporosis (diagnosis of osteoporosis with fracture); poorly controlled diabetes or

hypertension; contraindications to physical exercise;[24] receiving physiotherapy or supervised exercise targeting balance and mobility between the time of recruiting and the post-training assessment; and/or received PBT in the year before enrolment. Due to difficulty recruiting, the protocol was amended to allow individuals <50 years old to participate. Volunteers completed telephone screening and subsequently attended an initial assessment where written informed consent was obtained and eligibility was confirmed. To help alleviate barriers to participation, participants were compensated for travel expenses (public transit fare or parking).

Interventions

Participants completed 2 1-hour training sessions per week for 6 weeks, and 2 1-hour 'booster' training sessions 3- and 9-months after the initial training period. Interventions were administered by a physiotherapist (CJD or SK) on a 1:1 basis (i.e., one physiotherapist per participant) in research laboratories in academic hospitals. Both laboratories contained a 2.63 x 2.63m 4-post XY patient lift gantry (Prism Medical Ltd, Concord, ON, Canada), and the Sunnybrook laboratory also contained a 8.5m long ceiling lift track, to which the safety harness was attached during PBT. Physiotherapists were trained in delivering the control intervention by reviewing the intervention developers' documentation,[25] and in delivering the PBT intervention by study investigators (AM and VGD). Interventions followed a general guide, but were tailored to participants' ability and balance impairments. Participants rated perceived level of challenge on a 5-point scale (see Supplementary Material) after completing each exercise set. The physiotherapists documented activities in each session, perceived level of challenge, adverse events, and deviations from prescribed activities.

Control group

The control group completed the Keep Moving with Stroke program.[25] This is an exercise program for community-dwelling individuals with stroke, based on balance and mobility interventions evaluated in clinical trials.[9-11] This program was designed to be delivered in a group, but was delivered 1:1 in this study to match attention received from the physiotherapist by the PBT group. Each session included a 5-10 minute warm-up, 40 minutes of mobility and balance exercises, and a 5-10 minute cool-down with stretching. Exercises included walking, sit-to-stand, heel raises, walking while carrying an object, tap-ups or step-ups (forward and sideways), reaching and weight shifting, and standing with reduced base of support.

PBT group

PBT sessions included a 5-10 minute warm-up, voluntary tasks intended to induce internal perturbations, voluntary tasks combined with external perturbations, and a 5-10 minute cool-down. Participants were supervised by the physiotherapist and wore a custom safety harness (ABG Concept Médical Inc., Valcourt, QC, Canada) attached to the overhead support. Internal perturbations occurred when participants failed to control balance during voluntary movement; 'agility' tasks, such as kicking a soccer ball, were used to induce internal perturbations. External perturbations were caused by forces outside participants' control (e.g., push or pull from the physiotherapist). We aimed for at least 60 postural perturbations per session, and set the task difficulty such that participants required an upper extremity response, external assistance (i.e., from the overhead harness or physiotherapist), or a multi-step response ~50% of the time. The progression in voluntary tasks occurred on a continuum from stable to mobile, and from predictable to unpredictable.[26] Additionally, progression occurred by increasing the magnitude of external perturbation, or imposing sensory or environmental challenges. The full PBT program is available in the Supplementary Material.

Group allocation

Participants were assigned using blocked stratified randomization with allocation concealment to either the control or PBT group by the principal investigator (AM), who was not involved in recruiting, assessments, or intervention administration. A variable block size of 4, 6 or 8 was used. There were four strata from two stratification factors: site (two levels), and frequency of 'failures' during baseline reactive balance control assessment[17] (two levels). The random allocation sequence was computer generated and maintained in an electronic file by the principal investigator.

Outcomes

Cohort descriptors

Demographic and stroke information were recorded at study enrolment: age, sex, time since stroke, lesion location, falls history, National Institutes of Health Stroke Scale (NIH-SS[27]), and Chedoke-McMaster Stroke Assessment (CMSA) foot and leg scores.[28] Demographics and medical history were obtained by self-report and, when possible, verified from participants' hospital charts.

Primary outcome – falls

A fall was defined as "an event that results in a person coming to rest unintentionally on the ground or other lower level".[29] Participants completed 12-months of falls reporting after the initial 6-week training period. Participants were provided stamped addressed postcards containing a 2-week calendar to record falls, which they completed daily, and returned to the research team fortnightly. If a postcard was not returned within 2 weeks the research assistant called the participant to ascertain if they fell. Participants who fell completed a short telephone questionnaire regarding the cause, circumstances, and consequences of the fall. Falls were excluded from analysis, by unanimous decision of two blinded research assistants, if they were caused by loss of consciousness or an overwhelming external force

(i.e., if anyone would fall in that situation). If the research assistants could not agree that a fall should be excluded, that fall was included in the analysis.

Secondary outcomes

Balance and mobility and balance confidence were assessed immediately before, immediately after, and 6- and 12-months after the end of the initial training period. Functional balance and mobility were assessed using the Berg balance scale (BBS[30]), the mini-Balance Evaluation Systems test (mini-BEST[31]), and the Timed Up & Go (TUG[32]). The sub-scales of the mini-BEST were used to assess different components of balance control (anticipatory balance control, reactive balance control, sensory orientation, and gait). The Activities-specific Balance Confidence (ABC) questionnaire[33] was used to assess balance confidence in daily activities.

Physical activity and social integration were evaluated with the Physical Activity Scale for Individuals with Physical Disabilities (PASIPD[34]) and the Subjective Index of Physical and Social Outcome (SIPSO[35]), respectively, at baseline and every 2 months during the 12-month follow-up.

Blinding

The research assistants (AA and AC) were blinded to group allocation and were responsible for screening, recruiting, and collecting data. At the post-training, 6-month, and 12-month assessments, the research assistants guessed group allocation for each participant, rated their confidence in their guess of group allocation, and noted if they had received any information to violate blinding. In cases where blinding was violated, the balance measures were re-coded from video footage by another blinded research assistant.

Sample size

The target sample size was estimated for the primary outcome (fall rate in the year post-training) using a formula for negative binomial regression.[36] Assuming the control group would report 1.75 per person-year,[17] a rate ratio of 0.54,[14] mean follow-up time of 11 months per person, level of significance of 0.05, and power of 0.8, we estimated that 37 participants per group would be required to show a statistically significant between-group difference in fall rates.

Statistical analysis

Wilcoxon-Mann-Whitney test (continuous/ordinal variables) and Fisher's exact test (categorical/frequency variables) were used to compare the two groups at baseline. Negative binomial regression was used to compare fall rates and logistic regression was used to compare the proportion of fallers between the two groups. Intent-to-treat analysis was used; that is, all participants with some falls-monitoring data were included in the analyses. To account for variable falls-monitoring duration between participants (e.g., due to premature withdrawal from the study) the natural log of the monitoring duration was included as an offset variable in negative binomial regression, and as a covariate in logistic regression. Exploratory per-protocol analysis was also conducted, comparing proportion of fallers and fall rates between the two groups, including only those participants who attended at least 10/12 of the initial training sessions and 1 booster session. We initially planned to conduct repeated-measures analysis of variance, with group-by-time interaction, to evaluate the effect of the interventions on secondary outcome measures.[21] However, because the variables were not normally distributed we conducted analysis of co-variance (ANCOVA), comparing BBS, mini-BEST, mini-BEST subscale scores, TUG, ABC, PASIPD, and SIPSO at each time point between groups, controlling for the value at baseline. Dependent variables were rank transformed prior to entry into the ANCOVA to allow for non-parametric analysis.[37] Alpha was 0.05 for all analyses.

Patient and public involvement

Patients or the general public were not involved in the design of this study, development of research questions, or outcome measures. Some participants were recruited via referral from other participants. Participants received a letter of appreciation at the end of the study, which included a summary of the results. At the end of their involvement with the study, participants were invited to complete a short questionnaire about their experiences, including whether they found data collection and the intervention difficult.

RESULTS

Recruitment

Recruiting occurred between 24 April 2014 and 29 June 2016. Initially, we planned to recruit 46 participants per group to account for a 20% withdrawal rate.[21] However, recruiting was stopped when we had at least 37 participants per group who had returned at least one fall-reporting postcard. Any participants who had started the intervention at this point continued with the study until they either withdrew or completed all study elements. The trial ended when data collection for all recruited participants was complete (August 2017). Forty-four participants were assigned to each group, with 42 (control) and 41 (PBT) returning at least 1 fall-reporting postcard (Figure 1); thus 42 control and 41 PBT participants were included in analysis of the primary outcome (falls in daily life). Baseline characteristics for these participants are in Table 1; there were no significant differences between groups on any baseline characteristics.

Intervention adherence

During the initial 6-week training program, PBT participants attended a mean 10.5 sessions, with 34/41 participants attending at least 10 sessions (out of the prescribed 12). Participants experienced a mean of

577 perturbations during all sessions (standard deviation: 195 perturbations; minimum: 42 perturbations), or a mean of 55 perturbations per session (standard deviation: 9 perturbations). For all PBT sessions combined, mean rate of balance recovery 'failures' was 57%, and mean rate of perceived challenge was 2.4 (on a five-point scale). In the initial 6-week training phase, control participants attended a mean of 11 sessions, with 38/42 participants attending at least 10 sessions (out of the prescribed 12). On average, control participants completed 87% of the prescribed exercises (standard deviation: 18%). For all control training sessions combined, mean rate of perceived challenge was 2.4.

Outcomes and estimation

Blinding

Blinding was violated for 9 participants (7 PBT and 2 control), who revealed their group allocation in conversation with the research assistant. The BBS and mini-BEST scores for these participants were re-coded from video recordings by another blinded research assistant who had no interaction with participants. For the remaining participants, the research assistants correctly guessed group allocation 56% of the time; i.e., guesses were not correct more often than would be expected by random chance.

Missing data

Data were missing at assessment time points because participants: declined to complete the assessment (15 PBT and 21 control assessments); were unavailable due to acute illness (3 control assessments); were unavailable due vacation or other personal commitments (3 control assessments); or could not be contacted at the time of the assessment (6 control assessments). Some participants declined to come to the laboratories for the 6- and 12-month assessments, but were willing to complete the questionnaires (ABC, SIPSO, and PASIPD) over the telephone. Even when participants attended a study appointment,

some declined to complete individual tests; the number of individuals included in analysis of each variable at each time point is detailed in the Tables.

Falls

Data on number of individuals reporting 1 or more falls, and fall rates, are presented in Table 2. In intent-to-treat analysis, the between-group differences in odds of being a 'faller' (odds ratio: 0.71 [0.30, 1.70]; p=0.44) and fall rates (rate ratio: 0.85 [0.42, 1.69]; p=0.63) were not statistically significant. Thirty-two PBT participants and 34 control participants completed at least 10/12 of the initial training sessions and 1 booster session, and were included in per-protocol analysis. Within this sub-set, the between group differences in odds of being a 'faller' (odds ratio: 0.56 [0.21, 1.50]; p=0.25) and fall rates (rate ratio: 0.62 [0.29, 1.30]; p=0.20) were not statistically significant.

Balance confidence, balance, mobility, physical activity, and social integration

Post-training, the PBT group had higher scores than the control group for the reactive sub-scale of the mini-BEST ($F_{1,74}$=7.33, p=0.0084; Table 3), whereas the control group had higher scores than the PBT group for the sensory subscale ($F_{1,74}$=4.19, p=0.044). Scores for the reactive sub-scale of the mini-BEST were higher for the PBT group than the control group at 6-months ($F_{1,57}$=8.32, p=0.0055) and 12-months ($F_{1,53}$=11.59, p=0.0013). Likewise, at 12-months, the PBT group had a higher score on the total mini-BEST than the control group ($F_{1,53}$=4.04, p=0.049). There were no other statistically significant between-group differences for balance and mobility measures at any time point.

There were no significant between-group differences for the PASIPD at any time point (Table 4). SIPSO scores were significantly higher for the control group compared to the PBT group at 6-months ($F_{1,59}$=6.73, p=0.012), 8-months ($F_{1,54}$=4.25, p=0.044), 10-months ($F_{1,61}$=4.89, p=0.031), and 12-months ($F_{1,59}$=4.13, p=0.047).

Data showing change in secondary outcomes over time are presented in the supplementary data (Supplementary Tables S1 and S2). No analyses were conducted on these data.

Ancillary analysis

Additional exploratory analysis compared causes, circumstances, and consequences of falls in daily life between groups (Table 5). There was a significant between-group difference in motor activity at the time of the fall (p=0.010). Falls in control participants were more likely to occur during transfers than falls in PBT participants, whereas falls in PBT participants were more likely to occur during reaching/bending than falls in control participants. Participants had something in their hands at the time of 45% of control-group falls, compared to 23% of PBT-group falls (p=0.023). PBT participants attempted to stop themselves from falling by using a step response for 21%, or a grasping response for 18% of falls, whereas control participants tried to prevent the fall by stepping for only 9% of falls, and grasping for 30% of falls; however, this difference was not statistically significant (p=0.18). PBT participants required assistance to get up after 48% of falls, compared to just 27% of falls for control participants (p=0.040). Injuries resulted from 18 falls (39% of falls) in the PBT group and 20 falls (34% of falls) in the control group (p=0.68). Most injuries were minor (e.g., cuts and bruises). Participants sought medical attention after 3 falls (all control): visit to emergency room (2 falls), and treatment from an unspecified healthcare professional (1 fall).

Harms

Forty-eight adverse events were possibly, probably, or definitely related to study procedures or interventions among the 88 randomized participants. Events were: fatigue with training (3 PBT, 1 control); joint pain during or soon after training (14 PBT, 11 control); delayed onset muscle soreness (5 PBT, 8 control); seizure during training (1 PBT participant, with history of frequent seizures);

abnormally elevated heart rate and low blood pressure during training (1 control; this participant was withdrawn from the study). For all but this last event, medical attention was not necessary to treat adverse events. In the case of fatigue or joint/muscle pain, the intensity and/or duration of training was reduced until the issue resolved. Additionally, four falls that occurred during the training portion of the study were considered related to study procedures or interventions. In one case (control) the participant fell outside the hospital while on the way to a study appointment. The other three falls were reported by a single PBT participant who noted that he felt more confident, and may have increased risk-taking behaviour, as a result of the intervention. Eight participants experienced serious adverse events unrelated to study procedures, but that resulted in study withdrawal: prolonged hospitalization (1 PBT, 1 control); another stroke (2 PBT, 3 control); death (1 control); and cancer diagnosis (1 control).

DISCUSSION

We hypothesized that PBT would reduce fall rates among individuals with stroke; this hypothesis was not supported. While the rate ratio comparing falls rates between the PBT and control groups was 0.85, this was not statistically significant. The pooled rate ratio estimating the effect of exercise on fall rates in community-dwelling older adults is 0.80,[4] which is similar to that observed in the current study. Our sample size was based on a rate ratio of 0.54, which was estimated from a meta-analysis of PBT,[14] that included studies among older adults and individuals with Parkinson's disease. Another non-randomized study reported a fall rate ratio of 0.32 when comparing individuals with sub-acute stroke who completed PBT during in-patient rehabilitation to those who did not.[20] The effect of PBT on fall rates in chronic stroke may be much lower than in other patient populations or individuals with sub-acute stroke and, therefore, the current study may not have had sufficient power to detect the true effect. Conversely, the between-group difference in fall rates was much greater when only individuals who completed at least 80% of initial training sessions and 1 booster session were included in the analysis.

The booster sessions may have helped participants to retain the training benefits[38,39] by providing participants with opportunity to practice reactive balance skills throughout the 12-month follow-up period.

Importantly, the control group also completed balance training; previous studies using similar exercise programs found no effect of balance training on fall rates in people with chronic stroke when compared to a sham intervention[7] or 'usual care'.[40] Thus, we expect that control participants did not have reduced fall risk as a result of completing this program. However, after the initial six week training period, both groups improved balance confidence (ABC), anticipatory balance control (BBS and mini-BEST anticipatory sub-scale sore), and mobility (mini-BEST gait sub-scale score), with no significant difference between groups on these measures post-training It is possible that improved balance and mobility led to reduced fall risk in the both groups compared to their pre-training fall risk.. Furthermore, it seems that PBT leads to similar improvements in anticipatory balance and mobility as a traditional balance training program that is primarily focused on improving anticipatory balance control.

