Implementing reactive balance training in rehabilitation practice: a guide for healthcare professionals

UHN Toronto Rehabilitation Institute
The Kite Research Institute

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PUBLICATION INFORMATION

TERMS OF USE

This manual and accompanying toolkit materials were developed to assist clinicians in developing reactive balance training for their clients. The information within the manual and toolkit has been developed based on research evidence, clinical experience, and consensus of local experts at the time of development/publication.

 Feedback or suggestions on this guide can be made directly to the lead author (avril.mansfield@uhn.ca).

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ABBREVIATIONS

RBT = reactive balance training

GLOSSARY

Postural control	The ability to control 'static' posture (e.g., sitting or standing still).
Anticipatory balance control	The ability to control balance (i.e., prevent falling) during voluntary movement.
Balance perturbation	A perturbation is a deviation or disturbance from the normal state. A balance perturbation occurs when there is a disruption to the relationship between the centre of mass and the base of support resulting in a loss of balance. After experiencing a loss of balance, the person will fall if they do not take some corrective action (e.g., a reactive step).
Reactive balance control	The ability to respond to a loss of balance (or balance perturbation), to prevent a fall.
External perturbation	A loss of balance caused by an external force (e.g. push or pull from the physiotherapist).
Internal perturbation	A loss of balance caused by failure of anticipatory balance control during voluntary movement (see toolkit videos for examples).
Fall	"An event that results in a person coming to rest unintentionally on the ground or other lower level".[2]
Reactive balance training	A type of balance training method where patients intentionally experience repeated balance perturbations that require them to execute balance reactions to prevent a fall.
Volitional step training	A type of exercise where the client practices stepping in various directions, but does not necessarily experience a balance perturbation.

1.0 INTRODUCTION

In this chapter

- What is reactive balance control?
- What is reactive balance training?
- What is the evidence for reactive balance training?
- What are the risks with reactive balance training?

1.1 About this guide

This guide describes the reactive balance training (RBT) approach developed at the KITE Research Institute at University Health Network. This approach primarily focuses on improving control of reactive stepping, using internal and manual external perturbations to balance. Versions of this program have been used for rehabilitation of people with stroke, acquired brain injury, and spinal cord injury. Section 1.4 summarizes the current state of the evidence for RBT across different populations. Further details about this RBT approach, including resources to help plan training programs and videos demonstrating training approaches, are available at https://kite-uhn.com/tools/rebal.

RBT must be delivered by appropriately trained and licensed physiotherapists; other qualified healthcare providers might also be able to deliver RBT (e.g., registered kinesiologists, occupational therapists). A comprehensive sensorimotor and balance assessment is required prior to implementing RBT. RBT is deliberately challenging to balance control and there is a chance that participants will be unable to regain stability and fall; appropriate safety precautions should be in place to reduce the risk of injury to the participant (see details within the document). ***The information provided within this document does not replace clinical judgement***.

1.2 What is reactive balance control?

A loss of balance, or balance perturbation, happens when someone loses control of the relationship between the centre of mass and base of support. Reactive balance control is the ability to respond to this loss of balance and prevent a fall.[3] Balance reactions can be classified as 'change-in-support' or 'fixed support' reactions.[4] For change-in-support reactions, the size of the base of support changes to re-capture the falling centre of mass (e.g., stepping or reach-to-grasp reactions). For fixed support reactions, the base of support does not change (e.g., hip or ankle strategy). Change-in-support reactions are very important as they are the only option for responding to a large balance perturbation, and are preferred when people are able to respond freely.[5] Reactive balance control is distinct from anticipatory balance control. Anticipatory balance control is the ability to control balance before and during voluntary movement; for example, shifting weight to the stance limb before starting to walk.

When people who have poor anticipatory balance control are mobile and physically active, they are at increased risk of losing balance. If they also have poor reactive balance control, they are at risk of falling after this loss of balance. It is important to remember than there are complex relationships between underlying sensorimotor and cognitive impairments (e.g., due to aging or neurological disease), walking ability, physical activity, falls, injuries, fear of falling, and both reactive and anticipatory balance control (Figure 1.1).[1]

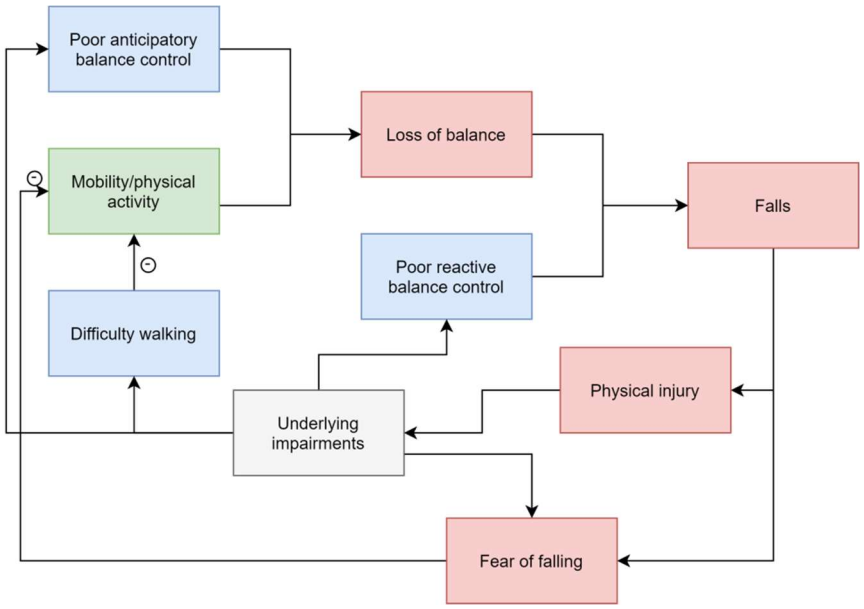

Figure 1.1. The complex relationship between anticipatory and reactive balance control and falls. Figure modified from Mansfield et al., 2018.[1] The minus sign indicates a negative relationship between two items; e.g., people who have difficulty walking will reduce their levels of mobility and physical activity.