Consistent with specificity of training, the PBT group improved reactive balance control (reactive sub-scale of the mini-BEST), but the control group did not;[41] these improvements were retained at 6- and 12-months. This finding agrees with those of Bhatt *et al*., who found that resistance to falling following a slip was retained up to 6-months after a single PBT session.[39] The mean between-group difference in the reactive sub-scale of the mini-BEST ranged from 0.6 (post-training) to 1.6 points (12-month follow-up). We are unaware of any study reporting minimal clinically important differences for the mini-BEST sub-scales; however, these between group differences represent 10-27% of the maximum score for this sub-scale (6 points) and, therefore, we interpret these differences as clinically meaningful. Despite these retained improvements in reactive balance control, PBT participants did not have a significantly reduced fall risk than control participants. Falls occur when

there is a loss of balance and subsequent failure to recover.[42] Improved reactive balance control following PBT should help to prevent falls by improving the ability to recover from a loss of balance. Loss of balance can occur due to an external force or failure of anticipatory balance control. Thus, it is possible that effective fall prevention post-stroke requires sustained improvements in both anticipatory and reactive balance control; home exercise may help participants to retain improvements in anticipatory balance control.[40]

Contrary to our hypothesis, control participants reported greater social integration 6-12 months post-training than the PBT group. Individual-item SIPSO scores suggest that this finding was primarily driven by control participants reporting increased independence in moving around their local neighbourhoods. The control training program included walking practice during every session, whereas the PBT program only included short bouts of walking in later sessions. This walking practice may have increased control participants' confidence with community mobility. While increased social integration at 6-12 months was not associated with improved physical function, it is likely that the tests used in the current study do not correlate highly with community mobility.[43] Training-related improvements in balance and mobility in both groups, and increased self-reported participation in the control group, were not associated with increased physical activity post-training. While impaired balance and mobility post-stroke may be a barrier to physical activity,[44] improved balance and mobility alone is not sufficient to increase activity.[7,45] It is likely that an intervention that combines behaviour change techniques with physical exercise is required to increase long-term participation in physical activity.[46]

Examining fall characteristics can provide further insight into intervention effects on falls.[20] Individuals with stroke seem to be reliant upon upper-extremity reactions to prevent falls in daily life.[29] In the current study, participants had something in their hands at the time of the fall for more control group falls than PBT falls, which may have prevented these individuals from using an upper-extremity

reaction to prevent the fall.[47] Conversely, training, with a specific focus on reactive stepping, may have made PBT participants less reliant on upper extremity reactions to prevent falls. In agreement with a previous study,[20] control participants were more likely than PBT participants to fall during transfers; this finding may support the idea that PBT helps to prevent falls in routine situations, but not falls in more challenging situations. Participants required assistance to get up from the ground after more PBT group than control group falls; this finding could suggest that those PBT participants who fell were more impaired than PBT participants who did not fall or than those in the control group who fell.

Limitations

The primary outcome (falls in daily life) was obtained via self-report. While the method of prospective falls reporting used in the current study is the best available,[48] falls may have been under-reported. The cohort was, on average, relatively high functioning (e.g., median BBS score ~50/56), but had a wide range of physical function (minimum scores for CMSA leg: 3, CMSA foot: 2, BBS: 23, mini-BEST: 5; maximum NIH-SS score: 13; highest TUG time: 119s). This study's findings apply to community-dwelling individuals with chronic stroke who can stand independently for at least 30s. Group allocation blinding was violated for 9 participants. Balance measures for these participants were re-scored by a truly blinded research assistant; however, knowledge of group allocation may have sub-consciously influenced how other data were collected for these participants.

PASIPD scores were higher at the time points when the questionnaire was administered in-person compared to over the telephone. Physical activity questionnaires, including the PASIPD,[34] are often designed to have several methods of administration (e.g., self-administered via in-person or telephone interview),[49] and investigators seem to treat administration methods as equivalent.[50] We are not aware of any study that directly compared scores from the PASIPD or any other physical activity questionnaire when administered using different methods. It is possible that scores are higher when

administered in-person versus over the telephone as participants' desire for social acceptance was higher when they interacted directly with the research assistant. Alternatively, in-person administration may have led to more accurate scores than telephone administration within this population, who may have subtle cognitive-communication deficits, as the research assistant and participant could avail of non-verbal communication to facilitate completing the questionnaire. However, SIPSO scores did not differ between telephone versus in-person administration. Finally, participants in the current study may have truly been more active in the week prior to the in-person interview compared to the telephone interview to prepare for the tests of physical function. Future studies should investigate the potential influence of administration methods on physical activity questionnaire scores.

Clinical implications

While this study found that PBT did not reduce fall rates among the entire cohort, PBT participants improved on measures of balance and mobility, and retained the improvements in reactive balance control up to 12-months post-training. Combined with results of previous studies reporting reduced fall rates following PBT among individuals with sub-acute stroke,[20] chronic stroke with a history of falling,[51] and without stroke,[14] and showing that PBT is the only intervention with capacity to improve reactive balance control,[41,52] these results suggest that PBT may be a useful addition to existing balance training post-stroke. The PBT program developed for this study used existing resources available in many clinical settings and, therefore, could be relatively easily implemented in clinical practice. Joint pain was the most common adverse event related to PBT, which appeared to be most prevalent among those with lower-extremity arthritis; these participants were able to complete training with modifications to avoid exacerbating pain (e.g., temporarily reducing perturbation intensity). Therefore, modifications to PBT may be required for those with lower-extremity arthritis. Regular 'booster' PBT training sessions may be necessary to prevent falls long-term.

Contributorship statement: AM conceived of the study, is the grant holder, performed statistical analysis and drafted the manuscript. AM, VGD, ASI, DB, ELI, and GM developed the study protocol. AM and GM led implementation of the study at each site. AM, VGD, and ELI developed the intervention. AA, AC and ASI collected data. CJD and SK delivered the interventions. All authors approved the final manuscript.

Competing interests statement: The authors declare that they have no competing interests.

Data sharing statement: Due to research ethics and privacy restrictions, raw data for this study are currently not available publicly.

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TABLES

Table 1: Participant characteristics at study enrolment. Values presented are medians with interquartile range in parentheses (for continuous/ordinal variables) or number with percentage in parentheses (for count/frequency variables). The p-value is for the Wilcoxon-Mann-Whitney test (continuous/ordinal variables) or Fisher's exact test (count/frequency variables).

	PBT (n=41)	**Control (n=42)**	***p-value***
Age (years)	66 (17)	67 (13)	*0.84*
Sex (number, %)			
Female	15 (36.6)	12 (28.6)	*0.49*
Male	26 (63.4)	30 (71.4)	
Time post-stroke (years)	2.0 (3.3)	3.2 (4.5)	*0.086*
More affected side (number, %)			
Left	22 (53.7)	22 (52.4)	*>0.99*
Right	19 (46.3)	20 (47.6)	
NIH-SS (score)	3 (4)	3 (5)	*0.57*
CMSA leg (score)	5 (1)	5 (1)	*0.54*
CMSA foot (score)	5 (3)	5 (1)	*0.45*
ABC scale (%)	65.6 (26.3)	79.1 (33.8)	*0.42*
BBS (score)	50 (10)	51 (7)	*0.94*
Mini-BEST (score)	18 (7)	18 (5)	*0.95*
TUG (s)	14.4 (12.3)	13.0 (7.6)	*0.62*
PASIPD (score)	8.4 (9.5)	11.6 (10.9)	*0.48*
SIPSO (score)	30 (9)	31 (13)	*0.74*
Fall in the past year (number, %)			
Yes	17 (41.5)	18 (42.9)	*>0.99*
No	24 (58.5)	24 (57.1)	

ABC=Activities-specific Balance Confidence scale, BBS=Berg Balance Scale, mini-BEST=mini-Balance Evaluation Systems Test, CMSA=Chedoke-McMaster Stroke Assessment, NIH-SS=National Institutes of Health Stroke Scale; PASIPD=Physical Activity Scale for Individuals with Physical Disabilities, SIPSO=Subjective Index of Physical and Social Outcome.

Table 2: Falls between groups. Values presented are absolute number of participants, or rate of falls per person-year. The p-value is for the difference in falls or fall rates from logistic regression or negative binomial regression, respectively.

	PBT	Control	*p-value*
Intent-to-treat analysis			
Participants (number)	41	42	
Participants reporting ≥1 fall (number)	19	23	*0.44*
Falls (total number)	53	64	
Falls (number per person-year)	1.45	1.72	*0.63*
Per-protocol analysis			
Participants (number)	32	34	
Participants reporting ≥1 fall (number)	14	20	*0.25*
Falls (total number)	32	57	
Falls (number per person-year)	1.07	1.75	*0.20*

Table 3: Balance and mobility measures between groups. Values presented are least-square means with 95% confidence intervals in brackets. The p-value is for the ANCOVA comparing groups at each time point, controlling for the baseline value.

	PBT	Control	*p-value*
Post-training			
N	39	38	
ABC (%)	75.6 [71.6, 79.7]	78.2 [74.1, 82.2]	*0.97*
BBS (score)	50.8 [50.0, 51.7]	51.2 [50.3, 52.1]	*0.99*
Mini-BEST (score)	20.3 [19.6, 21.0]	20.1 [19.3, 20.8]	*0.96*
BEST-anticipatory (score)	4.4 [4.2, 4.6]	4.4 [4.2, 4.6]	*0.94*
BEST-reactive (score)	4.2 [3.7, 4.7]	3.6 [3.0, 4.1]	*0.044*
BEST-sensory (score)	5.3 [5.2, 5.5]	5.6 [5.4, 5.7]	*0.0084*
BEST-gait (score)	6.4 [6.0, 6.7]	6.6 [6.2, 7.0]	*0.44*
TUG (s)	17.5 [15.8, 19.2]	17.4 [15.7, 19.1]	*0.30*
6-month follow-up			
N	30*	30*	
ABC (%)	75.4 [70.1, 80.8]	74.1 [68.6, 79.5]	*0.70*
BBS (score)	50.2 [49.2, 51.2]	51.3 [50.3, 52.4]	*0.11*
Mini-BEST (score)	19.8 [18.9, 20.7]	19.1 [18.2, 20.0]	*0.81*
BEST-anticipatory (score)	4.3 [4.0, 4.6]	4.3 [4.0, 4.6]	*0.99*
BEST-reactive (score)	4.0 [3.4, 4.5]	2.9 [2.3, 3.4]	*0.0055*
BEST-sensory (score)	5.4 [5.1, 5.7]	5.4 [5.2, 5.7]	*0.44*
BEST-gait (score)	6.2 [5.6, 6.7]	6.5 [6.0, 7.1]	*0.25*
TUG (s)	16.8 [15.3, 18.2]	15.4 [13.9, 16.9]	*0.32*
12-month follow-up			
N	27†	29†	
ABC (%)	75.2 [69.3, 81.1]	78.1 [72.1, 84.0]	*0.95*
BBS (score)	50.6 [49.5, 51.6]	51.1 [50.0, 52.1]	*0.27*
Mini-BEST (score)	20.6 [19.4, 21.8]	18.7 [17.5, 19.8]	*0.049*
BEST-anticipatory (score)	4.3 [4.0, 4.6]	4.3 [3.9, 4.6]	*0.45*
BEST-reactive (score)	4.2 [3.6, 4.9]	2.6 [2.0, 3.2]	*0.0013*
BEST-sensory (score)	5.4 [5.1, 5.7]	5.4 [5.1. 5.6]	*0.64*
BEST-gait (score)	6.6 [6.0, 7.3]	6.5 [5.9, 7.1]	*0.90*
TUG (s)	15.7 [14.3, 17.2]	17.3 [15.9, 18.7]	*0.79*

ABC=activities-specific balance confidence scale; BBS=Berg balance scale; BEST=balance evaluation systems test.

*N=32 PBT and 31 control for the ABC at 6-month follow-up. †N=31 PBT and 31 control for the ABC at 12-month follow-up.

Table 4: Physical activity and social integration between groups. Values presented are least-square means with 95% confidence intervals in brackets The p-value is for the ANCOVA comparing groups at each time point, controlling for the baseline value.

	PBT	Control	*p-value*
Post-training			
N	39	38	
PASIPD (score)	12.3 [10.0, 14.6]	11.2 [8.8, 13.6]	*0.92*
SIPSO (score)	29.8 [28.1, 31.4]	31.2 [29.5, 32.9]	*0.29*
2-month follow-up			
N	38	31	
PASIPD (score)	8.6 [6.4, 10.8]	9.5 [7.1, 11.9]	*0.51*
SIPSO (score)	29.7 [28.2, 31.2]	31.5 [29.8, 33.21]	*0.23*
4-month follow-up			
N	33	34	
PASIPD (score)	9.2 [7.3, 11.2]	7.8 [5.9, 9.8]	*0.34*
SIPSO (score)	30.0 [28.2, 31.9]	30.2 [28.4, 32.0]	*0.62*
6-month follow-up			
N	32	31*	
PASIPD (score)	11.3 [7.3, 15.3]	10.9 [6.8, 15.0]	*0.21*
SIPSO (score)	30.3 [29.0, 31.6]	32.6 [31.3, 33.9]	*0.012*
8-month follow-up			
N	31	26	
PASIPD (score)	7.0 [5.6, 8.4]	6.9 [5.4, 8.5]	*0.61*
SIPSO (score)	30.5 [29.3, 31.7]	32.3 [31.0, 33.6]	*0.037*
10-month follow-up			
N	32	32	
PASIPD (score)	7.0 [5.5, 8.5]	8.2 [6.7, 9.7]	*0.16*
SIPSO (score)	29.9 [28.4, 31.3]	32.3 [30.9, 33.8]	*0.031*
12-month follow-up			
N	31	31	
PASIPD (score)	11.1 [7.4, 14.8]	10.1 [6.4, 13.9]	*0.27*
SIPSO (score)	30.6 [29.1, 32.0]	32.6 [31.1, 34.0]	*0.047*

PASIPD=physical activity scale for individuals with physical disabilities; SIPSO=subjective index of physical and social outcome

*N=30 control for the SIPSO

Table 5: Between-group comparison of fall circumstances. Values are the number of falls in each category, with the percentage of falls in parentheses. The percentage was calculated from the total number of falls for which information was available (i.e., "do not recall" responses were excluded from the denominator). Percentages might not sum to 100 due to rounding error. The p-value is for Fisher's exact test comparing the two groups, excluding "do not recall" responses from analysis.

	PBT (53 falls)	**Control (64 falls)**	***p-value***
Cause of fall			
Do not recall	8	6	
Slip	16 (35.6)	22 (37.9)	*0.26*
Trip	11 (24.4)	6 (10.3)	
Push/external force	1 (2.2)	3 (5.2)	
Incorrect weight transfer[53]	17 (37.8)	27 (46.6)	
Posture at the time of the fall			
Do not recall	7	4	
Lying	1 (2.2)	0 (0)	*0.33*
Sitting	4 (8.9)	7 (12.1)	
Standing	9 (20.0)	6 (10.3)	
Walking	32 (68.9)	47 (77.6)	
Motor activity at the time of the fall			
Do not recall	7	4	
Not moving	4 (8.9)	2 (3.5)	*0.010*
Transferring	2 (4.4)	12 (20.7)	
Turning/reaching/bending	10 (22.2)	4 (5.2)	
Walking on level surface	18 (37.8)	20 (34.5)	
Walking on ramp/stairs/uneven surface	12 (26.7)	22 (36.2)	
Cognitive activity at the time of the fall			
Do not recall	10	9	
None	34 (78.6)	44 (81.1)	*0.80*
Distracted	9 (21.4)	11 (18.9)	
Where did the fall occur			
Outdoors	19 (35.8)	22 (34.4)	*>0.99*
Indoors	34 (64.2)	42 (65.6)	
Using an assistive device			
Do not recall	7	5	
Never use one	11	23	
No	16 (45.7)	24 (66.7)	*0.096*
Yes	19 (54.3)	12 (33.3)	
Holding onto a handrail			
Do not recall	7	6	
No	41 (89.1)	48 (82.8)	*0.41*
Yes	5 (10.9)	10 (17.2)	

	PBT (53 falls)	Control (64 falls)	*p-value*
Anything in hands			
Do not recall	9	6	
No	34 (77.3)	32 (55.2)	*0.023*
Yes (one or both hands)	10 (22.7)	26 (44.8)	
Action to try to prevent the fall			
Do not recall	9	18	
None	27 (61.4)	28 (60.9)	*0.18*
Grasp	8 (18.2)	14 (30.4)	
Step or step + grasp	9 (20.5)	4 (8.7)	
Length of lie on floor or ground			
Do not recall	7	4	
A few minutes or less	39 (84.8)	57 (95.0)	*0.098*
More than a few minutes but less than an hour	7 (15.2)	3 (5.0)	
Assistance required to get up from fall			
Do not recall	7	4	
No	24 (52.2)	44 (73.3)	*0.040*
Yes	22 (47.8)	16 (26.7)	
Injuries			
Do not recall	7	5	
None	28 (60.9)	39 (66.1)	*0.68*[*]
Cuts or bruises	17 (37.0)	19 (32.2)	
Joint sprain or dislocation	1 (2.2)	1 (1.7)	
Medical assistance required after fall			
Do not recall	7	5	
No injuries	30	42	
Injured but did not seek treatment	16 (100)	14 (82.4)	*0.23*[†]
Saw other healthcare professional	0 (0)	1 (5.9)	
Treated in hospital emergency room	0 (0)	2 (11.8)	

[*]Analysis compared injury vs no injury

[†]Analysis compared sought treatment vs did not seek treatment

FIGURE CAPTIONS

Figure 1: Participant flow through the study. Eight participants who consented to participate in the study were excluded on the initial assessment because they could not tolerate the lean-and-release postural perturbations. Participants were withdrawn after randomization because it became apparent that they did not meet the study criteria (1 PBT participant had osteoporosis with history of fracture, and 1 control participant had uncontrolled hypertension), or because they had a significant decline in health during the training portion of the study (1 PBT and 1 control participant). One PBT participant was withdrew from the study because she did not like the group allocation. Therefore, there were 42 control participants and 41 PBT participants available for analysis of the primary outcome (falls in daily life). Participants withdrew during the 12-month follow-up period because they: no longer wished to be in the study (2 PBT, 1 control); experienced a serious adverse event (2 PBT, 5 control); were lost to follow-up (2 PBT, 3 control); or enrolled in a conflicting study (2 PBT).

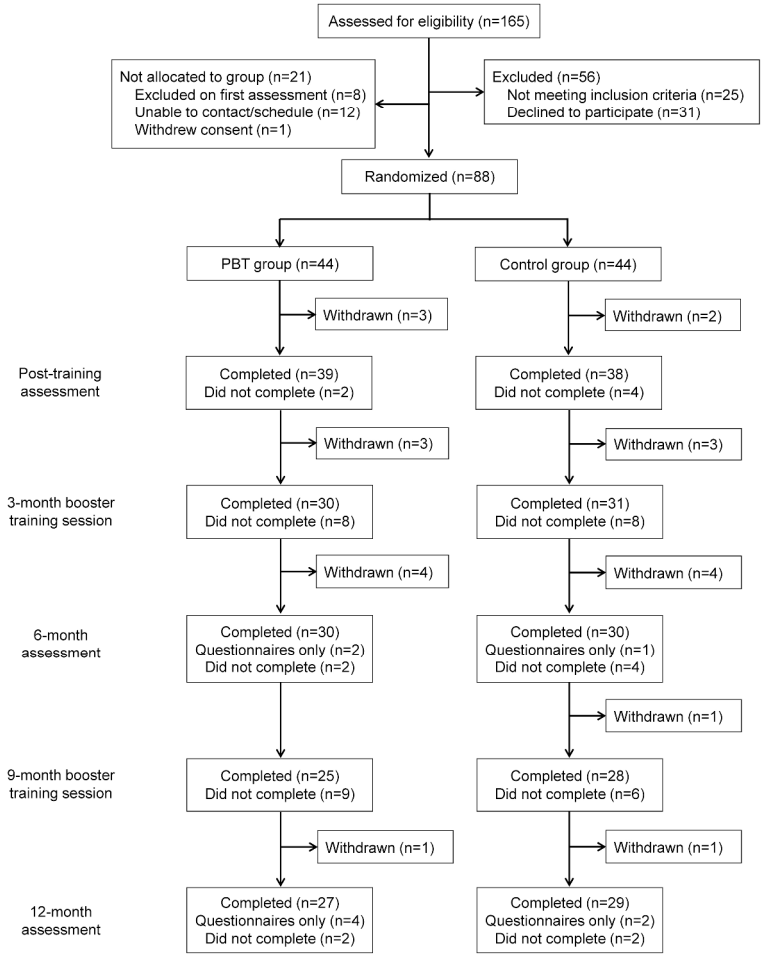

Figure 1: Participant flow through the study. Eight participants who consented to participate in the study were excluded on the initial assessment because they could not tolerate the lean-and-release postural perturbations. Participants were withdrawn after randomization because it became apparent that they did not meet the study criteria (1 PBT participant had osteoporosis with history of fracture, and 1 control participant had uncontrolled hypertension), or because they had a significant decline in health during the training portion of the study (1 PBT and 1 control participant). One PBT participant was withdrew from the study because she did not like the group allocation. Therefore, there were 42 control participants and 41 PBT participants available for analysis of the primary outcome (falls in daily life). Participants withdrew during the 12-month follow-up period because they: no longer wished to be in the study (2 PBT, 1 control); experienced a serious adverse event (2 PBT, 5 control); were lost to follow-up (2 PBT, 3 control); or enrolled in a conflicting study (2 PBT).

300x400mm (300 x 300 DPI)

SUPPLEMENTARY TABLES

Table S1: Balance and mobility measures, change over time. Values presented are the differences from pre-training with 95% confidence intervals in brackets. A positive difference value indicates an improvement for all variables except the TUG, where a negative value indicates an improvement (i.e., faster TUG time compared to baseline).

	PBT	Control
Post-training		
N	39	38
ABC (%)	5.2 [0.7, 9.8]	6.6 [1.5, 11.6]
BBS (score)	1.8 [0.7, 2.9]	1.9 [1.0, 2.9]
Mini-BEST (score)	2.6 [1.8, 3.4]	2.2 [1.5, 3.0]
BEST-anticipatory (score)	0.5 [0.2, 0.8]	0.5 [0.2, 0.8]
BEST-reactive (score)	1.5 [0.9, 2.1]	0.8 [0.3, 1.2]
BEST-sensory (score)	0 [-0.2, 0.2]	0.3 [0.0, 0.5]
BEST-gait (score)	0.6 [0.1, 1.0]	0.7 [0.3, 1.1]
TUG (s)	-1.0 [-2.9, 0.8]	-1.1 [-2.8, 0.5]
6-month follow-up		
N	30*	30*
ABC (%)	3.5 [-2.3, 9.2]	0.6 [-5.2, 6.3]
BBS (score)	0.3 [-0.8, 1.4]	1.3 [0.2, 2.4]
Mini-BEST (score)	1.6 [0.6, 2.6]	0.8 [-0.1, 1.7]
BEST-anticipatory (score)	0.3 [-0.1, 0.6]	0.3 [-0.1, 0.7]
BEST-reactive (score)	1.2 [0.5, 1.8]	0.0 [-0.5, 0.5]
BEST-sensory (score)	0.1 [-0.2, 0.3]	0.2 [-0.1, 0.5]
BEST-gait (score)	0.1 [-0.6, 0.8]	0.3 [-0.1, 0.8]
TUG (s)	1.0 [-1.0, 2.9]	-0.5 [-1.4, 0.5]
12-month follow-up		
N	27†	29†
ABC (%)	3.5 [-3.1, 10.2]	3.8 [-2.7, 10.3]
BBS (score)	0.6 [-0.7, 1.8]	0.8 [-0.3, 2.0]
Mini-BEST (score)	2.2 [0.9, 3.4]	0.1 [-1.1, 1.4]
BEST-anticipatory (score)	0.2 [-0.1, 0.5]	0.2 [-0.2, 0.7]
BEST-reactive (score)	1.4 [0.5, 2.3]	-0.4 [-1.0, 0.2]
BEST-sensory (score)	0.1 [-0.2, 0.4]	0.1 [-0.1, 0.4]
BEST-gait (score)	0.4 [-0.3, 1.2]	0.2 [-0.4, 0.8]
TUG (s)	0.1 [-1.0, 1.2]	1.6 [-0.4, 3.6]

ABC=activities-specific balance confidence scale; BBS=Berg balance scale; BEST=balance evaluation systems test.

*N=32 PBT and 31 control for the ABC at 6-month follow-up. †N=31 PBT and 31 control for the ABC at 12-month follow-up.

Table S2: Physical activity and social integration, change over time. Values presented are the difference from pre-training with 95% confidence intervals in brackets. A positive difference value indicates an improvement.

	PBT	Control
Post-training		
N	39	38
PASIPD (score)	1.1 [-2.0, 4.2]	-1.0 [-3.1, 1.0]
SIPSO (score)	0.5 [-1.4, 2.5]	1.8 [0.0, 3.7]
2-month follow-up		
N	38	31
PASIPD (score)	-2.1 [-5.1, 0.8]	-2.8 [-5.8, 0.3]
SIPSO (score)	-0.1 [-1.7, 1.6]	1.5 [-0.4, 3.4]
4-month follow-up		
N	33	34
PASIPD (score)	-1.7 [-4.2, 0.8]	-4.1 [-6.6, -1.5]
SIPSO (score)	0.5 [-1.2, 2.2]	0.7 [-1.3, 2.7]
6-month follow-up		
N	32	31*
PASIPD (score)	0.4 [-5.3, 6.2]	-2.2 [-5.6, 1.1]
SIPSO (score)	0.3 [-1.0, 1.7]	2.5 [0.8, 4.2]
8-month follow-up		
N	31	26
PASIPD (score)	-4.5 [-7.3, -1.6]	-5.7 [-9.7, -1.6]
SIPSO (score)	0.2 [-1.1, 1.5]	1.8 [0.4, 3.3]
10-month follow-up		
N	32	32
PASIPD (score)	-4.1 [-6.6, -1.7]	-3.5 [-6.7, -0.4]
SIPSO (score)	-0.3 [-1.6, 1.0]	2.2 [0.4, 3.9]
12-month follow-up		
N	31	31
PASIPD (score)	0.4 [-4.6, 5.4]	-2.9 [-6.0, 0.2]
SIPSO (score)	0.8 [-0.7, 2.3]	2.7 [0.9, 4.4]

PASIPD=physical activity scale for individuals with physical disabilities; SIPSO=subjective index of physical and social outcome

*N=30 control for the SIPSO

Toronto Perturbation-Based Balance Training

Program Manual

Program developed and manual written by: Avril Mansfield, Vincent DePaul, Cynthia Danells, Elizabeth Inness, Louis Biasin, Vivien Poon, and Svetlana Knorr

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We thank Cynthia Campos, who provided illustrations, and Luigi Bianchi, who agreed to be photographed for the manual.

LIST OF ABBREVIATIONS

AFO = ankle-foot orthosis
BOS = base of support
BP = blood pressure
CMSA = Chedoke-McMaster Stroke Assessment
DF = dorsiflexion
EV = eversion
HR = heart rate
INV = inversion
Mini-BES = Mini Balance Evaluation Systems (test)
PBT = perturbation-based balance training
PF = plantarflexion
RPC = rating of perceived challenge
TUG = timed-up and go

INTRODUCTION

The **goal of PBT** is to improve reactive balance control in order to optimize safe independent mobility. The program requires that individuals repeatedly experience loss of balance (i.e., internal or manual postural perturbations) and are provided the opportunity to practice stepping reactions to regain balance following this instability. As participants adapt to the challenge and improve their balance control, the challenge should be increased. Challenge can be increased by increasing the magnitude of the manual perturbation, adding more challenging secondary movement and cognitive tasks, removing or altering sensory feedback, and changing the environment.

Note, for convenience and clarity of expression in this document, we use feminine pronouns to refer to the treating physiotherapist, and masculine pronouns to refer to the participant.

1. SCREENING AND ASSESSMENT

1.1 An initial assessment is required to inform and guide treatment, and ensure patient safety.

Information regarding significant medical history is obtained; specifically, does the participant:

- Have arthritis in the lower extremities or any other joint pain;
- Normally wear glasses or contact lenses;
- Normally use a cane, a rollator, or any other mobility aid;
- Normally wear an orthotic (brace) around the ankle and/or knee;
- Normally wear a sling around the arm/shoulder;
- Have diabetes;
- Take any medication on an "as needed" basis (i.e., PRN medication);
- Report any recent falls; and
- Have fear of falling?

Modifications to the manner in which the program is provided may be made based on responses to the questions above. For example, some activities might be avoided to prevent exacerbation of a previous injury.

The initial assessment includes:

- Assessment of reactive stepping using
    - Forward-fall lean-and-release perturbations under two conditions: usual response and encouraged use (5 trials per condition); and
    - Observation of reactions in the 'Reactive' component of the mini-Balance Evaluation Systems (mini-BES) test.
- Consideration of some of the contributors to impaired reactive stepping:
    - Stroke severity/stroke symptoms – e.g., using the National Institutes of Health Stroke Scale;
    - Stage of motor recovery – e.g., using the Chedoke McMaster Stroke Assessment (CMSA);
    - Balance confidence – e.g., using the Activity-specific Balance Confidence scale; and
    - Sensation (see Sections 1.4 and 1.5).

1.2 Lean and release assessment instructions.

Control of reactive stepping following a postural perturbation is assessed using a lean-and-release system. Participants wear a safety harness attached to an overhead support system. The harness is also connected at the back to a beam via a quick-release mechanism (i.e., a modified crossbow trigger). The participant must lean forward from the ankles far such that approximately 10% of his body weight supported by the cable. Once achieved, the cable is released creating a forward fall from which the participant needs to recover. He is instructed step as quickly as possible to regain balance and come to stable stance. If he cannot regain stability independently, then the assessor can aid in the recovery and prevent a 'fall' (i.e., being caught by the safety harness).

Two conditions are assessed and recorded on the score sheet (see Section 1.3) – the 'usual response' and the 'encouraged use'. The first five trials are completed as described above and the limb that

responds first to the release is recorded. This is the **'usual response'**. If the same limb responds ≥4/5 times, this is considered to be the 'preferred limb'. In the **'encouraged use'** condition, five trials are completed with the preferred limb blocked and the participant is instructed to attempt to react with the non-preferred limb. The blocking is accomplished with the hand or foot of the physiotherapist/assessor. If it appears that the participant is going to step with the blocked limb, the hand/foot can be removed quickly, but the participant is not told that the block will be removed. If there is no obvious preferred limb (i.e., participant stepped 3 times with one leg and 2 with the other), then the limb that is blocked should alternate 2 times for one limb and 3 for the other.

The lean-and-release assessment is video-recorded and the video is reviewed later to observe any participant-specific impairments in reactive stepping (see also Section 4). While it might be possible to observe some obvious impairments in 'real time', often the reaction happens so quickly that this is not possible.

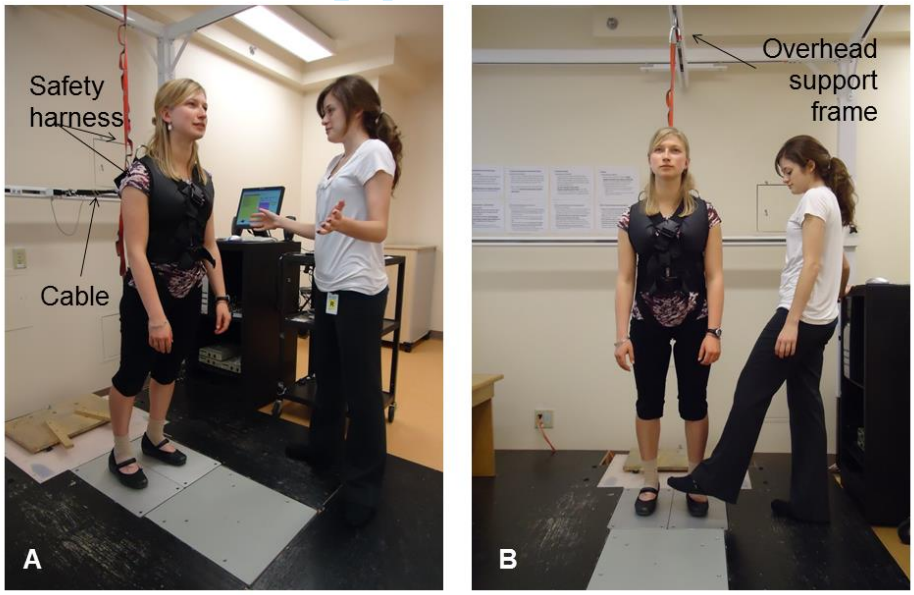

Figure 1.1: The lean-and-release system. Panel A (left) shows the usual response condition. Panel B (right) shows the encouraged-use condition. Figure taken from Mansfield et al., BMC Neurol. 2015;15:87

1.3 Lean and release collection sheet.

Usual response

- ❑ Participant wearing harness
- ❑ Aim for 10% body weight on the cable
- ❑ Random delay between 'ready' signal and perturbation
- ❑ Review video to determine preferred limb & assists (if not clear during testing)
- ❑ Record limb for first step

Test	Trial #	Comments	Limb	Assist
1			❑ Right ❑ Left	❑ No ❑ Yes
2			❑ Right ❑ Left	❑ No ❑ Yes
3			❑ Right ❑ Left	❑ No ❑ Yes
4			❑ Right ❑ Left	❑ No ❑ Yes
5			❑ Right ❑ Left	❑ No ❑ Yes

Preferred limb (initiated stepping in ≥4/5 trials with this limb):

- ❑ Right
- ❑ Left
- ❑ No clear preference

Encouraged use

- ❑ Block preferred limb with researchers hand/foot; if no limb preference do two trials blocking one limb and three blocking the other
- ❑ Aim for 10% body weight on the cable
- ❑ Random delay between 'ready' signal and perturbation
- ❑ Review video to determine preferred limb & assists (if not clear during testing)
- ❑ Record limb for first step

Test	Trial #	Comments	Limb	Assist
6			❑ Right ❑ Left	❑ No ❑ Yes
7			❑ Right ❑ Left	❑ No ❑ Yes
8			❑ Right ❑ Left	❑ No ❑ Yes
9			❑ Right ❑ Left	❑ No ❑ Yes
10			❑ Right ❑ Left	❑ No ❑ Yes

1.4 Sensation assessment instructions.

Exteroceptive and proprioceptive sensation are assessed in the affected foot and ankle. It is necessary to know if the participant appreciates light touch and movement of the ankle and foot. If these are absent or decreased, steps should be taken to accommodate the deficits in order to minimize potential injury due to PBT.

Sensation is assessed with the participant sitting on a raised plinth, feet dangling, with shoes and socks removed. Demonstration of the test should be done with the participant's eyes open and administered to the less-affected foot/ankle. The actual test should be administered to the more-affected foot/ankle following the demonstration with the participant's eyes closed.

Light touch is assessed using a cotton ball; the cotton ball should lightly touch but not brush the sole of the participant's foot. The foot is touched 5 times and the participant is instructed to respond when the touch is felt. Responses are recorded on the score sheet (see Section 1.5). If there is no response (and you are certain that the participant understood the instructions) this is recorded as a negative response.

The **perception of joint movement** is assessed in the ankle (dorsiflexion and plantar flexion) and in the foot (inversion and eversion). The participant's foot is held in two places: the bony prominences of the first and fifth meta-tarsal phalangeal joints and at the medial and lateral malleoli. Movements of the ankle should be demonstrated on the less-affected side as "up" for dorsiflexion and "down" for plantar flexion and, of the foot, as "in" for inversion and "out" for eversion. Care should be taken not to change the pressure of the hold during the movement. When being tested, movements should be through small ranges and time should be allowed for the participant to respond. If the participant is unsure of the direction of the movement, the range should be increased. If the participant is still unsure, then this is a negative response for the test. Five movements should be tested at the ankle and five at the foot.