1.3 What is reactive balance training?

The **goal of reactive balance training (RBT)** is to improve reactive balance control to promote safe independent mobility. RBT is a balance training method where clients ***intentionally*** experience repeated losses of balance (or balance perturbations) that require them to use balance reactions to prevent a fall. By repeatedly practicing these balance reactions, clients should improve their reactive balance control. In RBT, the balance perturbations can be:

- 'internal' (e.g., client loses balance while completing challenging balance tasks); or
- caused by an external force (e.g., a push or pull from the therapist, or from a device such as a programmable treadmill).

The perturbations during RBT are typically unannounced to mimic the accidental and unexpected nature of falls in daily life.[6] However, perturbations that are predictable in timing and/or direction are recommended early in training to help acclimate clients to RBT or to initially target training of a specific feature of balance reactions.

The term 'perturbation-based balance training' (or just 'perturbation training') is also used to describe RBT. We prefer the term 'reactive balance training' for a few reasons. The goal of RBT is for clients to improve their reactive balance control. Therefore, clients should not just experience balance perturbations, but should also use and practice balance reactions. RBT should be done in such a way that clients ***react to, rather than resist***, the perturbation. For example, if the perturbations are always predictable (in direction, timing, and force), clients will learn the specific perturbation features and learn to resist the perturbations rather than react to them. The term 'perturbation training' is also used to refer to a training strategy to improve stability of a single joint after soft-tissue injury or surgery.[7] The term 'reactive balance training' distinguishes RBT from this type of perturbation training.

1.4 What is not reactive balance training?

The following balance training approaches are not necessarily RBT:

- Balance training on unstable surfaces, where the goal is to *maintain* balance.
- Voluntary step or reach-to-grasp training where the client does not lose balance.
- Balance training with perturbations that are ***always*** predictable in direction, timing, and force, so that clients can learn feedforward or anticipatory strategies to maintain balance during the perturbations.

With this in mind, predictable perturbations and/or volitional step training can be useful to include as part of an RBT program, particularly in early stages, to help clients get used to the perturbations and practice the movements involved in the reaction. Likewise, unstable surfaces can be used as part of an RBT program (see details in other sections of this toolkit).

1.5 Evidence for reactive balance training

Randomized controlled trials have studied the effect of RBT on control of balance and mobility, falls in daily life, neuromotor function, and balance confidence. These trials have included apparently healthy older adults, frail older adults with mixed diagnoses, people with sub-acute and chronic stroke, people with Parkinson's disease, and people with incomplete spinal cord injury.

Table 1.1: Summary of evidence for reactive balance training

Outcome	Evidence statements	Population studied
Reactive balance control	RBT is superior to other balance training methods for improving reactive balance control	Apparently healthy older adults[8-10] Sub-acute & chronic stroke[11-14] Parkinson's disease[15]
Falls in daily life	RBT is likely superior to other balance training methods for preventing falls in daily life	Apparently healthy older adults[16-18] Frail older adults[19] Chronic stroke[11,14] Parkinson's disease[20,21] Incomplete spinal cord injury[22]
Functional balance and mobility	RBT is similar to other balance training methods for improving functional balance and mobility	Apparently healthy older adults[23-26] Frail older adults[19] Sub-acute & chronic stroke[11,13,14] Parkinson's disease[15,20,21,27-31] Incomplete spinal cord injury[22]
Balance confidence/fear of falling	RBT is similar to other balance training methods for improving balance confidence/fear of falling	Apparently healthy older adults[8,25] Sub-acute & chronic stroke[11,13,14] Parkinson's disease[20,30,31] Incomplete spinal cord injury[22]
Reaction time	RBT is superior to other balance training methods for improving volitional reaction time	Apparently healthy older adults[10,24-26,32] Frail older adults[19] Chronic stroke[14] Parkinson disease[29]

Randomized controlled trials consistently show that RBT improves reactive balance control more than other types of exercise, such as stretching,[8] unperturbed walking,[9,13,15] or 'traditional' balance training with a focus on improving anticipatory balance control.[10-13] The finding that RBT improves reactive balance control is consistent with the specificity of training principle; that is, RBT specifically aims to improve reactive balance control, but other balance training programs do not.[33] Some studies have found that these improvements in reactive balance control last for several months to a year after the end of the training program;[11,15,34] these findings contrast with other exercise interventions where training effects are quickly lost after stopping training.

Most randomized controlled trials of RBT to date have used sample sizes that were too small to show between-group differences in falls in daily life. Two meta-analyses combined the results of these small-sample studies and provided evidence that RBT almost halves the rate of falls in daily life.[35,36] However, one study reported a significantly *increased* risk of falls after training for older adults who completed RBT compared to no intervention.[18] The RBT group in this study also reported reduced fear of falling; it is possible that increased fall rates were due to reduced fear and increased participation in 'risky' physical activities. Therefore, therapists might consider including education on fall risks in addition to RBT to help to prevent falls in daily life. Alternatively, increased fall rates might not be considered a negative outcome if the falls do not lead to injury or restricting activity.[37]

Case studies, case series', non-randomized controlled studies, and crossover studies provide evidence for the feasibility and potential efficacy of RBT among people with conditions such as progressive supranuclear palsy,[38] multiple sclerosis,[39] cerebral palsy,[40-42] and unilateral amputation.[43]

1.6 Risks with reactive balance training

Evidence currently suggests that adverse events related to RBT are mostly similar in type, frequency and severity to those observed with other types of exercise (e.g., muscle or joint pain, fatigue). However, a few adverse events seem to be more likely with RBT than with other types of exercise. Table 1.2 summarizes the adverse events that have been reported across 12 randomized controlled trials of RBT that included apparently healthy older adults,[8-10,44] sedentary older adults,[45] older adults referred to a falls clinic with various diagnoses,[46] people with chronic[11,47] or sub-acute stroke,[13] people with Parkinson's disease,[48,49] or people with incomplete spinal cord injury or disease.[22]

Two studies reported injuries, most of which were mild, that were related to being caught by the safety harness during RBT.[10,45] For two participants in one study, these injuries required withdrawal from the study; however, the investigators changed the style of safety harness during the study, and believe that this change prevented further injuries.[10] One study reported a fall, without injury, when practicing RBT without a safety harness.[22]

Subjective or psychological adverse events may be more prevalent and severe with RBT than with other types of balance training. Six participants in RBT groups (2.7%) withdrew from the study due to fear/anxiety, poor compliance with exercise, or lack of interest in the training. Six RBT participants (2.7%) reported milder feelings of fear and anxiety, but were able to continue with the study. In contrast, only 2 participants (<1%) in the other exercise groups reported similar adverse events.

One participant with chronic stroke in one study who was assigned to the RBT group experienced a seizure during training.[11] This participant had a history of seizures and reported that he often experienced seizures when fatigued. This adverse event did not require medical attention, and the participant was able to continue with the study.

Pain and delayed onset muscle soreness were the most frequently reported adverse (reported by 16.4% of all participants), with no apparent difference in the frequency of these adverse events between the RBT and control groups, who completed other types of exercise. Pain was mostly reported as worsening of pre-existing pain, for example for those participants with osteoarthritis (particularly in the lower extremity) or a history of chronic back pain.

Table 1.2. Adverse events reported in studies of reactive balance training. The list reflects adverse events that were reported for RBT. Bolded text indicates adverse events that, despite being rare or infrequent, were more frequently reported in the RBT groups compared to the control groups, who completed another type of exercise or balance training.

	Rare adverse events (reported by <1% of participants)	**Infrequent adverse events (reported by 1-19% of participants)**	**Likely or very likely adverse events (reported by >20% of participants)**
Minor *Alleviated with rest and/or medication* *May require adaptation of training program*	• Seizure • Headache • Fall to the floor (without injury)*	• Musculoskeletal injury • Delayed-onset muscle soreness • Dizziness • Fatigue • **Anxiety/fear** • **Joint pain**	*None reported to date*
Moderate *Requires withdrawal from the intervention*	• Musculoskeletal injury†	• **Anxiety/fear** • Joint pain	*None reported to date*
Severe *Leads to lasting or permanent change in function, disability, or death, or is life threatening*	*None reported to date*	*None reported to date*	*None reported to date*

**The client not wearing a safety harness at this time.*
†Injuries related to being caught by the safety harness.

2.0 SCREENING AND ASSESSMENT

In this chapter

- Contraindications, precautions, and screening for reactive balance training
- Assessing reactive balance control
- Other assessment considerations

2.1 Screening

Clinical judgement will prevail, but please consider the following and when in doubt consult the expertise of other healthcare professionals (e.g. physician) or err on the side of caution for yourself and the client.

You should use your clinical judgement with respect to patient and therapy related goals. Clients and therapists may choose not to participate in RBT if it is not relevant to the plan of care or client rehabilitation goals, despite being eligible for RBT. When considering eligibility, also consider acuity and severity of injury or health conditions.

General contraindication:

Table 2.1 provides guidelines regarding contraindications and precautions for RBT. Note that ***this is not an exhaustive list of conditions***. In general, any clients with an illness, injury, or condition that may be exacerbated by repeated exposure to balance perturbations and/or that would prevent wearing a safety harness should not participate in RBT. RBT should be discontinued, paused, or reduced in intensity if a client reports joint pain or worsening of an existing condition (see Section 1.6).

Table 2.1: Recommended contraindications and precautions for reactive balance training.

Contraindications	Precautions - consult with healthcare team before proceeding with RBT
Musculoskeletal: • Weight bearing restrictions in lower extremity • Acute trauma, hip or knee arthroplasty or other surgery, fractures, soft tissue injury • Severe instability in hips, knees, ankles (could be musculoskeletal or neurological in origin) • Acute low back or lower limb pain • Halo orthosis or cervical collar • History of lower extremity fragility fracture/severe osteopenia/osteoporosis • Limited range of motion of lower extremity joints that may pose risk of injury (e.g., due to contractures)	• Weight bearing restrictions in the upper extremity* • Osteoarthritis • Rheumatoid arthritis • Instability in hips, knees, ankles (could be musculoskeletal or neurological in origin)*

Contraindications	Precautions - consult with healthcare team before proceeding with RBT
Cardiorespiratory/cardiovascular: • Cardiac event or surgery where activity restrictions are still in effect • Abnormal or unstable cardiovascular responses to exercise (e.g., see contraindications to exercise from the American College of Sports Medicine[50]) • Arterial dissection**	• Tracheostomy • Postural hypotension/low blood pressure • Hypertension
Neurological: • Craniotomy without a helmet • Severe spasticity in the legs	• Shoulder subluxation with sling* • Craniotomy with helmet • History of seizures • Epilepsy • Chronic subdural hemorrhage • Dizziness/vertigo • Poor sensation/proprioception*
Cognitive/communicative: • Unable to understand the purpose of the training and/or to provide informed consent • Unable to reliably communicate pain or discomfort	• Cognitive impairments (decreased attention, impulsivity, low frustration tolerance, decreased judgement) • Communication impairments • Hearing impairments
Functional mobility: • Unable to stand unsupported with or without a gait aid	
Other: • Acute illness – vomiting, migraine, fever etc. • Body mass exceeds the limits of safety harness system (see Section 3.5.2) • Colostomy bags • Indwelling catheters • Pressure sore on pelvis or trunk	• Pregnancy • High anxiety/fear of falling • Medications affecting balance • Hypo/hyperglycemia • Hernias • Nasopharyngeal/gastrostomy tubes • Infection control issues (e.g., C-diff, MRSA) – consult your institution's infection control policies regarding proceeding with therapy in these cases and/or appropriate precautions (gown, gloves, wipe down equipment etc)

Additional notes:
*Ankle stabilizer/sling/brace as needed for clients who present with joint instability, sensory impairment etc., for safety
**Arterial dissections can be a contraindication or precaution and should be considered on a case by case basis. Consider acuity of event. Consult with physician. Consider monitoring blood pressure during training.

2.2 An initial comprehensive assessment is required to inform treatment and ensure patient safety

Reactive balance assessment and training should occur within the context of a more comprehensive assessment of the individual. An initial assessment is performed to ensure that RBT will be safe for the client (see Section 2.1), to understand how RBT aligns with the patient's goals, and to identify other underlying impairments that may contribute to reactive stepping and need to be considered in the treatment plan. Information regarding significant medical history, relating to contraindications and precautions is obtained. Modifications to the manner in which the program is provided may be made based on past medical history. For example, some activities might be avoided to prevent exacerbation of a previous injury.