Each correct, incorrect, or absent response is recorded on the score sheet (Section 1.5). If the participant scores <4/5 for light touch appreciation, and/or <8/10 for joint movement perception, then consideration is made for use of an Aircast Airsport Ankle Brace during training.

1.5 Sensation assessment collection sheet.

Position recognition

Position	Correct response?
Dorsiflexion	❑ Yes ❑ No
Plantarflexion	❑ Yes ❑ No
Dorsiflexion	❑ Yes ❑ No
Dorsiflexion	❑ Yes ❑ No
Plantarflexion	❑ Yes ❑ No
Number correct	

Position	Correct response?
Inversion	❑ Yes ❑ No
Eversion	❑ Yes ❑ No
Inversion	❑ Yes ❑ No
Eversion	❑ Yes ❑ No
Eversion	❑ Yes ❑ No
Number correct	

If number correct is <8/10, an AirSport ankle brace should be used to prevent injury during PBT.

Light touch sensation

Trial	Correct response?
Trial 1	❑ Yes ❑ No
Trial 2	❑ Yes ❑ No
Trial 3	❑ Yes ❑ No
Trial 4	❑ Yes ❑ No
Trial 5	❑ Yes ❑ No
Number correct	

If number correct is <4/5, an AirSport ankle brace should be used to prevent injury during PBT.

2. PLANNING THE PROGRAM

2.1 The program is individualized to the participant's specific impairments in reactive balance control

In order to create an effective training program, consideration is made of the participant's unique areas of dyscontrol (identified on initial assessment; see Section 1). Section 4 (Perturbation Training Log) outlines areas of dyscontrol and suggested treatment approaches for each problem. The principle of individual differences considers an individual's response to exercise. Therefore, progression should be gradual and systematic and occur at the individual participant's rate of improvement. Task difficulty is not absolute and could vary from participant-to-participant depending on specific control problems and other deficits.

2.2 List of equipment

The following equipment is required for this specific program:

- Overhead harness support track;
- Fall-arrest approved safety harness;
- Equipment for task-specific activities:
    - Thin foam mat (e.g., thickness of yoga mat or 2.5 cm gym mat);
    - Thick foam pad (dense blue foam);
    - Hand ball (2 sizes; e.g., 10 cm diameter and tennis ball);
    - Soccer ball;
    - Steps (10 cm and 20 cm high);
    - Stop watch;
    - Unstable 'step' (if an unstable step is not available, place a regular step on a thin foam mat);
    - Cross marked out in tape on the floor (2 pieces of tape each at least 60 cm long placed to intersect at right angles (see Figure 6.24);
    - Set of 6 – 23 cm diameter multi-colored Agility Dots;
    - Foam obstacles (e.g., pool noodles or half-round foam rollers); and
- Participant-specific equipment (e.g., walking aid, ankle brace/orthosis, helmet, arm sling).

2.3 Ensuring safety during training

2.3.1 Safety harness

Participants wear a safety harness attached to an overhead track at all times to prevent a fall to the ground. However, the harness system should be used as a back-up; the supervising physiotherapist still intervenes and provides physical assistance to 'brake the fall' when she feels the individual will not be able to recover balance. (Note, to allow participants the opportunity to practice stepping reactions, the physiotherapist ***only*** provides hands-on assistance if the participant is unable to regain stability alone.) The harness can prevent a fall to the floor but cannot prevent all possible injuries. Appropriate selection of participants, consideration of their underlying impairments, and appropriate supervision is still required. For example, it is possible that an individual could experience an ankle sprain while stepping in response to a perturbation (see Section 2.3.2). It is also possible that a frail individual who falls completely into the harness will experience an injury (e.g., bruise) because he is caught by the safety harness; a fracture could also be possible with a participant who has very low

bone mineral density. Participants should not be left 'dangling' in the safety harness as the straps can restrict circulation.

2.3.2 Protective equipment for ankle

An ankle-foot orthosis (AFO; if prescribed) or an Aircast AirSport Ankle Brace is used during PBT if the participant meets one or more of the following criteria:

- Participant typically uses an AFO during home and/or community walking;
- CMSA foot score is stage 3 or lower;
- Ankle joint position sense score is <8/10 (see Section 1.4 and 1.5);
- Light touch sensation of the plantar surface of the foot score is <4/5 (see Section 1.4 and 1.5); and/or
- The treating physiotherapist feels this is necessary to preserve stability of the ankle joint and prevent injury.

Use of the AirSport Ankle Brace, AFO, or any other assistive devices should be documented in the Perturbation Training Log (Section 4).

2.3.3 Monitoring heart rate and blood pressure

Heart rate (HR) and blood pressure (BP) are taken from the less affected arm using an automatic BP cuff. The less-affected arm is repositioned in an extended position resting on a table slightly below the level of the heart. If BP and/or HR fall outside of an 'acceptable' range (systolic BP is outside 90-140 mmHg; diastolic BP is outside 60-90 mmHg; or, HR is outside 60-100 bpm), a second measure is obtained. If the values continue to be outside of the range, the participant is asked to sit quietly for 5 minutes and perhaps, take a few deep breaths or drink a glass of water, before taking a third measurement. Participants with HR/BP measurements outside of the acceptable range are also questioned regarding recent medications (what they have taken and when, or if they have not taken their usual medications), when they last had something to eat/drink, and if the recently took caffeine, exercised, or smoked. The decision to continue or terminate the session is made by the physiotherapist considering factors such as the participants' usual resting HR/BP, how far the measured values are outside of the acceptable range, the participants' usual medication (e.g., beta-blockers), and the participants' perception of how they are feeling. If the visit is terminated, the physiotherapist may advise that the participant follow-up with his primary care physician. If the visit continues, the physiotherapist may choose to monitor HR and BP regularly throughout the visit and observe cardiovascular responses to exercise.

3. THE PROGRAM

3.1 Overview

The PBT program involves 12 1-hour training sessions provided 2 times per week for 6 weeks. Each session is 60 minutes in length and is provided in a one-to-one format. This core program is modified to fit with delivery of in-patient rehabilitation to allow for evaluation among individuals with sub-acute stroke.

Sessions begin with a 10-minute warm-up and end with a 10-minute cool-down following the warm-up and cool-down from the Keep Moving with Stroke program. Each session involves a minimum of ten 'voluntary' tasks that are each practiced for about 2 minutes. Once the participant is comfortable doing the task, the physiotherapist provides a manual perturbation to cause the participant to lose balance with the intent of evoking a reactive step (see Section 3.3). Six external perturbations are provided per task such that there are 60 external perturbations per session; however, fewer perturbations may be performed if participant tolerance is low. Participants might also experience a loss of balance (i.e., internal perturbation) due to failure to properly control balance during the voluntary task. Intensity of the session is determined by participant response; the participant should successfully regain stability with 1 or 2 steps and no assistance from the physiotherapist or safety harness 50% of the time. If the participant is too 'successful', the level of challenge is increased, or vice versa.

3.2 Voluntary Tasks

Each session involves 'voluntary' tasks that progress along a mobility continuum to evoke internal perturbations (i.e., loss of balance or self-destabilization):

a) 'Stable' – the voluntary task is to maintain a static base of support;
b) 'Quasi-mobile' – the voluntary task is to move the feet (e.g., stepping forward with alternate feet); however, the participant remains in place;
c) 'Mobile' – the voluntary task is to move from one location to another (e.g., walking, side-stepping); and
d) 'Unpredictably mobile' – the voluntary task is to move from one location to another in an unpredictable manner (e.g., kicking a soccer ball).

The challenge of each voluntary task can be influenced by manipulating other factors, such as:

a) The sensory condition (e.g., firm to compliant surfaces, eyes open to eyes closed).
b) The cognitive requirements (e.g. single task to multi-task, counting backwards, moving on cue).
c) The environment (e.g., walking on even surface to walking over obstacles).

See "Description of Voluntary Tasks" in Section 5 for further information.

3.3 Methods of Perturbation

Internal perturbations are evoked when the participant attempts to perform a task that causes instability. Various voluntary tasks, including rapid 'agility' tasks (e.g., rapid step-ups) are used to evoke internal perturbations. A task that appears as easy as standing with eyes closed may cause an internal perturbation for a participant with poor balance control. However, some participants do not put themselves in situations causing a loss of balance or necessitating a stepping reaction (i.e., they will

perform agility tasks slowly); therefore, external perturbations are also included in every session to ensure a sufficient training dose.

External perturbations are caused by a force outside of the participant's control. Small-magnitude external perturbations may be used with participants who have lower functional abilities. It is usually easiest to start with perturbations that cause a fall towards the physiotherapist (i.e., pull or lean-and-release) so that the physiotherapist can control the outcome and alleviate participants' anxiety and facilitate participants' perceptions of safety. There are three methods for evoking external perturbations: 1) lean-and-release (predictable direction/magnitude; 2) push/pull (can be unpredictable in terms of direction and magnitude; or 3) trip during walking (see Section 5 for details).

3.4 Measurement

Measures are taken throughout the training to ensure: 1) focus on participant-specific problems; 2) ongoing progression; and 3) participant safety. The Perturbation Training Log (Section 4) is used to document the following:

- Performance on reactive stepping linked to key areas of focus (e.g., if a goal is to reduce frequency of multiple stepping then frequency of multiple stepping should be documented);
- Number of repetitions (i.e., number of times the participant experiences a loss of balance): '0' = balance recovered using 2 steps or fewer; '1' = balance recovered using more than 2 steps; and, 'X' = assistance provided by the safety harness or physiotherapist to recover balance;
- Additional tasks/conditions;
- Number of rest breaks;
- 'Rating of perceived challenge' (RPC) (Section 6);
- HR and/or BP (if indicated);

3.5 Format of training session

1) Participant arrives.
2) HR and BP are taken.
3) Warm-up is completed.
4) Harness is donned.
5) Tasks, as outlined in the Perturbation Training Log (Section 4), are performed for that particular session. Detailed descriptions of each task can be found in Section 5.
6) Documentation about and scoring of each task are completed before moving on to the next task.
7) Rest is taken as required, or after each task.
8) Cool-down and stretching are completed.

4. PERTURBATION TRAINING LOG

Participant ID: _____

Affected side of body: _____ **Does HR &/or BP need monitoring through session?** Y N

Harness size: _____ **Participant Equipment:** AFO AirsSport Arm Sling Other

Participant Goal(s):

_____

_____

Highlights of Assessment Findings:

CMSA stage (/7): Leg _____ Foot _____

Position Recognition (#correct/5): DF/PF _____ INV/EV _____

Light touch (#correct/5): _____

Berg balance scale (/56): _____

Mini-BES - Reactive Postural Control (/12): _____

TUG (sec): _____

Lean & Release – Preferred trials (#): Right _____ Left _____

Lean & Release – Encouraged use trials (#): Right _____ Left _____

Comments:

_____

Participant ID: _____ Date: _____

Treatment planning:

Area of dyscontrol	Treatment suggestions	Additional treatment strategies/comments
❑ Requires external assist to regain stability	❑ Start with low-magnitude perturbation, increase magnitude as tolerated ❑ Consider other problems that contribute, like delayed stepping or no stepping	
❑ Does not step when magnitude of perturbation requires a step	❑ Instruct participant to step when s/he feels unstable ❑ Start with low-magnitude perturbations ❑ Start with predictable time/direction of perturbation ❑ Practice the step prior to perturbation ❑ Consider other problems that contribute, like unwillingness to step with paretic limb	
❑ Has low foot clearance during step: foot 'slides', or shuffles	❑ Use obstacles to 'force' a step-over	
❑ Demonstrates delayed stepping reaction	❑ Instruct participant to step as quickly as possible ❑ Start with predictable time/direction of perturbation ❑ If delay is with non-paretic limb, have participant weight-shift to paretic limb prior to perturbation	

Area of dyscontrol	Treatment suggestions	Additional treatment strategies/comments
❑ Is unwilling to step with paretic limb	❑ Block the non-paretic limb with obstacles, or hand/ foot of physiotherapist ❑ Instruct participant to step with paretic limb ❑ Start with predictable time/direction of perturbation ❑ Time perturbation to coincide with paretic leg/foot being un-weighted	
❑ Demonstrates multi-step reactions	❑ Instruct participant to take as few steps as possible ❑ Instruct participant to take long(er) steps	
❑ Stands asymmetrically prior to perturbation	❑ Instruct participant to increase loading on the less-loaded limb ❑ Consider using video or feedback of stance symmetry	
❑ Takes short steps	❑ Instruct participant to take longer steps ❑ Step to targets ❑ Step over obstacles	
❑ Attempts to use upper extremity to regain stability	❑ Physiotherapist should stand as far away as safely possible ❑ Instruct to not use reach-to-grasp reactions ❑ Have participant hold object to prevent grasping	

Area of dyscontrol	Treatment suggestions	Additional treatment strategies/comments
❑ Falls laterally on step termination	❑ Instruct participant to take as few steps as possible ❑ Start with low-magnitude perturbation ❑ Try forward/backward perturbations initially with a narrow base of support	
❑ Uses 'crossover' steps to respond to lateral perturbations	❑ Instruct participant to use side-stepping strategy ❑ Place large obstacles in front and behind participant to deter cross-overs	
❑ Is unable to step equally well in all directions	❑ Use multi-directional perturbations ❑ Do more perturbations in the most challenging direction	

'Stable' tasks*: *session 1

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Standing still with feet hip-width apart	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, eyes closed	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, on a thin foam mat	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, on a thick foam pad	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, turning head left and right	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, looking up and down	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing with feet hip-width apart, counting backwards by 3's	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Standing with feet hip-width apart, eyes closed & counting backwards by 3's	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing with feet hip-width apart, rapid weight-shifting left and right	❑ Wide BOS	❑ Feet together	6 multi-directional push/pull				
Standing with feet hip-width apart, or in stride position, rapid weight-shifting forward and backward	❑ Wide BOS	❑ Feet together	6 multi-directional push/pull				
Standing with feet hip-width apart, throwing & catching a ball	❑ Wide BOS	❑ Feet together	internal				
Standing with feet hip-width apart, rapid arm raises forward and to the sides	❑ Wide BOS	❑ Feet together	internal				

HR: _____ BP: _____ ***Overall rating of perceived challenge:*** _____

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

'Stable' tasks*: *Session 2

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Standing still with feet hip-width apart	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, eyes closed	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, on a thin foam mat	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, on a thick foam pad	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, turning head left and right	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing still with feet hip-width apart, looking up and down	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing with feet hip-width apart, counting backwards by 3's	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing with feet hip-width apart, eyes closed & counting backwards by 3's	❑ Wide BOS	❑ Feet together	6 multi-directional lean-and-release				
Standing with feet hip-width apart, rapid weight-shifting left and right	❑ Wide BOS	❑ Feet together	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests During task	Rest After task (Y/N)
Standing with feet hip-width apart, or in stride position, rapid weight-shifting forward and backward	❑ Wide BOS	❑ Feet together	6 multi-directional push/pull				
Standing with feet hip-width apart, throwing & catching a ball	❑ Wide BOS	❑ Feet together	internal				
Standing with feet hip-width apart, rapid arm raises forward and to the sides	❑ Wide BOS	❑ Feet together	internal				
Rapid stepping forward with alternate feet	❑ Short steps	❑ Long steps	internal				
Rapid stepping backward with alternate feet	❑ Short steps	❑ Long steps	internal				
Rapid stepping to the right (right foot)	❑ Short steps	❑ Long steps	internal				
Rapid stepping to the left (left foot)	❑ Short steps	❑ Long steps	internal				

HR: _____ BP: _____ ***Overall rating of perceived challenge:*** _____

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Quasi-mobile' tasks: Session 3

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Rapid stepping forward with alternate feet	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid stepping backward with alternate feet	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid stepping to alternate sides	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid tap-ups forward with alternate feet	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				
Walking in place	❑ Feet barely off floor	❑ Knees to hip-height	6 multi-directional push/pull				
Rapid stepping forward with alternate feet, on a thin foam mat	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid stepping backward with alternate feet, on a thin foam mat	❑ Short steps	❑ Long steps	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Rapid stepping to alternate sides, on a thin foam mat	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid tap-ups forward with alternate feet, on a thin foam mat	❑ Low step Step Height: ____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				
Walking in place, on a thin foam mat	❑ Feet barely off floor	❑ Knees to hip-height	6 multi-directional push/pull				

HR: _____ BP: _____ ***Overall rating of perceived challenge*: _____**

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Quasi-mobile' tasks: Session 4

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Rapid stepping forward and backward with right foot	❑ Short steps; rest in stance	❑ Long steps	6 multi-directional push/pull				
Rapid stepping forward and backward with left foot	❑ Short steps; rest in stance	❑ Long steps	6 multi-directional push/pull				
Rapid tap-ups forward with alternate feet	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				
Rapid step-ups with alternate feet	❑ Low step Step Height: _____	❑ Unstable surface (e.g. dense foam)	6 multi-directional push/pull				
Rapid tap-ups to alternate sides	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				
Rapid stepping forward and backward with right foot, on a thin foam mat	❑ Short steps; rest in stance	❑ Long steps	6 multi-directional push/pull				
Rapid stepping forward and backward with left foot, on a thin foam mat	❑ Short steps; rest in stance	❑ Long steps	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Rapid tap-ups forward with alternate feet, on a thin foam mat	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				
Rapid step-ups with alternate feet, on a thin foam mat	❑ Low step Step Height: _____	❑ Unstable surface (e.g. dense foam)	6 multi-directional push/pull				
Rapid tap-ups to alternate sides, on a thin foam mat	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				