The initial assessment includes:

- Identification of clients' rehabilitation goals
- Assessment of underlying impairments (especially those related to impaired reactive stepping):
  - Motor function, strength, range of motion
  - Sensory impairment (e.g. ankle proprioception and plantar sensation)
  - Visual/perceptual impairments
  - Cognitive impairment
  - Fear of falling or balance confidence – e.g., using the Activities-specific Balance Confidence scale[51]
- Functional mobility status
- Assessment of reactive stepping (Section 2.3); recommend using:
  - Forward-fall lean-and-release perturbations[52]; and/or
  - Observation of reactions in the 'reactive' component of the Balance Evaluation Systems Test or the Push-and-Release test[53-55]

2.3 Reactive balance assessment

Observation of client responses to the 'reactive' component of the Balance Evaluation Systems Test, or a modified version of the Push-and-Release test, can be used to identify impairments in reactive balance control. See Table 2.2 for impairments commonly observed and features that are linked to increased falls risk in daily life. Use the Assessment Data Collection Sheet (Appendix 1) to document assessment conditions and client responses. Use the Treatment Planning Guide (Appendix 2) to document the specific areas of dyscontrol that you observe.

2.3.1 Equipment/instrumentation

- Safety equipment: ***Clients should wear a safety harness attached to a secure point overhead*** to prevent a fall to the floor. Some clients may also require ankle support (e.g., an ankle-foot

orthosis or brace. The same safety considerations apply for reactive balance assessment as for RBT (see Section 3.5).

- Video camera (optional): balance reactions are fast, and it can be difficult to administer the test, be mindful of client safety, and observe the responses all at once. Video recording the test allows you to replay the client's responses several times to observe features of the response that you might have missed 'in the moment' during the assessment.
- Force plates, weighing scales, balance boards (optional): if you have access to these instruments, you can place two force plates, weighing scales, or balance boards (e.g., Nintendo® Wii Fit) side-by-side. If the client places one foot on each, you can observe weight-bearing asymmetry in standing or prior to the perturbation. Force plates may also provide information about delays in timing of step initiation and execution. If these instruments create a raised surface, ensure that there is enough space on this raised surface for the client to execute the step reaction.
- Obstacles (optional): obstacles can be used to block stepping with one limb (see modifications below). Alternatively, you can use your own foot to block the step, but might find this difficult to coordinate if you are administering the test alone.

The instructions below are modified from http://bestest.us/files/9613/4756/3990/BESTest_Script.pdf

2.3.2 Tests

Forward direction

Stand in front of the client with one hand on each shoulder and ask them to push forward (make sure there is room for them to step forward). Ask them to lean until their shoulders and hips are in front of their toes. Suddenly release your support when the client is in place.

Figure 2.1. Forward-directed lean-and-release test.

Instructions to the client:

> "Stand with your feet shoulder width apart, arms at your sides. Lean forward against my hands beyond your forward limits. When I let go, do whatever is necessary to avoid a fall. If you need to take a step, try to take as few steps as possible."

Backward direction

Stand behind the client with one hand on each scapula and ask them to lean backward (make sure there is room for them to step backward). Ask them to lean until their shoulders and hips are over their heels. Release your support when the client is in place.

Instructions to the client:

> "Stand with your feet shoulder width apart, arms at your sides. Lean backward against my hands beyond your backward limits. When I let go, do whatever is necessary to avoid a fall. If you need to take a step, try to take as few steps as possible."

Figure 2.2. Backward-directed lean-and-release test.

Lateral direction

If the client has an asymmetrical condition (e.g., hemiparesis, lower-extremity joint replacement) start with a lean towards the less-affected side.

Stand beside the client, place one hand on the right (or left) side of the pelvis and the other hand lightly on the shoulder (make sure there is room for them to step laterally). Ask the client to lean their whole body into your hands. Ask them to lean until the midline of pelvis is over the right (or left) foot and then suddenly release your support.

Instructions to the client:

> "Stand with your feet together, arms down at your sides. Lean into my hands beyond your sideways limit. When I let go, do whatever is necessary to avoid a fall. If you need to take a step, try to take as few steps as possible."

Figure 2.3. Lateral lean-and-release test.

Table 2.2: Frequently-observed areas of reactive balance dyscontrol. See Appendix 2 for suggestions for documenting these areas of dyscontrol, and RBT strategies to target them.

Area of dyscontrol	Link to falls in daily life
Failed step reactions – requires external assistance (from the therapist and/or safety harness) to regain stability	In people with sub-acute stroke[56]
Does not step when the magnitude of perturbation requires a step	In people with sub-acute stroke[56]
Low foot clearance during reactive steps (foot slides or shuffles)	In people with sub-acute stroke[56]
Delayed stepping reactions	No evidence, but may contribute to failed step reactions
Unwilling/unable to step with both limbs	In people with chronic stroke[57]
Multi-step reactions	In apparently healthy older adults[58]
Stands asymmetrically prior to the perturbation	No evidence, but may increase difficulty of stepping with both limbs
Short reactive steps	No evidence, but may contribute to failed step reactions
Attempts to use the upper extremity to regain stability	No evidence, but may accompany failed step reactions or suggest fear of falling
Falls laterally on step termination when responding to antero-posterior perturbations	In apparently healthy older adults[58]
Experiences limb collisions when responding to lateral perturbations	In apparently healthy older adults[58]

2.3.3 Suggested modifications

- Number of repetitions: The Balance Evaluation Systems Test only requires one repetition of each perturbation direction. You can complete several repetitions to determine if the area of dyscontrol identified is a 'one-off' or more persistent.
- Assess under other conditions, including:
    - Encouraged-used of non-preferred limb (block the preferred limb): Most people have a strong preference for initiating a stepping reaction with one limb, but should still be able to initiate the step with their non-preferred limb. However, some people, particularly those with asymmetrical conditions like stroke, are unable to take a step with both limbs. Use an obstacle or your foot to block the clients' step with their preferred limb during forward- or backward-directed perturbations to evaluate the capacity of the non-preferred limb to respond to a loss of balance. See the toolkit videos for examples.
    - Dual-task: To probe ability to switch attention to recover from a balance perturbation, consider adding a cognitive task prior to the perturbation (e.g., counting backwards by 3s or 7s, or listing words beginning with a specified letter).

3.0 PLANNING THE PROGRAM

In this chapter

- Considerations for planning a reactive balance training program
- Recommended equipment
- Ensuring client safety during reactive balance training

3.1 RBT is just one part of a comprehensive physical rehabilitation plan

RBT is one part of the physical rehabilitation plan, which considers client's specific impairments and function, and rehabilitation goals. Depending on the clients' functional level, it may be appropriate to prescribe exercises to build strength, endurance, standing balance, walking function etc. prior to starting RBT.[59]

3.2 The program is individualized to the client's specific impairments in reactive balance control

To create an effective training program, consideration is made of the client's unique areas of dyscontrol (identified on initial assessment; see Section 2.3 and Appendix 1) and functional goals. Appendix 2 outlines areas of dyscontrol and some suggested treatment approaches for each problem. The principle of individual differences considers an individual's response to exercise. Therefore, progression should be gradual, systematic, and occur at the individual client's rate of improvement. Task difficulty is not absolute and could vary from client-to-client depending on specific control problems and other deficits.

3.3 List of equipment

The following equipment is required for this specific program:

- Safety harness and overhead support system (see Section 3.5.2);
- Client-specific equipment (e.g., walking aid, ankle brace/orthosis, helmet, arm sling).
- Additional therapy equipment used for motor, cognitive, sensory, or environmental challenges (e.g., see Appendix 3).

3.4 Preparing the client

Many clients express fear and anxiety related to loss of balance during RBT.[59,60] It is important to adequately prepare the client and monitor throughout. As with all interventions, informed consent is required. Given the nature of RBT, we recommend adequate explanation with a demonstration to ensure clients understand the purpose, risks, benefits, and what is expected of them during training. The patient leaflet within this toolkit may be useful to help clients understand what is involved in RBT.

- Review safety considerations with the client (e.g., the harness will prevent a fall, the therapist will offer assistance if a fall into the harness is likely).
- Explain the importance of the loss of balance; that losing balance is the only way to learn to react and that it is the therapist's responsibility to ensure that the client loses their balance over and over.
- Make sure that the client understands that, as their ability to react improves, the challenge of the training will be increased. Remind the client that, if the challenge is not great enough, the training will not help the client to learn the reactive balance skills required for everyday life.
- Monitor how the client is feeling regularly throughout the treatment session.

- Reinforce with the client that they should tell you if they are experiencing any pain, discomfort or other symptoms and that they can stop the treatment or take a rest at any time should they be feeling anxious.
- Start with tasks that are predictable and less challenging to allow the client to gain some experience and comfort with the training (see information on progressions in Section 4.3.3 and the progressions video in the toolkit).

While clients may express fear and anxiety during RBT, clients and therapists report that repeatedly executing successful balance reactions during RBT can help to build balance confidence and reduce fear of falling.[59,60] Clients and therapists alike report that building trust between the therapist and the client can help to assuage these fears and anxiety.[59,60]

3.5 Ensuring safety during training

RBT involves putting clients in situations where they lose their balance. The goal is for them to practice and improve control of balance reactions, such as reactive steps. There is a chance that clients' balance reactions will not be sufficient to prevent a fall. Appropriate measures should be in place to reduce the risk of client injury during RBT, and to ensure that clients do not fall.

3.5.1 Supervision

RBT should be closely supervised by an appropriately trained regulated healthcare professional (e.g., physiotherapist), who can provide physical assistance in the event of a failure to recover balance following a balance perturbation. To optimize effectiveness of training, the therapist should aim to provide assistance only if the client is unable to recover balance independently; this ensures that the client has the opportunity to practice balance reactions unaided. See the toolkit videos for suggestion on how to provide supervision. A second 'spotter' may be required for low functioning and/or high risk clients – ***exercise your clinical judgement at all times to avoid risk of injury to yourself or client.***

3.5.2 Safety harness & overhead support

During RBT, participants are placed in situations where they lose balance and could fall to the floor. A safety harness that is securely attached to an overhead support is required to prevent a fall. While some therapists and clients may feel comfortable doing RBT without a safety harness (e.g., with 2-person assist, in parallel bars, and/or with mats surrounding the client), ***we do not recommend doing RBT without a safety harness***. Note that ***falling completely into the harness could cause physical discomfort, anxiety or soft tissue injury***. The ***harness should be considered a 'last resort'***, and healthcare professionals should attempt to intervene with some assistance in the event of failed balance recovery.

The components of the safety harness system are: 1) the harness; 2) carabiner; 3) rope/line; and 4) anchor.

Harness

A good-quality full-body safety harness should be used. The harness should have the following features/characteristics:

1. Leg straps that wrap around each leg separately;
2. When the client's body weight is fully supported by the harness (e.g., if they fall and are caught by the harness), they must be upright with most of their weight supported by the leg straps. The harness must not catch clients primarily at the waist;

3. A single attachment point at the upper back (approximately between the shoulder blades) and/or a double attachment on top of both shoulders; and
4. Able to support a load of at least 3.6 kN*.[61]

We have found two styles of safety harness that generally meet these requirements: industrial-style fall-arrest harnesses used by people working at heights (e.g., construction workers), and harnesses used for body-weight supported gait training.

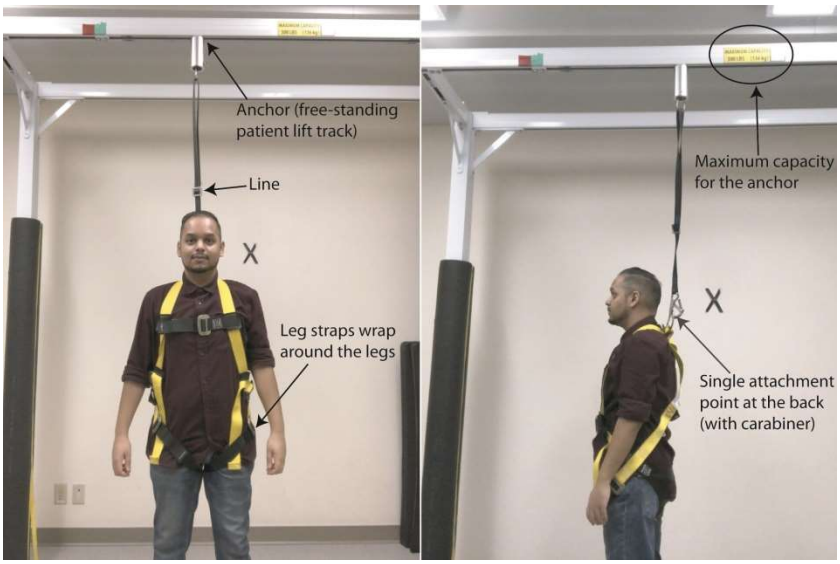

Figure 3.1: Example of an industrial harness.