HR: _____ BP: _____ ***Overall rating of perceived challenge*: _____**

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Quasi-mobile' tasks: Session 5

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Rapid stepping forward and backward with right foot	❑ Short steps; rest in stance	❑ Long steps	6 multi-directional push/pull				
Rapid stepping forward and backward with left foot	❑ Short steps; rest in stance	❑ Long steps	6 multi-directional push/pull				
Rapid stepping to alternate sides	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid diagonal forward stepping with alternate feet	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Walking in place	❑ Feet barely off floor	❑ Knees to hip-height	6 multi-directional push/pull				
Walking in place, eyes closed	❑ Feet barely off floor	❑ Knees to hip-height	6 multi-directional push/pull				
Rapid stepping with alternate feet in random cued direction	❑ Short steps	❑ Long steps	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Rapid step-ups with alternate feet	❑ Low step Step Height: _____	❑ Unstable surface (e.g. dense foam)	6 multi-directional push/pull				
Rapid tap-ups forward with alternate feet	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				
Rapid tap-ups to alternate sides	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				

HR: _____ BP: _____ ***Overall rating of perceived challenge*:** _____

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Quasi-mobile' tasks: Session 6

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Rapid stepping forward with alternate feet	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid stepping backward with alternate feet	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid stepping to alternate sides	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Walking in place, eyes closed	❑ Feet barely off floor	❑ Knees to hip-height	6 multi-directional push/pull				
'Jogging' (or fast walking) in place	❑ Feet barely off floor	❑ Knees to hip-height	6 multi-directional push/pull				
Rapid diagonal forward stepping with alternate feet	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid stepping with alternate feet in random cued direction	❑ Short steps	❑ Long steps	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
'Jogging' (or fast walking) in place, on a thin foam mat	❑ Feet barely off floor	❑ Knees to hip-height	6 multi-directional push/pull				
Rapid diagonal forward stepping with alternate feet, on a thin foam mat	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Rapid stepping with alternate feet in random cued direction, on a thin foam mat	❑ Short steps	❑ Long steps	6 multi-directional push/pull				

HR: _____ BP: _____ ***Overall rating of perceived challenge*: _____**

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Mobile' tasks: Session 7

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Walking forward	❑ Short steps; walk slowly	❑ Long steps; traffic light	6 multi-directional push/pull				
Walking forward, turning head left and right	❑ Short steps; walk slowly	❑ Long steps; traffic light	6 multi-directional push/pull				
Walking forward, looking up and down	❑ Short steps; walk slowly	❑ Long steps; traffic light	6 multi-directional push/pull				
Walking and stepping over obstacles	❑ Low/short obstacles Define: _____	❑ High/long obstacles Define: _____	6 multi-directional push/pull				
Forward braiding	❑ Walk on the line	❑ Step further across; long steps; traffic light	6 multi-directional push/pull				
Side stepping	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Turning on the spot (alternate between turning to the left and to the right)	❑ Turn slowly	❑ Turn quickly	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Turning on the spot with eyes closed (alternate between turning to the left and to the right)	❑ Turn slowly	❑ Turn quickly	6 multi-directional push/pull				
Turning on the spot, in cued direction	❑ Turn slowly	❑ Turn quickly	6 multi-directional push/pull				
Four square stepping	❑ Short steps	❑ Long steps	6 multi-directional push/pull				

HR: _____ BP: _____ ***Overall rating of perceived challenge*: _____**

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Mobile' tasks: Session 8

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Walking forward	❑ Short steps; walk slowly	❑ Long steps; traffic light	6 multi-directional push/pull				
Walking backward	❑ Short steps; walk slowly	❑ Long steps; traffic light	6 multi-directional push/pull				
Walking forward with eyes closed	❑ Short steps; walk slowly	❑ Long steps; walk quickly	6 multi-directional push/pull				
Tandem walking forward	❑ Not heel-toe; steps close to line	❑ Traffic light	6 multi-directional push/pull				
Side stepping	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Sideways braiding	❑ Steps not fully crossed	❑ Traffic light	6 multi-directional push/pull				
Side stepping over obstacles	❑ Low/short obstacles Define: _____	❑ High/long obstacles Define: _____	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Turning on the spot (alternate between turning to the left and to the right)	❑ Turn slowly	❑ Turn quickly	6 multi-directional push/pull				
Turning on the spot in cued direction	❑ Turn slowly	❑ Turn quickly	6 multi-directional push/pull				
Four square stepping	❑ Short steps	❑ Long steps	6 multi-directional push/pull				

HR: _____ BP: _____ ***Overall rating of perceived challenge*: _____**

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Mobile' Tasks: Session 9

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Walking forward on a thin foam mat	❑ Short steps; walk slowly	❑ Long steps; traffic light	6 multi-directional push/pull				
Walking backward on a thin foam mat	❑ Short steps; walk slowly	❑ Long steps; traffic light	6 multi-directional push/pull				
Side stepping on a thin foam mat	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Four square stepping on a thin foam mat	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Tandem walking forward	❑ Not heel-toe; steps close to line	❑ Traffic light	6 multi-directional push/pull				
Tandem walking backward	❑ Not heel-toe; steps close to line	❑ Traffic light	6 multi-directional push/pull				
Sideways braiding	❑ Steps not fully crossed	❑ Traffic light	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Turning on the spot with eyes closed (alternate between turning to the left and to the right)	❑ Turn slowly	❑ Turn quickly	6 multi-directional push/pull				
Forward braiding	❑ Walk on the line	❑ Step further across; long steps; traffic light	6 multi-directional push/pull				
Walking forward with eyes closed	❑ Short steps; walk slowly	❑ Long steps; walk quickly	6 multi-directional push/pull				

HR: _____ BP: _____ ***Overall rating of perceived challenge:*** _____

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Mobile' tasks: Session 10

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Tandem walking forward	❑ Not heel-toe; steps close to line	❑ Traffic light	6 multi-directional push/pull				
Tandem walking backward	❑ Not heel-toe; steps close to line	❑ Traffic light	6 multi-directional push/pull				
Forward braiding	❑ Walk on the line	❑ Step further across; long steps; traffic light	6 multi-directional push/pull				
Backward braiding	❑ Walk on the line	❑ Step further across; long steps; traffic light	6 multi-directional push/pull				
Tandem walking forward on a thin foam mat	❑ Not heel-toe; steps close to line	❑ Traffic light	6 multi-directional push/pull				
Tandem walking backward on a thin foam mat	❑ Not heel-toe; steps close to line	❑ Traffic light	6 multi-directional push/pull				
Forward braiding on a thin foam mat	❑ Walk on the line	❑ Step further across; long steps; traffic light	6 multi-directional push/pull				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Backward braiding on a thin foam mat	❑ Walk on the line	❑ Step further across; long steps; traffic light	6 multi-directional push/pull				
Sideways braiding on a thin foam mat	❑ Steps not fully crossed	❑ Traffic light	6 multi-directional push/pull				
Turning on the spot with eyes closed in cued direction	❑ Turn slowly	❑ Turn quickly	6 multi-directional push/pull				

HR: _____ BP: _____ ***Overall rating of perceived challenge*: _____**

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Mobile & Unpredictable' Tasks: Session 11

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Kicking soccer ball against wall	[none]	❑ Stand further from wall; kick outside BOS; kick with each leg	6 perturbations: PT attempts to take ball, nudges participant				
Throwing hand ball against a wall	❑ Large ball	❑ Small ball; stand further from wall; throw with each arm	6 perturbations: PT attempts to take ball, nudges participant				
Kicking soccer ball against wall, standing on a thin foam mat	[none]	❑ Stand further from wall; kick outside BOS; kick with each leg	6 perturbations: PT attempts to take ball, nudges participant				
Throwing hand ball against a wall, standing on a thin foam mat	❑ Large ball	❑ Small ball; stand further from wall; throw with each arm	6 perturbations: PT attempts to take ball, nudges participant				
Walking with sudden stops and changes in direction	❑ Walk slowly	❑ Walk quickly	6 multi-directional push/pull/trip				
Move to different corners of the room	❑ Walk slowly	❑ Walk quickly	6 multi-directional push/pull/trip				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Walking with sudden stops and changes in direction, obstacles around the room	❑ Walk slowly	❑ Walk quickly	6 multi-directional push/pull/trip				
Move to different corners of the room, obstacles around the room	❑ Walk slowly	❑ Walk quickly	6 multi-directional push/pull/trip				
Four square stepping to unpredictable cued direction	❑ Short steps	❑ Long steps	12 multi-directional push/pull/trip				
'Dodgeball'	❑ Ball thrown at upper body	❑ Ball thrown rapidly at feet	internal				

HR: _____ BP: _____ ***Overall rating of perceived challenge:*** _____

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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'Mobile & unpredictable' tasks: Session 12

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Kicking soccer ball back and forth with physiotherapist	❑ Within reach; kicked slowly	❑ Step to reach; kicked quickly	internal				
Throwing ball back and forth with physiotherapist	❑ Large ball; within reach	❑ Small ball; step to reach	internal				
Kicking soccer ball with physiotherapist, standing on a thin foam mat	❑ Within reach; kicked slowly	❑ Step to reach; kicked quickly	internal				
Throwing ball with physiotherapist, standing on a thin foam mat	❑ Large ball; within reach	❑ Small ball; step to reach	internal				
Walking with sudden stops and changes in direction	❑ Walk slowly	❑ Walk quickly	12 multi-directional push/pull/trip				
Move to different corners of the room	❑ Walk slowly	❑ Walk quickly	12 multi-directional push/pull/trip				
Walking with sudden stops and changes in direction, obstacles around the room	❑ Walk slowly	❑ Walk quickly	12 multi-directional push/pull/trip				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Move to different corners of the room, obstacles around the room	❑ Walk slowly	❑ Walk quickly	12 multi-directional push/pull/trip				
Four square stepping to unpredictable cued direction	❑ Short steps	❑ Long steps	12 multi-directional push/pull/trip				
'Dodgeball'	❑ Ball thrown at upper body	❑ Ball thrown rapidly at feet	internal				

HR: _____ BP: _____ ***Overall rating of perceived challenge:*** _____

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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Booster sessions

Initial - HR: **BP:**	**Repeat 1 - HR:** **BP:**	**Repeat 2 - HR:** **BP:**

Voluntary task	**Adaptation to reduce difficulty**	**Adaptation to increase difficulty**	**Perturbation**	**Outcome** (0=≤2 steps, 1=multi step, X=loss of balance)	**RPC**	**# Rests during task**	**Rest after task (Y/N)**
Standing still with feet hip-width apart, eyes closed	❑ Wide base of support	❑ Feet together	6 multi-directional lean-and-release				
Rapid tap-ups forward with alternate feet	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				
Rapid tap-ups to alternate sides	❑ Low step Step Height: _____	❑ Unstable surface (e.g. soccer ball)	6 multi-directional push/pull				
Rapid stepping with alternate feet in random cued direction	❑ Short steps	❑ Long steps	6 multi-directional push/pull				
Turning on the spot, in cued direction	❑ Turn slowly	❑ Turn quickly; eyes closed	6 multi-directional push/pull				
Side stepping/braiding	❑ Short steps	❑ Long steps; thin foam mat	6 multi-directional push/pull/trip				
Forward tandem/braiding	❑ Steps close to line	❑ Long steps; thin foam mat	6 multi-directional push/pull/trip				

Voluntary task	Adaptation to reduce difficulty	Adaptation to increase difficulty	Perturbation	Outcome (0=≤2 steps, 1=multi step, X=loss of balance)	RPC	# Rests during task	Rest after task (Y/N)
Backward tandem/braiding	❑ Steps close to line	❑ Long steps; thin foam mat	6 multi-directional push/pull/trip				
Walking with sudden stops and changes in direction, obstacles around the room	❑ Walk slowly	❑ Walk quickly	6 multi-directional push/pull/trip				
Kicking soccer ball against wall	[none]	❑ Kick outside BOS; on thin foam mat	6 perturbations: PT attempts to take ball, nudges participant				

HR: _____ BP: _____ ***Overall rating of perceived challenge:*** _____

TOTALS/AVERAGES	0= 1= X=				

Overall comments for the session: _____

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5. TASK DESCRIPTIONS

Types of external perturbations

1) Lean and release

a. Forward-directed lean-and-release perturbation. The participant stands facing the physiotherapist, leaning forward with some of his body weight supported by the physiotherapist. He should be leaning far enough forward that his shoulders and hips are ahead of his toes; however, smaller lean angles can be used with more impaired individuals. The physiotherapist's hands are on the participants' shoulders. At an unexpected time, the physiotherapist releases her hands and the participant starts to fall forward, requiring a step to regain stability. The goal is for the participant to take as few steps as possible to recover.

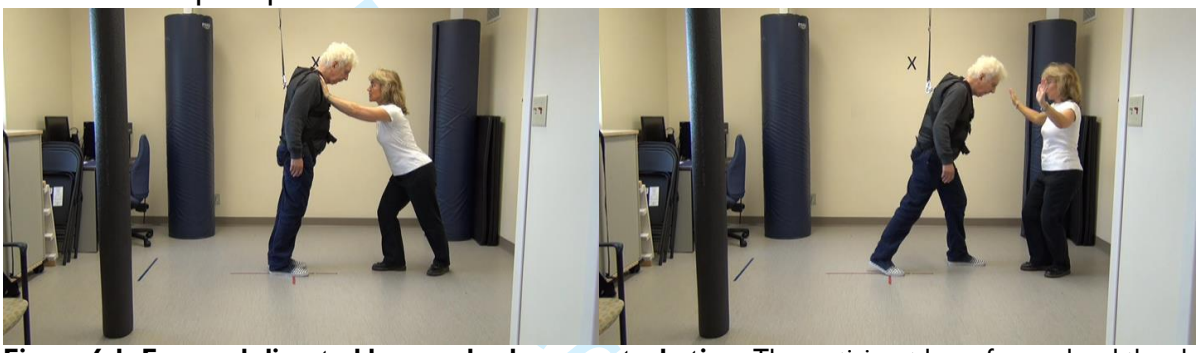


Figure 6.1. Forward-directed lean-and-release perturbation. The participant leans forward and the physiotherapist supports his weight (left). The physiotherapist releases her support and the participant steps to recover his balance (right).

b. Backward-directed lean-and-release perturbation. The participant stands in front of and facing away from the physiotherapist, leaning backward with some of his body weight supported by the physiotherapist. He should be leaning far enough backward that his shoulders and hips are behind his heels; however, smaller lean angles can be used with more impaired individuals. The physiotherapist's hands are on the participants' shoulders. At an unexpected time, the physiotherapist releases her hands and the participant starts to fall backward, requiring a step to regain stability. The goal is for the participant to take as few steps as possible to recover upright standing balance.

Figure 6.2. Backward-directed lean-and-release perturbation. The participant leans backward and the physiotherapist supports his weight (left). The physiotherapist releases her support and the participant steps to recover his balance (right).

c. Lateral-directed lean-and-release perturbation. The participant stands with his feet close together, leaning to the right (or left) with some of his body weight supported by the physiotherapist's hands. He should be leaning far enough to the right (or left) that the midline of the pelvis is aligned over the right (or left) foot; however, smaller lean angles can be used with more impaired individuals. The physiotherapist's hands are on the participant's right (or left) shoulder and

right (or left) hip. At an unexpected time, the physiotherapist releases her hands and the participant starts to fall to the right (or left), requiring a step to regain stability. The goal is for the participant to take as few steps as possible to recover balance.

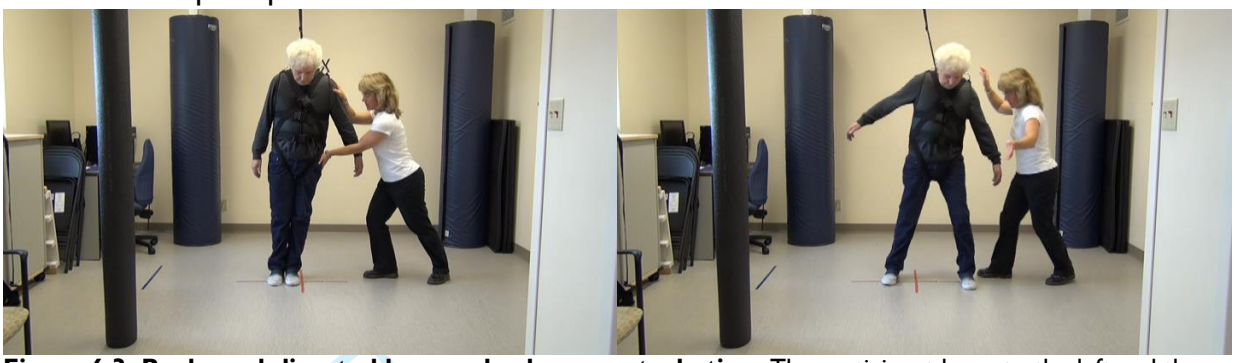


Figure 6.3. Backward-directed lean-and-release perturbation. The participant leans to the left and the physiotherapist supports his weight (left). The physiotherapist releases her support and the participant steps to recover his balance (right).

2) Multi-directional push/pull/trip

a. Multidirectional push. The physiotherapist places her hands on the participant's hips or shoulders and pushes him forward, requiring a reactive step to regain stability. Alternatively, one of the physiotherapist's hands could be on the hip and the other on the shoulder; a push forward at the level of one scapula would facilitate a diagonal reactive step. In all scenarios, the physiotherapist should be ready to assist with the recovery, if necessary, by having a light hold of the safety harness. The physiotherapist should only provide assistance if the participant is unable to regain stability independently; this is true with every reaction. Note that backward-directed pushes are not performed.