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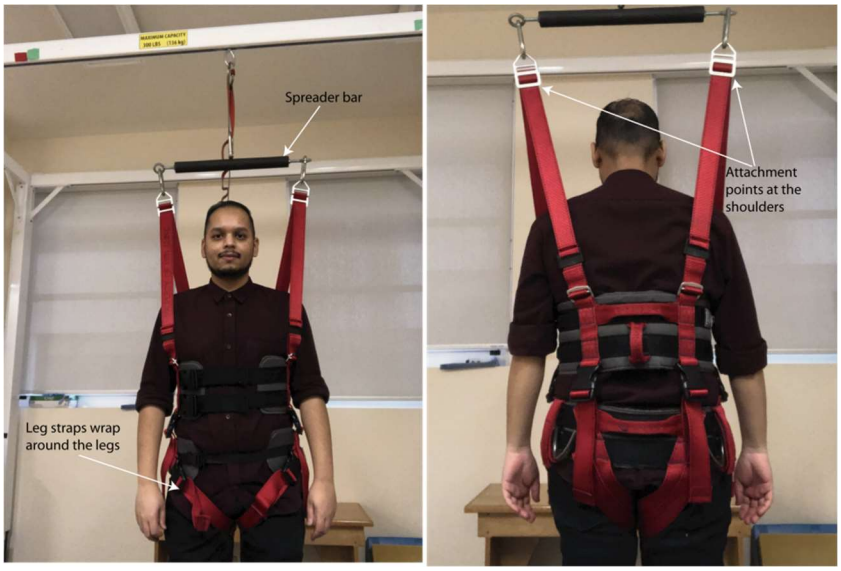


Figure 3.2. Example of a body-weight support harness.

In our experience, we find that a safety harness with a two-point shoulder attachment is better for lower-functioning clients than the single-point harness, particularly those with poor trunk control. A

* The manufacturer should indicate a maximum load (force) than the harness can withstand in Newtons (N) or kiloNetwons (kN). If gravity is the only acceleration acting on the body, then 3.6kN is equivalent to a body mass of 367kg (i.e., force = mass multiplied by acceleration due to gravity). However, during fall arrest, the force borne by the harness can be higher than body mass multiplied by acceleration due to gravity.

two-point shoulder harness may also feel more supportive for clients that are anxious. A spreader bar, such as those used for body-weight supported gait training, must be included in the line to keep the shoulder attachment lines away from the client's head (see Figure 3.2). Conversely, a single-point harness might allow for more freedom of movement in the lateral direction, for example, for lateral perturbations, or when including turning movements in training.

You may add temporary padding to the harness for client comfort. However, any padding must not interfere with the buckles or safe operation of the harness. DO NOT make any permanent changes to the harness (e.g., by sewing or cutting the straps).

Industrial harnesses are designed to prevent death or serious injury in the event of a fall from a height (>3m) and comply with stringent fall-arrest standards (e.g., CSA Z259.17:16 in Canada). While these standards may be excessive for protecting against falls from a standing height, other types of harnesses are not well regulated. If you choose to use a body-weight support style harness, check with the manufacturer/supplier regarding use of the harness for fall prevention during RBT, and the maximum load that the harness can withstand. Do not use a climbing harness for RBT.

Industrial fall-arrest harnesses can be purchased from industrial suppliers. Ensure that the harness meets the appropriate fall-arrest standard in your local jurisdiction (CSA Z259.17:16 in Canada). Body-weight support harnesses can be purchased from rehabilitation/medical suppliers.

Carabiner
A carabiner is a metal link with a safety closure used to attach a harness to the subject line. The carabiner must be rated to 22 kN or higher.[61] Carabiners also must have a locking mechanism to hold the opening in the closed position, such as a twisting gate or a spring loaded gate. These mechanisms ensure that you must do two actions to open them, so they will not accidentally open at the wrong time. If a carabiner can open with a single action, do not use it.

Carabiners can be purchased from industrial suppliers and sporting goods stores.

Line
A line is a flexible link between the harness and the anchor. Lines can be a fixed length via a rope, linked webbing or a metal link. Other lines can spool in and out, locking if pulled out too quickly (like a seat belt in a car). The line must be rated to 22 kN or higher.[61]

Spool lines can be purchased from industrial suppliers. Ropes and linked webbing can be purchased from industrial suppliers and sporting goods stores (e.g., rope for mountain climbing).

Anchor
An anchor is the secure point for attaching the line, marked with its maximum capacity, as the "safe working load". The safe working load is the maximum mass that can be supported under that point (i.e., the client).

The anchor can be a single point, or can be a track that allows the client to move freely around a limited space (e.g., a ceiling mounted or free-standing patient lift track). Check with the maintenance department at your institution and the manufacturer/supplier regarding use of the anchor for fall prevention during RBT, and the maximum load that the anchor can withstand

Correct use of the safety harness system

1. Visually inspect the safety harness, carabiner, line, and anchor prior to each use. Check for frayed edges, broken fibres, pulled stiches, cuts, burns, bent or chipped metal, torn rubber gaskets, deformation etc. There should be no knots in the line. Do not use the safety harness system if it shows any signs of wear or defect.
2. Follow the manufacturer's instructions regarding regular replacement of the safety harness, and the maximum client weight.
3. Do not use the safety harness system with a client who exceeds the maximum weight limits of the safety harness or anchor.
4. Follow the manufacturer's instructions regarding the correct way to don the safety harness. The harness should be fitted so that it is snug, but not so tight that it restricts movement or is unnecessarily uncomfortable.
5. Secure the harness to the line with enough slack so that it is not tugging on the client, but not so much slack that their knees can touch the ground if they fall.
6. Once secured to the line and anchor, allow the client to 'test' the safety harness system by asking them to gradually try to kneel down (note that they should not actually be able to kneel; see Figure 3.3).

Figure 3.3: Correct use of the safety harness system. When the client's body weight is completely supported by the safety harness, their knees should not touch the ground (image on the left). To ensure that there is not too much slack in the safety harness or the line, you can ask clients to test the harness by trying to kneel down. If the participant is unable to attempt to kneel with both knees, you can ask them to try a lunge instead, and to try to lower one knee to the ground (image on the right).

7. There is a risk of injury to clients when they fall into the safety harness. The risk of injury is greater for more frail clients. Avoid activities where clients can very vigorously and abruptly fall. Avoid situations where ***all*** of the clients' body weight is supported by the safety harness after a loss of balance (i.e., their feet are off the ground). Ideally, if a client is unable to recover balance on their own, they would remain on their feet with just a portion of their body weight supported by the harness system, and a portion supported by the spotter(s).
8. Pressure from body weight being supported by the harness can restrict blood flow. Therefore, if a client falls completely into the safety harness they should not be left supported by the harness

for long. Ideally, the client would be able to immediately return to a fully upright position on their own, or with assistance from the spotter(s). If you are unable to get the client upright after a fall into the safety harness (e.g., the client loses consciousness), you should have two people support the clients' body weight while you cut the line or release the harness buckles and lower the client slowly to the floor or a chair/plinth.

9. Clean the harness between clients by following manufacturer instructions and infection control policies at your institution

It is a good idea to try the safety harness out yourself before using it with your clients.

3.5.3 Protective equipment for ankle

Reactive stepping elicits responses that necessarily are much faster than voluntary steps (e.g., during walking). An ankle-foot orthosis (if prescribed) or an ankle stabilizing brace (e.g., Figure 3.4) may be required during RBT to prevent injury. Even if the client does not typically use an orthosis or brace during walking (i.e., where the individual can control the speed of their stepping), they may require an orthosis or brace during reactive stepping. Err on the side of caution.

An ankle-foot orthosis or stabilizing brace is recommended if the client meets one or more of the following criteria:

- Client typically uses an ankle-foot orthosis during home and/or community walking;
- Client does not typically use an ankle-foot orthosis but exhibits:
    - poor motor control in the foot/ankle (weakness, impaired movement, instability),
    - spasticity (e.g., risk of ankle inversion during fast movements),
    - poor ankle joint position sense,
    - poor plantar somatosensation; and/or
- The treating therapist feels this is necessary to preserve stability of the ankle joint and prevent injury.

Figure 3.4: Example of an ankle brace. The brace helps provide some lateral stability to the ankle for clients with poor ankle/foot control or sensation.

3.5.4 Additional safety equipment

Additional safety equipment may be required to prevent injury in the event of a fall or unintentional contact with surrounding structures. Clients with a cranial bone flap removed should wear a safety helmet during RBT. There should be no sharp objects in the environment that clients can contact during training. You may place padding around walls, posts, or other objects in the environment to prevent injury in the event of collision during training.

3.5.5 Other safety considerations

If you would normally measure your client's heart rate and blood pressure before exercise, you should also do so at the start of each RBT session. If heart rate and/or blood pressure are outside of an acceptable range, a second measure should be obtained. If the values continue to be outside of the range, the client should be 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. Clients with measurements outside of the acceptable range can also be 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 they recently took caffeine, exercised, or smoked. The decision to continue or terminate the session is made by the therapist considering factors such as the client's usual resting heart rate or blood pressure, how far the measured values are outside of the acceptable range, the client's usual medication (e.g., beta-blockers), and the client's perception of how they are feeling. If the visit is terminated, the therapist may advise that the client follow-up with his primary care physician. The therapist may also choose to monitor heart rate and blood pressure regularly throughout the visit and observe cardiovascular responses to exercise.

4.0 IMPLEMENTATION

In this chapter

- How to provide balance perturbations for reactive balance training
- Principles of training, including client-specific adaptations and progressions
- Suggested approaches for documenting the training

4.1 Methods of perturbation

Internal perturbations are evoked when the client attempts to perform a task that causes instability. Various voluntary tasks, including rapid 'agility' tasks (e.g., rapid step-ups) can be used to evoke internal perturbations. A task that appears as easy as standing with eyes closed may cause an internal perturbation for a client with poor balance control. See the accompanying toolkit videos for examples of tasks that can cause internal perturbations. However, some clients 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 can also be included in every session to ensure a sufficient training dose.

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

4.2 External perturbation methods

1) Lean and release

a. Forward-directed lean-and-release perturbation. The client stands facing the therapist, leaning forward with some of his body weight supported by the therapist. 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 therapist's hands are on the clients' shoulders. At an unexpected time, the therapist releases her hands and the client starts to fall forward, requiring a step to regain stability. Expected or predictable releases may be used initially. The goal is for the client to take as few steps as possible to recover.

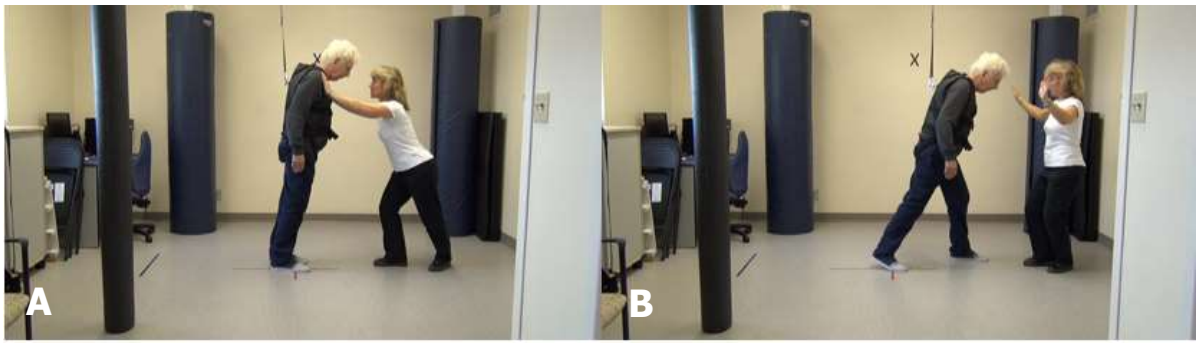


Figure 4.1. Forward-directed lean-and-release perturbation. The client leans forward and the therapist supports his weight (A). The therapist releases her support and the client steps to recover his balance (B).