Figure 6.4. Forward-directed push perturbation. The physiotherapists' hands may be placed at the hips (top images) or with one hand on the hips and one on the shoulders.

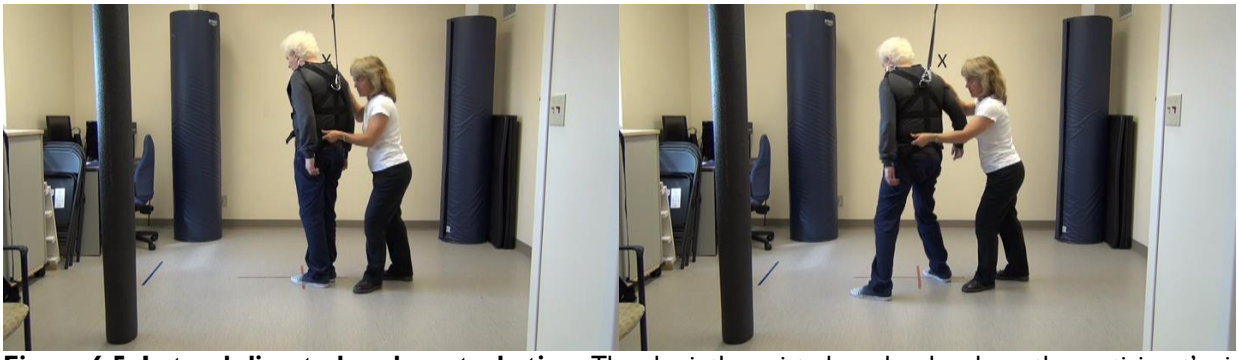


Figure 6.5. Lateral-directed push perturbation. The physiotherapist places her hands on the participant's right (or left) hip or shoulder and pushes him to the left (or right), requiring a reactive step to regain stability.

b. Multi-directional pull perturbation. The physiotherapist may pull the participant's shoulders or pull on the harness to cause the participant to start to fall forward, requiring a reactive step to regain stability.

Figure 6.6. Forward-directed pull perturbation. The physiotherapist places her hands on the participant's shoulders (top) or pulls on the harness (bottom).

Figure 6.7. Backward-directed pull perturbation. The physiotherapist uses the shoulders, hips, or harness to pull the participant backward, requiring a reactive step to regain stability.

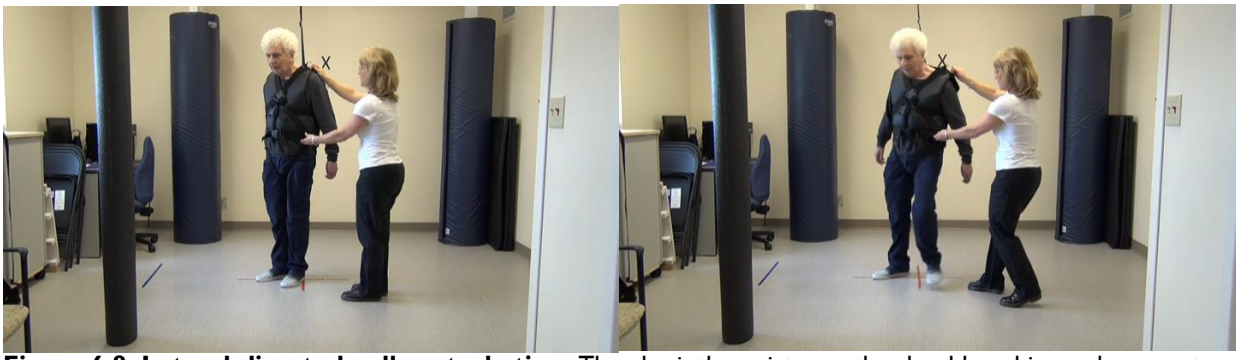


Figure 6.8. Lateral-directed pull perturbation. The physiotherapist uses the shoulders, hips or harness, to pull the participant to the right (or left), requiring a reactive step to regain stability.

c. Trip perturbation while walking. As the participant walks (forward, backward, sideways), the physiotherapist places her foot in the path of the swing limb causing a trip. A reactive step is required to regain stability. A second person is recommended in this scenario as it is difficult for the physiotherapist doing the tripping to be in a place to provide support should it be needed.

Figure 6.9. Trip perturbation. The physiotherapist catches the participants' limb with her foot while walking.

Descriptions of voluntary tasks

Standing still with feet hip-width apart – participant stands unassisted with the eyes open and the feet positioned as wide as the hips. The lean-and-release perturbations are performed in random directions (forward, backward and lateral).

Adaptation to reduce difficulty – have participant adopt a wider base of support (BOS)
Adaptation to increase difficulty – have participant stand with the feet together
Progressions of this task:
Eyes closed – if participant is unable, the lights in the room should be dimmed (alternatively, dark sunglasses may be worn)
Standing on a thin foam mat
Standing on a thick foam mat
Turning head to the right and left – to spot a target
Looking up and down – to spot a target
Counting backwards by 3's – from a random number given by physiotherapist
Eyes closed and counting backwards – as written above, but combined

Rapid weight-shifting left and right – participant shifts his body weight from one foot to the other as quickly as possible, and the feet remain in contact with the floor. The task is repeated until all perturbations are accomplished.

Adaptation to reduce difficulty – have participant adopt a wider BOS

Adaptation to increase difficulty – have participant stand with the feet together

Rapid weight-shifting forward and backward –participant stands with feet either 'side-by-side' or in a 'stride position' and shifts his body weight forward and backward; if feet are 'side-by-side' then body weight rocks from toes to heels and back; if feet are in stride then body weight transfers from one foot to the other as quickly as possible; part of each foot always remains in contact with the floor. The task is repeated until all perturbations are accomplished.

Adaptation to reduce difficulty –have participant adopt a wider BOS, with the feet either side-by-side or in stride

Adaptation to increase difficulty – have participant stand with the feet together (if side-by-side) or with the feet in tandem (if in stride position)

Throwing and catching a ball – if the participant has use of both arms he should catch and throw a ball back and forth with the physiotherapist; if the participant has functional use of only one arm he should hit a ball back that has been thrown by the physiotherapist.

Adaptation to reduce difficulty – have participant adopt a wider BOS

Adaptation to increase difficulty – have participant stand with the feet together

Rapid arm raises forward and to the sides – participant raises one arm, then both arms, to 90 degrees of shoulder flexion as quickly as possible and stops as quickly as possible; participant raises two arms, then one arm at a time, to 90 degrees of shoulder abduction as quickly as possible and stops as quickly as possible.

Adaptation to reduce difficulty – have participant adopt a wider BOS

Adaptation to increase difficulty – have participant stand with the feet together

Rapid stepping forward with alternate feet – participant steps forward as quickly as possible with the right foot then returns it to the starting position, then steps forward as quickly as possible with the left foot, and then returns it to the starting position; there should be a transfer of body weight to the stepping foot once it touches down in the forward position. The task is repeated until all perturbations are accomplished.

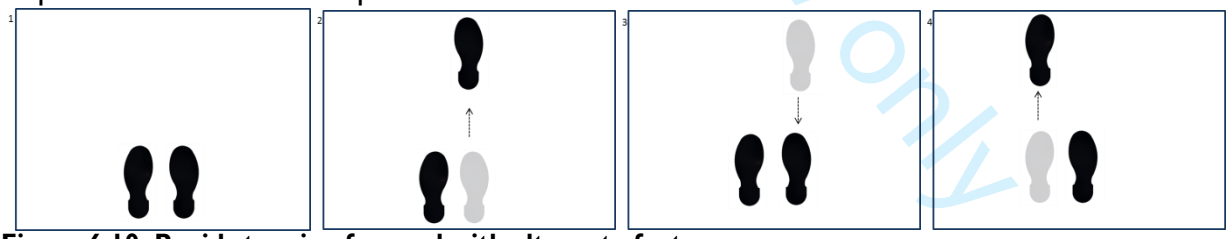


Figure 6.10. Rapid stepping forward with alternate feet

Adaptation to reduce difficulty – have participant take short steps

Adaptation to increase difficulty – have participant take long steps

Progressions of this task:

Standing on a thin foam mat

Rapid stepping backward with alternate feet – participant steps backward as quickly as possible with the right foot, then returns it to the starting position, then steps backward as quickly as possible with the left foot, and then returns it to the starting position; there should be a transfer of body weight to the stepping foot once it touches down in the backward position. The task is repeated until all perturbations are accomplished.

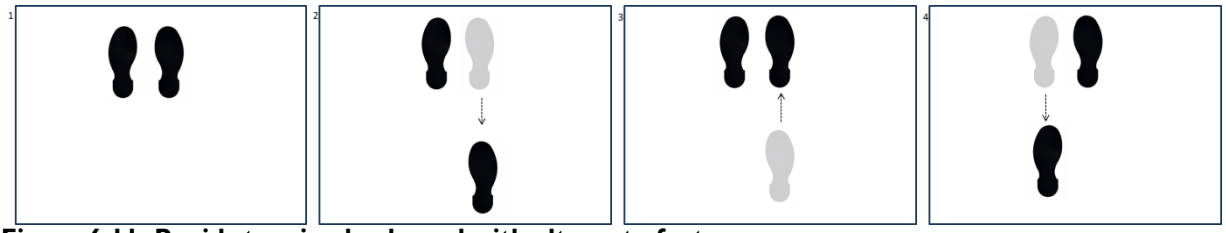


Figure 6.11. Rapid stepping backward with alternate feet

Adaptation to reduce difficulty – have participant take short steps
Adaptation to increase difficulty – have participant take long steps
Progressions of this task:
Standing on a thin foam mat

Rapid stepping to the right (right foot) – participant steps with the right foot to the right as quickly as possible, then back to the starting position; there should be transfer of body weight to the right foot once it touches down in the lateral position. The task is repeated until all perturbations are accomplished.

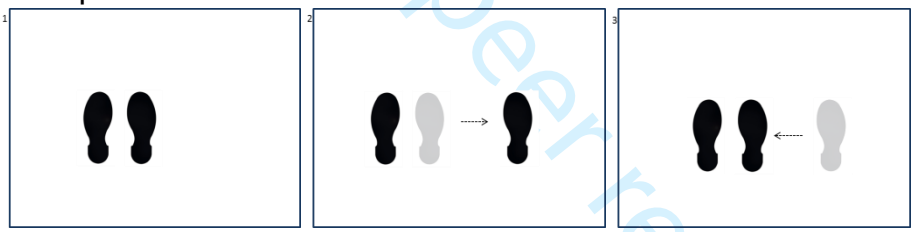


Figure 6.12. Rapid stepping to the right (right foot)

Adaptation to reduce difficulty – have participant take short steps
Adaptation to increase difficulty – have participant take long steps

Rapid stepping to the left (left foot) – participant steps with the left foot to the left as quickly as possible, then back to the starting position; there should be transfer of body weight to the left foot once it touches down in the lateral position. The task is repeated until all perturbations are accomplished.

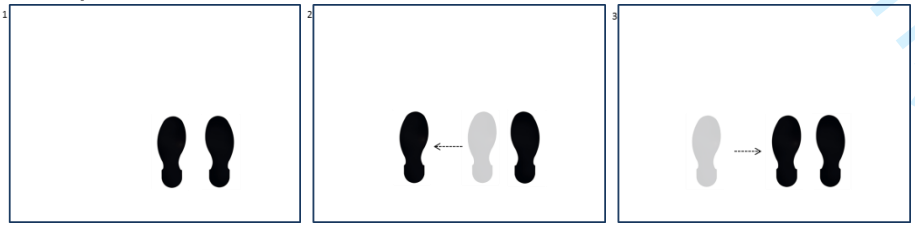


Figure 6.13. Rapid stepping to the left (left foot)

Adaptation to reduce difficulty – have participant take short steps
Adaptation to increase difficulty – have participant take long steps

Rapid stepping to alternate sides– participant steps with the right foot to the right as quickly as possible (including body weight transfer), then back to the starting position; then he steps with the left foot to the left as quickly as possible (including body weight transfer), then back to the starting position. The task is repeated until all perturbations are accomplished.

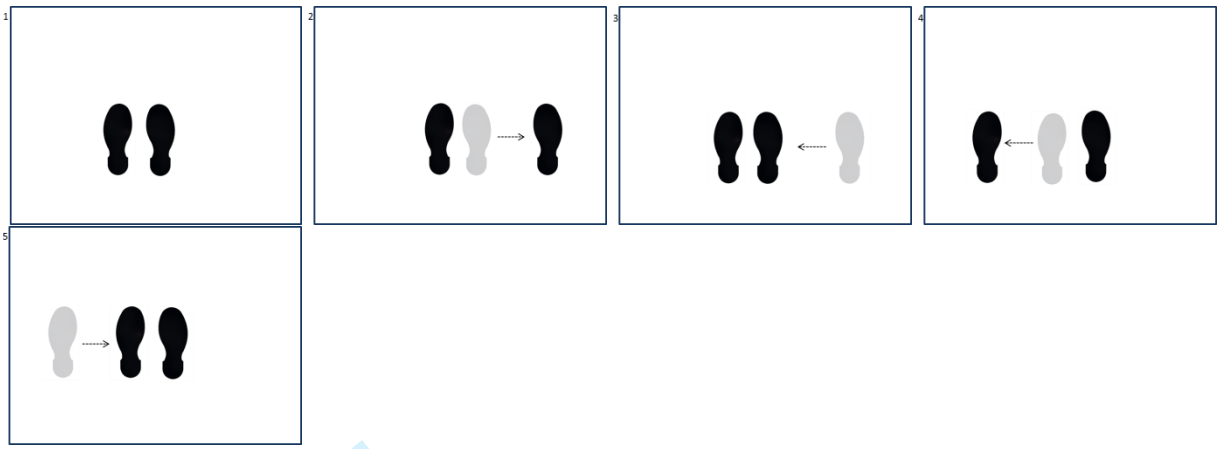


Figure 6.14. Rapid stepping to alternate sides

Adaptation to reduce difficulty – have participant take short steps
Adaptation to increase difficulty – have participant take long steps
Progressions of this task:
Standing on a thin foam mat

Rapid tap-ups forward with alternate feet – participant stands with a step in front of his feet; he lifts up the right foot and lightly touches the step, then places it back on the floor; then he lifts up the left foot and lightly touches the step, then places it back on the floor. The goal is to maintain the body weight over the stance limb, i.e. no transfer of body weight forward. The task is repeated until all perturbations are accomplished.

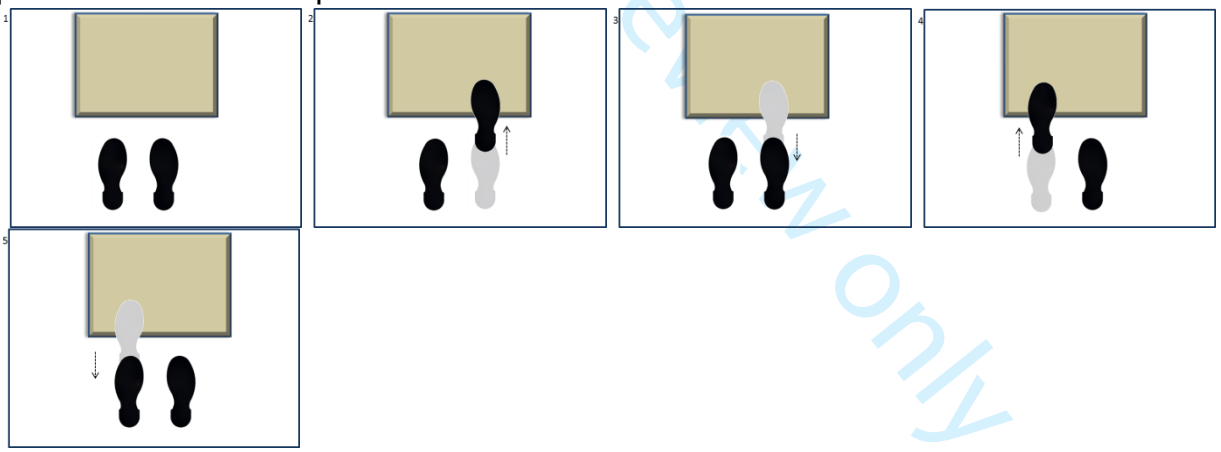


Figure 6.15. Rapid tap-ups forward with alternate feet

Adaptation to reduce difficulty – have participant tap-up to a low step
Adaptation to increase difficulty – have participant tap-up to an unstable surface, e.g. a soccer ball
Progressions of this task:
Standing on a thin foam mat

Walking in place – participant alternates stepping with the right and the left foot. The participant should not move from the spot, though a small amount of 'drift' is typical. The task is repeated until all perturbations are accomplished.
Adaptation to reduce difficulty – have participant step with minimal height from floor

Adaptation to increase difficulty – have participant step with maximum height from floor, i.e. knees raised to hip-height

Progressions of this task:

Walking on the spot on a thin foam mat

Eyes closed – if participant is unable, the lights in the room should be dimmed

Increased speed to 'jogging', or fast walking, on the spot

Jogging, or fast walking, on the spot on a thin foam mat

Rapid stepping forward and backward with the right foot – participant shifts his body weight to the left foot and then steps forward with the right foot, shifting some body weight forward but not enough to completely unweight the left; then the participant shifts his body weight back to the left foot in order to take a full step as far backward as possible with the right foot, and accepts some body weight on the right. The task is repeated until all perturbations are accomplished.

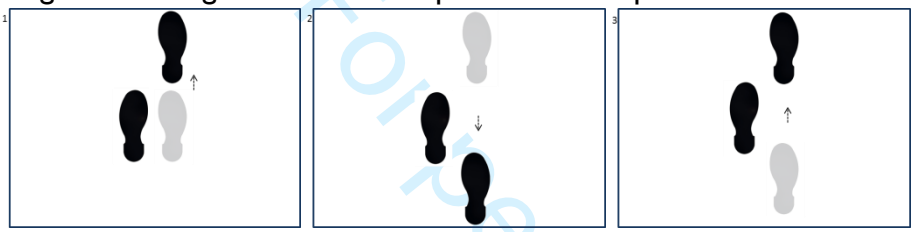


Figure 6.16. Rapid stepping forward and backward with the right foot

Adaptations to reduce difficulty – have participant take short steps; have participant rest momentarily between transitioning from front to back or from back to front

Adaptation to increase difficulty – have participant take long steps

Progressions of this task:

Standing on a thin foam mat

Rapid stepping forward and backward with the left foot – participant shifts his body weight to the right foot and then steps forward with the left foot, shifting some body weight forward but not enough to completely unweight the right; then the participant shifts his body weight back to the right foot in order to take a full step as far backward as possible with the left foot, and accepts some body weight on the left. The task is repeated until all perturbations are accomplished.

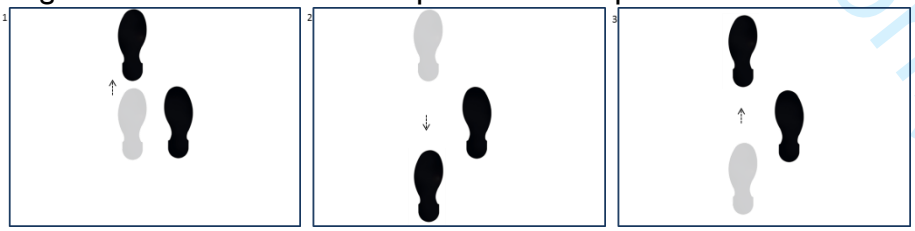


Figure 6.17. Rapid stepping forward and backward with the left foot

Adaptations to reduce difficulty – have participant take short steps; have participant rest momentarily between transitioning from front to back or from back to front

Adaptation to increase difficulty – have participant take long steps

Progressions of this task:

Standing on a thin foam mat

Rapid step-ups with alternate feet - participant stands with a step in front of his feet; he steps up onto the step with the right foot, shifts his body weight forward and steps up with the left foot, placing it on the step in a comfortably-wide position; then he steps down with the right foot, shifts his

body weight back onto the right foot and steps down with the left. The process is repeated with the right foot leading until 3 perturbations are completed; then the left leads until the final 3 perturbations are completed.

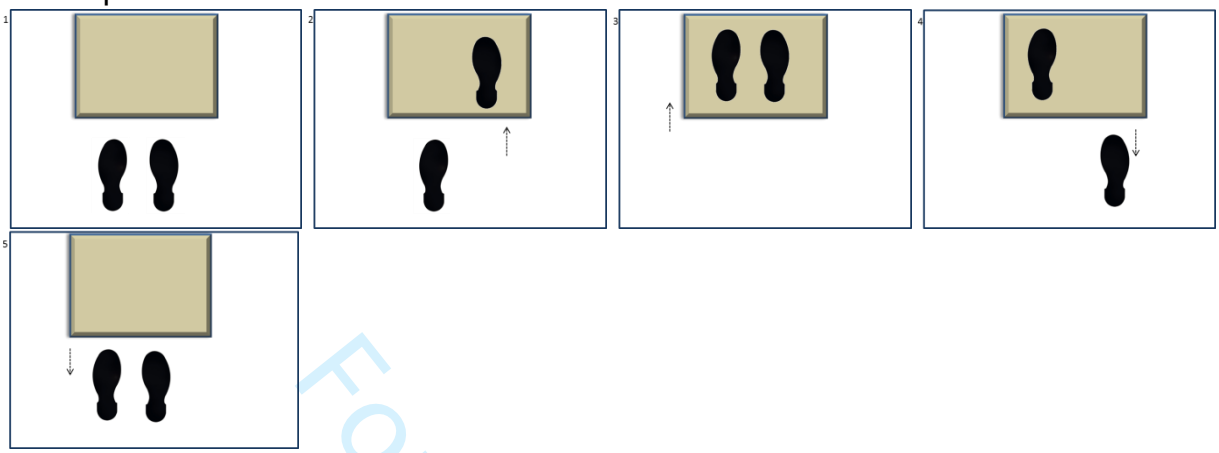


Figure 6.18. Rapid step-ups with alternate feet

Adaptation to reduce difficulty – have participant step-up to a low step
Adaptation to increase difficulty – have participant step-up to an unstable surface, for e.g., a step placed on a thin foam mat, or thick foam pad
Progressions of this task:
Standing on a thin foam mat – i.e. the person is standing on the mat, but the step may be on a hard surface, depending on the adaptation for difficulty

Rapid tap-ups to alternate sides – participant stands with a step lateral to each foot; he lifts up the right foot and lightly touches the step on the right, then places it back on the floor; then lifts up the left foot and lightly touches the step on the left, then places it back on the floor. The goal is to maintain the body weight over the stance limb, i.e., no transfer of body weight to the side tapping-up. The task is repeated until all perturbations are accomplished.

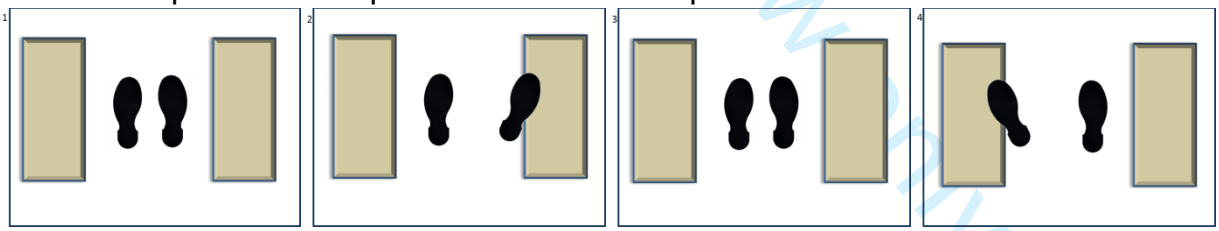


Figure 6.19. Rapid tap-ups to alternate sides

Adaptation to reduce difficulty – have participant tap-up to a low step
Adaptation to increase difficulty – have participant tap-up to an unstable surface, e.g. a soccer ball
Progressions of this task:
Standing on a thin foam mat – i.e. the person is standing on the mat, but the step/obstacle may be on a hard surface, depending on the adaptation for difficulty

Rapid diagonal forward stepping with alternate feet – participant steps diagonally forward (a 45° angle) as quickly as possible with the right foot, then returns it to the starting position, then steps diagonally forward as quickly as possible with the left foot, then returns it to the starting position; there should be a transfer of body weight to the stepping foot once it touches down in the diagonal position. The task is repeated until all perturbations are accomplished.

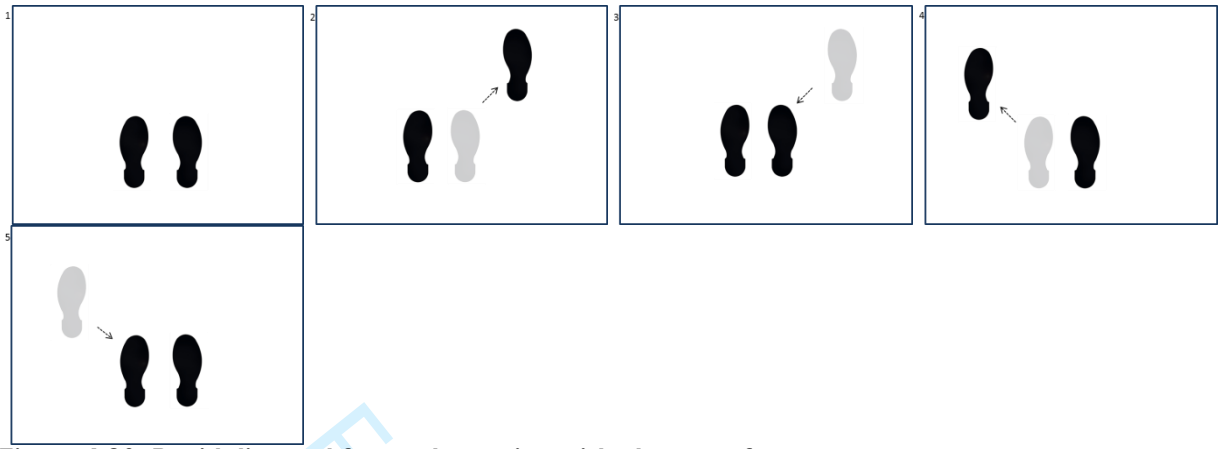


Figure 6.20. Rapid diagonal forward stepping with alternate feet

Adaptation to reduce difficulty – have participant take short steps
Adaptation to increase difficulty – have participant take long steps
Progressions of this task:
Standing on a thin foam mat

Rapid stepping with alternate feet in random physiotherapist-cued directions – participant stands in the centre of 6 targets placed on the floor (e.g., different colored Agility Dots); physiotherapist calls out a color and the participant steps to the colored dot with one foot (transferring some body weight) and then returns that foot to the centre; the process repeats with the next randomly called color. The task is repeated until all perturbations are accomplished.

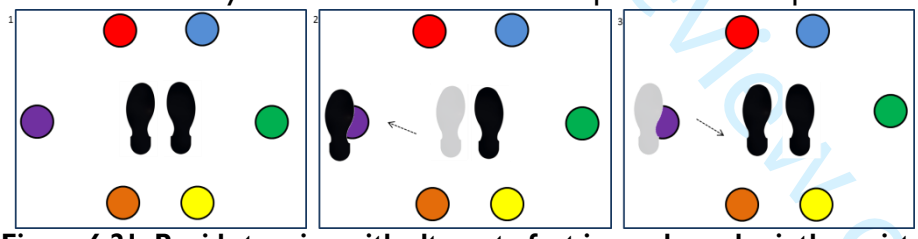


Figure 6.21. Rapid stepping with alternate feet in random physiotherapist-cued directions

Adaptation to reduce difficulty – targets require short steps
Adaptation to increase difficulty – targets require long steps
Progressions of this task:
Standing on a thin foam mat

Walking forward – participant takes steps to travel in a forward direction. Walking continues until all perturbations are accomplished.

Adaptations to reduce difficulty – have participant take short steps, or walk slowly
Adaptation to increase difficulty – have participant take long steps; traffic light*
Progressions of this task:
Turning head to the right and left – to spot a target
Looking up and down – to spot a target
Stepping over obstacles –e.g. pool noodles

* Traffic Light = participant walks at a fast pace like he would if crossing a street; physiotherapist counts down like the traffic light would in the crosswalk

Eyes closed – if participant is unable, the lights in the room should be dimmed
Walking on a thin foam mat

Forward braiding – participant takes a step forward with the right foot that crosses the midline path and lands lateral to, and slightly ahead of, the left foot; then he brings the left foot out and around the right foot, taking a step across the midline path that lands lateral to, and slightly ahead of, the right foot; then the process repeats until all perturbations are accomplished.

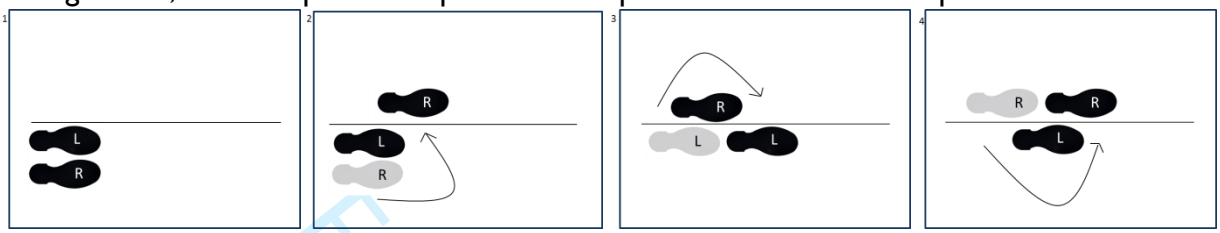


Figure 6.22. Forward braiding

Adaptation to reduce difficulty – walk on the line
Adaptations to increase difficulty - increase distance of step across line; take bigger steps; increase the walking speed
Progressions of this task:
Walking on a thin foam mat

Side stepping – participant stands on left side of room; he takes a step to the right with the right foot, followed by a step to the right (medially) with the left foot; the stepping continues until the edge of the room/available space is reached; then, starting from the right side of the room, he will walk in the opposite direction – left foot steps to left, followed by right foot stepping to left. Stepping continues until all perturbations are accomplished.

Figure 6.23. Side stepping

Adaptation to reduce difficulty – have participant take short steps
Adaptation to increase difficulty – have participant take long steps
Progressions of this task:
Stepping over obstacles –e.g. pool noodles
Walking on a thin foam mat

Turning on the spot, alternating to the right and left – participant takes steps to turn continuously in a clockwise direction. After a few turns (or 3 perturbations) the participant changes direction and turns counter-clockwise (until the final 3 perturbations are completed).

Adaptation to reduce difficulty – have participant turn slowly
Adaptations to increase difficulty – have participant turn quickly
Progressions of this task:
Eyes closed – if participant is unable, the lights in the room should be dimmed
Cued direction – physiotherapist calls out 'right' or 'left' and the participant turns in the direction called; it may be the same direction or a change in direction
Cued and Eyes closed – as written above but combined

Four square stepping – using tape, a cross is marked out on the floor creating 4 squares; participant stands in the bottom right-hand square facing forward; he is asked to step forward over the line with one foot then the other into the top right-hand square; then to step sideways, over the tape with the left foot and then the right into the top left-hand square; then to step backwards with one foot and then the other into the bottom left-hand square; and then finally, to step sideways with the right foot, then the left into the bottom right-hand square. He does that pattern a few times (or 3 perturbations) and then switches directions, moving in a clockwise pattern (until the final 3 perturbations are completed).

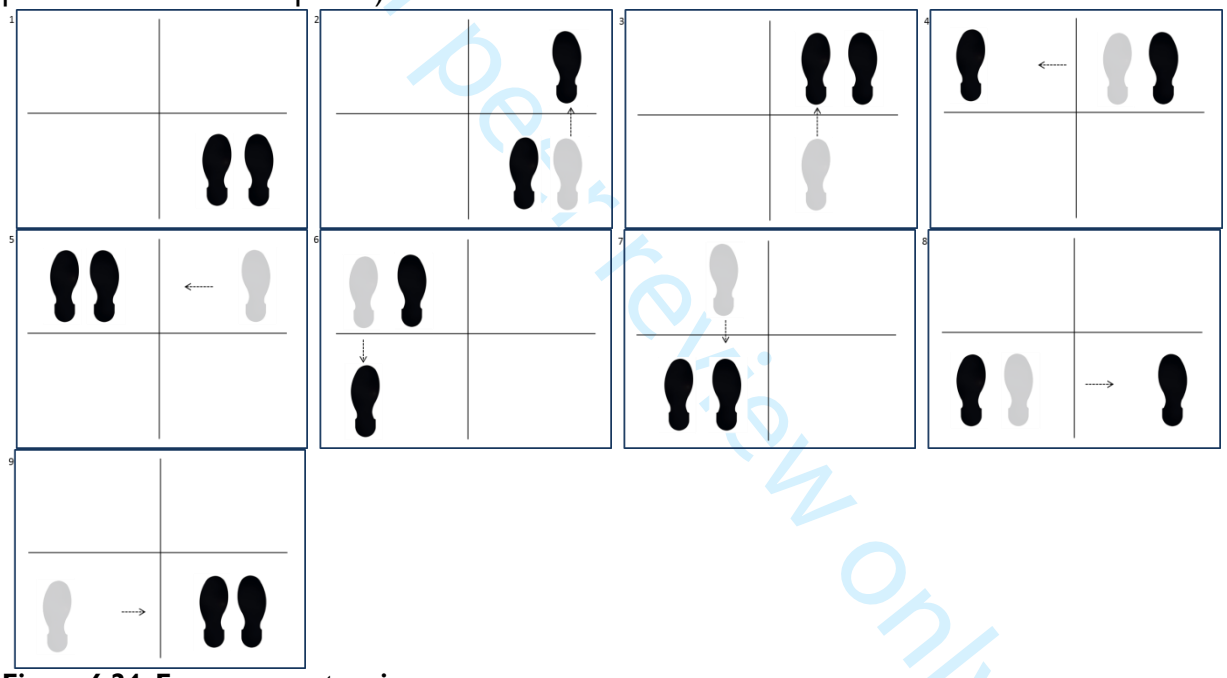


Figure 6.24. Four square stepping

Adaptation to reduce difficulty – have participant take short steps over the lines
Adaptation to increase difficulty – have participant take long steps over the lines
Progressions of this task:
Stepping on a thin foam mat
Cued direction – physiotherapist calls out 'change' or 'switch' and the participant begins moving in the opposite direction

Walking backward – participant takes steps to travel in a backward direction. Walking continues until all perturbations are accomplished.
Adaptation to reduce difficulty – have participant take short steps, or walk slowly
Adaptation to increase difficulty – have participant take long steps; traffic light
Progressions of this task:
Walking on a thin foam mat

Tandem walking forward - participant takes a step forward with the right foot and places the right heel ahead of the left toes; then he brings the left foot out and around the right foot, and places the left heel ahead of the right toes; then the process repeats until all perturbations are completed.

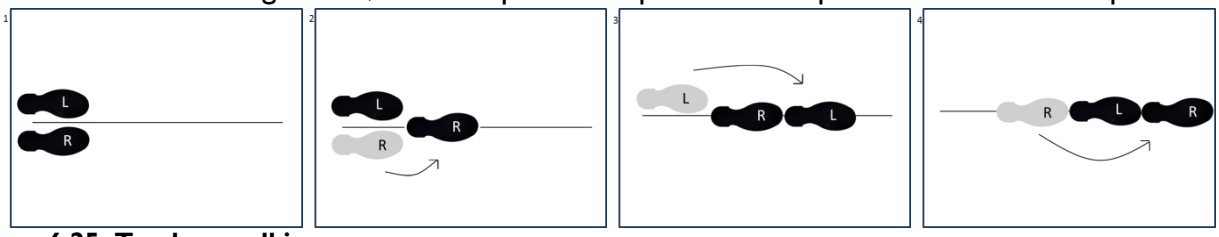


Figure 6.25. Tandem walking

Adaptations to reduce difficulty – participant takes longer steps (i.e. heel and toes don't touch) or participant places feet close to the line but not on the line
Adaptation to increase difficulty – traffic light
Progressions of this task:
Walking on a thin foam mat

Sideways braiding – participant stands at the right edge of the room; he is asked to walk to the left; he takes a step with the right foot that crosses over the left foot and lands lateral to, and slightly ahead of, the left foot, with part of his foot on the midline; then he brings the left foot out from behind the right and steps to the left, landing on the midline; then he takes a step with the right foot that crosses behind the left foot and lands lateral to, and slightly behind, the left foot, with part of his foot on the midline; then he takes the left foot over the right foot and steps to the left; and then the process repeats until he walks as far as he possibly can within the available space. Then he is asked to do the opposite and walk to the right. This pattern continues until all perturbations are accomplished.

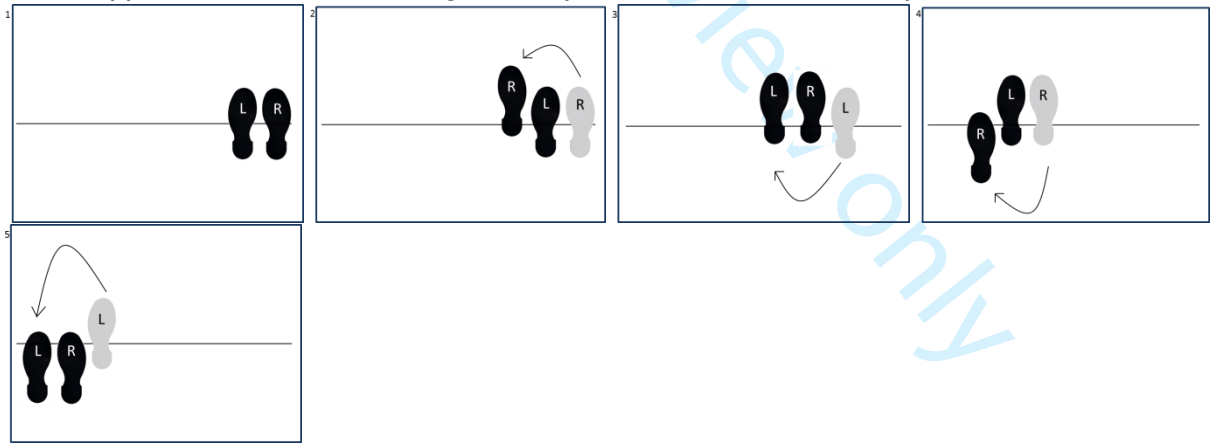


Figure 6.26. Sideways braiding

Adaptations to reduce difficulty – participant's foot does not fully cross over or behind the stance foot; or, participant's foot crosses but does not come into contact with midline
Adaptation to increase difficulty – traffic light
Progressions of this task:
Walking on a thin foam mat

Tandem walking backward - participant takes a step backward with the right foot and places the right toes behind the left heel; then he brings the left foot out and around the right foot, and places the left toes behind the right heel; then the process repeats until all perturbations are completed.

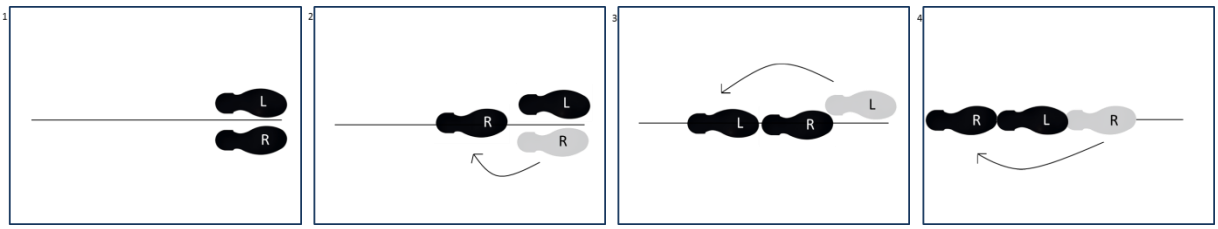


Figure 6.27. Tandem walking backward

Adaptations to reduce difficulty – participant takes longer steps (i.e. heel and toes don't touch) or participant places feet close to the line but not on the line
Adaptation to increase difficulty – traffic light
Progressions of this task:
Walking on a thin foam mat

Backward braiding – participant takes a step backward with the right foot that crosses the midline path and lands lateral to, and slightly behind, the left foot; then he brings the left foot out and around the right foot, taking a step backwards across the midline path that lands lateral to, and slightly behind, the right foot; then the process repeats until all perturbations are accomplished.

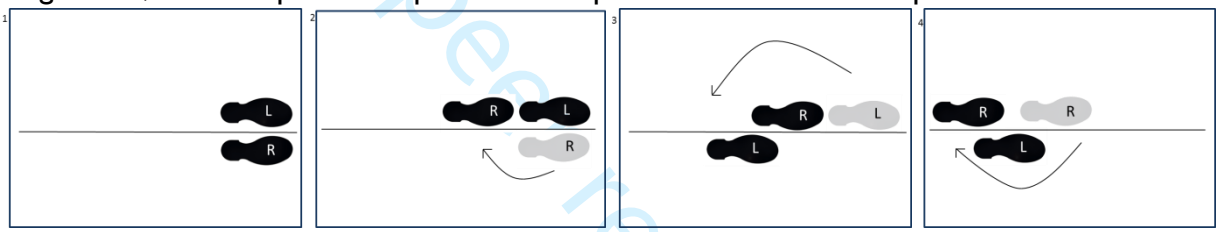


Figure 6.28. Backward braiding

Adaptation to reduce difficulty – walking on the line
Adaptations to increase difficulty - increase distance of step across line; take longer steps; traffic light
Progressions of this task:
Walking on a thin foam mat

Kicking a soccer ball against wall – participant stands at least 1 metre away from a wall; he kicks a soccer ball with enough force that it bounces back to him from the wall; he receives the ball and kicks it again. The task is repeated until all perturbations are accomplished.

Adaptation to reduce difficulty – none
Adaptations to increase difficulty – have participant stand further away from the wall; have participant kick it outside of his base of support; have participant alternate kicking with each foot
Progressions of this task:
Standing on a thin foam mat
Kicking the ball to the physiotherapist and receiving it back; this may require moving to reach the ball
Kicking the ball with the physiotherapist while standing on a thin foam mat

Throwing a handball against the wall – participant stands at least 1 metre away from a wall; he throws a hand ball with enough force that it bounces back to him from the wall; he receives the ball and throws it again. The task is repeated until all perturbations are accomplished.

Adaptation to reduce difficulty – have participant throw a large ball

Adaptations to increase difficulty – have participant throw a small ball; have participant stand further away from the wall; have participant throw the ball with each arm

Progressions of this task:

Standing on a thin foam mat

Throwing the ball to the physiotherapist and receiving it back; this may require moving to catch it

Throwing the ball with the physiotherapist while standing on a thin foam mat

Walking with sudden stops and changes in direction – participant walks forward and at any time, the physiotherapist says 'stop', and the participant has to stop walking quickly, or says 'right' ('left'), and the participant has to turn to the right (left) and continue walking. The task continues until all perturbations are accomplished.

Adaptation to reduce difficulty – have participant walk slowly

Adaptation to increase difficulty – have participant walk quickly

Progressions of this task:

Stepping over obstacles, e.g. pool noodles or steps – the participant has to walk in the frame and manage the obstacles while also stopping or changing direction on command

Move to different corners of the room – participant stands in the centre of the room facing forward; he is asked to move to one corner of the room (marked with different colored Agility Dots or numbers); he walks forward to the corners in front of him, then backward to return to the start position, or he walks backward to the corners behind him, then forward to return to the start position. The task continues until all perturbations are accomplished.

Adaptation to reduce difficulty – have participant walk slowly

Adaptation to increase difficulty – have participant walk quickly

Progressions of this task:

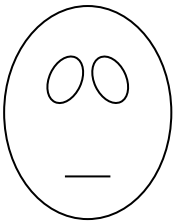
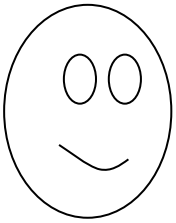
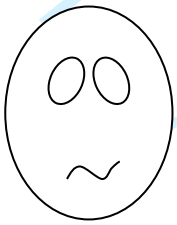
Stepping over obstacles, e.g. pool noodles or steps – the participant has to walk in the frame and manage the obstacles while making his way to the correct pole

Dodgeball – the participant must avoid being hit by the ball that is being thrown at him by the physiotherapist. This requires transfer of weight and reactive stepping.

Adaptation to reduce difficulty – physiotherapist throws ball at upper body

Adaptation to increase difficulty – physiotherapist throws ball rapidly at participant's feet

6. RATING OF PERCEIVED CHALLENGE SCALE

NO CHALLENGE AT ALL		1
A LITTLE BIT OF CHALLENGE		2
SOME CHALLENGE		3
MUCH CHALLENGE		4
CAN NOT DO		5

ADAPTED FROM: DARTHMOUTH COOP FUNCTIONAL ASSESSMENT CHARTS / WONCO (World Organization of Family Doctors) 1995

CONSORT 2010 checklist of information to include when reporting a randomised trial*

Section/Topic	Item No	Checklist item	Reported on page No
Title and abstract			
	1a	Identification as a randomised trial in the title	
	1b	Structured summary of trial design, methods, results, and conclusions (for specific guidance see CONSORT for abstracts)	
Introduction			
Background and objectives	2a	Scientific background and explanation of rationale	
	2b	Specific objectives or hypotheses	
Methods			
Trial design	3a	Description of trial design (such as parallel, factorial) including allocation ratio	
	3b	Important changes to methods after trial commencement (such as eligibility criteria), with reasons	
Participants	4a	Eligibility criteria for participants	
	4b	Settings and locations where the data were collected	
Interventions	5	The interventions for each group with sufficient details to allow replication, including how and when they were actually administered	
Outcomes	6a	Completely defined pre-specified primary and secondary outcome measures, including how and when they were assessed	
	6b	Any changes to trial outcomes after the trial commenced, with reasons	
Sample size	7a	How sample size was determined	
	7b	When applicable, explanation of any interim analyses and stopping guidelines	
Randomisation:			
Sequence generation	8a	Method used to generate the random allocation sequence	
	8b	Type of randomisation; details of any restriction (such as blocking and block size)	
Allocation concealment mechanism	9	Mechanism used to implement the random allocation sequence (such as sequentially numbered containers), describing any steps taken to conceal the sequence until interventions were assigned	
Implementation	10	Who generated the random allocation sequence, who enrolled participants, and who assigned participants to interventions	
Blinding	11a	If done, who was blinded after assignment to interventions (for example, participants, care providers, those	

		assessing outcomes) and how	
	11b	If relevant, description of the similarity of interventions	
Statistical methods	12a	Statistical methods used to compare groups for primary and secondary outcomes	
	12b	Methods for additional analyses, such as subgroup analyses and adjusted analyses	
Results			
Participant flow (a diagram is strongly recommended)	13a	For each group, the numbers of participants who were randomly assigned, received intended treatment, and were analysed for the primary outcome	
	13b	For each group, losses and exclusions after randomisation, together with reasons	
Recruitment	14a	Dates defining the periods of recruitment and follow-up	
	14b	Why the trial ended or was stopped	
Baseline data	15	A table showing baseline demographic and clinical characteristics for each group	
Numbers analysed	16	For each group, number of participants (denominator) included in each analysis and whether the analysis was by original assigned groups	
Outcomes and estimation	17a	For each primary and secondary outcome, results for each group, and the estimated effect size and its precision (such as 95% confidence interval)	
	17b	For binary outcomes, presentation of both absolute and relative effect sizes is recommended	
Ancillary analyses	18	Results of any other analyses performed, including subgroup analyses and adjusted analyses, distinguishing pre-specified from exploratory	
Harms	19	All important harms or unintended effects in each group (for specific guidance see CONSORT for harms)	
Discussion			
Limitations	20	Trial limitations, addressing sources of potential bias, imprecision, and, if relevant, multiplicity of analyses	
Generalisability	21	Generalisability (external validity, applicability) of the trial findings	
Interpretation	22	Interpretation consistent with results, balancing benefits and harms, and considering other relevant evidence	
Other information			
Registration	23	Registration number and name of trial registry	
Protocol	24	Where the full trial protocol can be accessed, if available	
Funding	25	Sources of funding and other support (such as supply of drugs), role of funders	

*We strongly recommend reading this statement in conjunction with the CONSORT 2010 Explanation and Elaboration for important clarifications on all the items. If relevant, we also recommend reading CONSORT extensions for cluster randomised trials, non-inferiority and equivalence trials, non-pharmacological treatments, herbal interventions, and pragmatic trials. Additional extensions are forthcoming: for those and for up to date references relevant to this checklist, see www.consort-statement.org.

TIDieR
Template for Intervention Description and Replication

The TIDieR (Template for Intervention Description and Replication) Checklist*:

Information to include when describing an intervention and the location of the information

Item number	Item	Where located **	
		Primary paper (page or appendix number)	Other † (details)
	BRIEF NAME		
1.	Provide the name or a phrase that describes the intervention.	_____	_____
	WHY		
2.	Describe any rationale, theory, or goal of the elements essential to the intervention.	_____	_____
	WHAT		
3.	Materials: Describe any physical or informational materials used in the intervention, including those provided to participants or used in intervention delivery or in training of intervention providers. Provide information on where the materials can be accessed (e.g. online appendix, URL).	_____	_____
4.	Procedures: Describe each of the procedures, activities, and/or processes used in the intervention, including any enabling or support activities.	_____	_____
	WHO PROVIDED		
5.	For each category of intervention provider (e.g. psychologist, nursing assistant), describe their expertise, background and any specific training given.	_____	_____
	HOW		
6.	Describe the modes of delivery (e.g. face-to-face or by some other mechanism, such as internet or telephone) of the intervention and whether it was provided individually or in a group.	_____	_____
	WHERE		
7.	Describe the type(s) of location(s) where the intervention occurred, including any necessary infrastructure or relevant features.	_____	_____

	WHEN and HOW MUCH		
8.	Describe the number of times the intervention was delivered and over what period of time including the number of sessions, their schedule, and their duration, intensity or dose.	_____	_____
	TAILORING		
9.	If the intervention was planned to be personalised, titrated or adapted, then describe what, why, when, and how.	_____	_____
	MODIFICATIONS		
10.‡	If the intervention was modified during the course of the study, describe the changes (what, why, when, and how).	_____	_____
	HOW WELL		
11.	Planned: If intervention adherence or fidelity was assessed, describe how and by whom, and if any strategies were used to maintain or improve fidelity, describe them.	_____	_____
12.‡	Actual: If intervention adherence or fidelity was assessed, describe the extent to which the intervention was delivered as planned.	_____	_____

** **Authors** - use N/A if an item is not applicable for the intervention being described. **Reviewers** – use '?' if information about the element is not reported/not sufficiently reported.

† If the information is not provided in the primary paper, give details of where this information is available. This may include locations such as a published protocol or other published papers (provide citation details) or a website (provide the URL).

‡ If completing the TIDieR checklist for a protocol, these items are not relevant to the protocol and cannot be described until the study is complete.

* We strongly recommend using this checklist in conjunction with the TIDieR guide (see *BMJ* 2014;348:g1687) which contains an explanation and elaboration for each item.

* The focus of TIDieR is on reporting details of the intervention elements (and where relevant, comparison elements) of a study. Other elements and methodological features of studies are covered by other reporting statements and checklists and have not been duplicated as part of the TIDieR checklist. When a **randomised trial** is being reported, the TIDieR checklist should be used in conjunction with the CONSORT statement (see www.consort-statement.org) as an extension of **Item 5 of the CONSORT 2010 Statement.** When a **clinical trial protocol** is being reported, the TIDieR checklist should be used in conjunction with the SPIRIT statement as an extension of **Item 11 of the SPIRIT 2013 Statement** (see www.spirit-statement.org). For alternate study designs, TIDieR can be used in conjunction with the appropriate checklist for that study design (see www.equator-network.org).