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

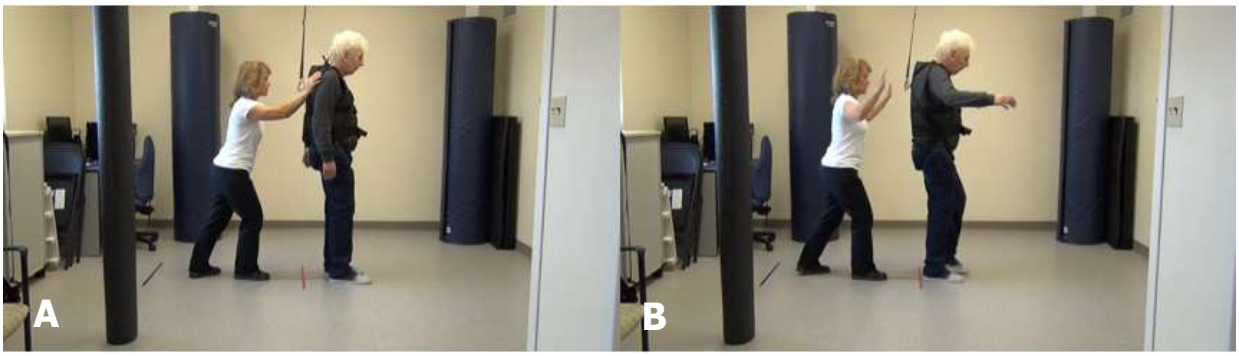


Figure 4.2. Backward-directed lean-and-release perturbation. The client leans backward and the therapist supports his weight (A). The therapist releases her support and the client steps to recover his balance (B).

c. Lateral-directed lean-and-release perturbation. The client stands with his feet close together, leaning to the right (or left) with some of his body weight supported by the therapist'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 therapist's hands are on the client's right (or left) shoulder and right (or left) hip. At an unexpected time, the therapist releases her hands and the client starts to fall to the right (or left), requiring a step to regain stability. The goal is for the client to take as few steps as possible to recover balance.

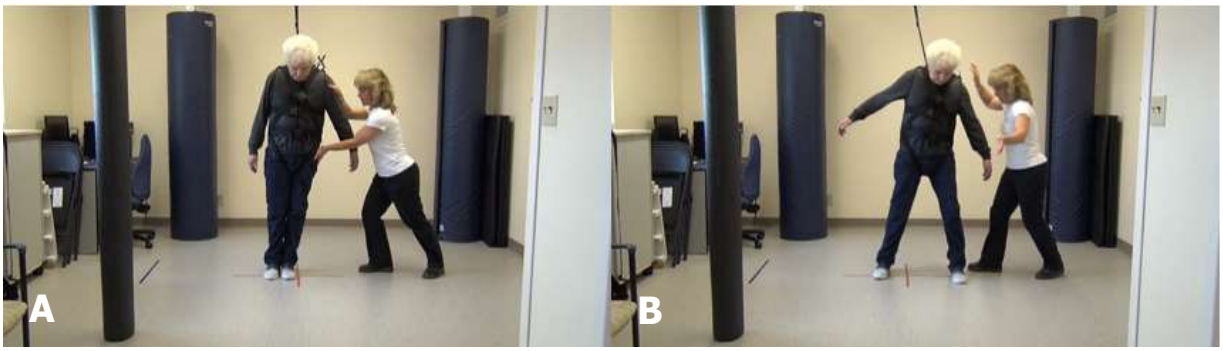


Figure 4.3. Lateral-directed lean-and-release perturbation. The client leans to the left and the therapist supports his weight (A). The therapist releases her support and the client steps to recover his balance (B).

2) Multi-directional push/pull

a. Multidirectional push. The therapist places her hands on the client's hips or shoulders and pushes him forward, requiring a reactive step to regain stability. Alternatively, one of the therapist'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 therapist should be ready to assist with the recovery, if necessary, by having a light hold of the safety harness. The therapist should only provide

assistance if the client is unable to regain stability independently; this is true with every reaction. Note that ***backward-directed pushes are not performed***.

Figure 4.4. Forward-directed push perturbation. The therapists' hands may be placed at the hips (A & B) or with one hand on the hips and one on the shoulders.

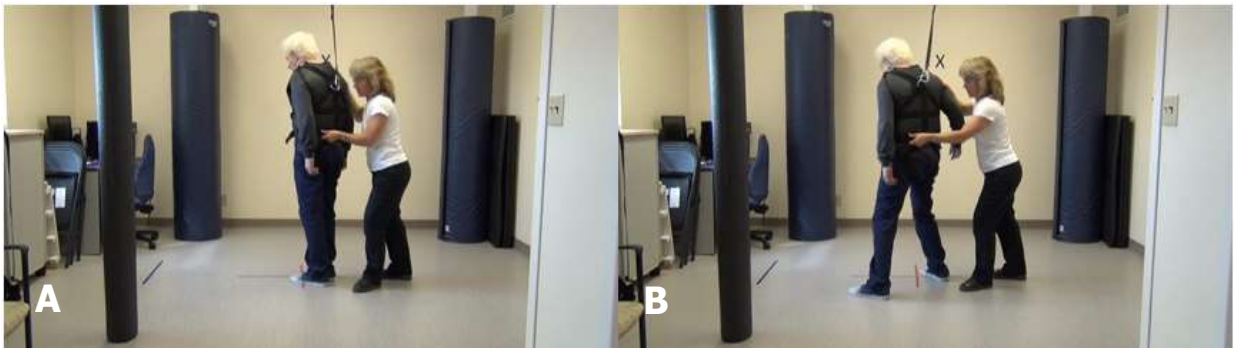


Figure 4.5. Lateral-directed push perturbation. The therapist places her hands on the client's right (or left) hip or shoulder and pushes him to the left (or right), requiring a reactive step to regain stability.

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

Figure 4.6. Forward-directed pull perturbation. The therapist places her hands on the client's shoulders (A & B) or pulls on the harness (C & D).

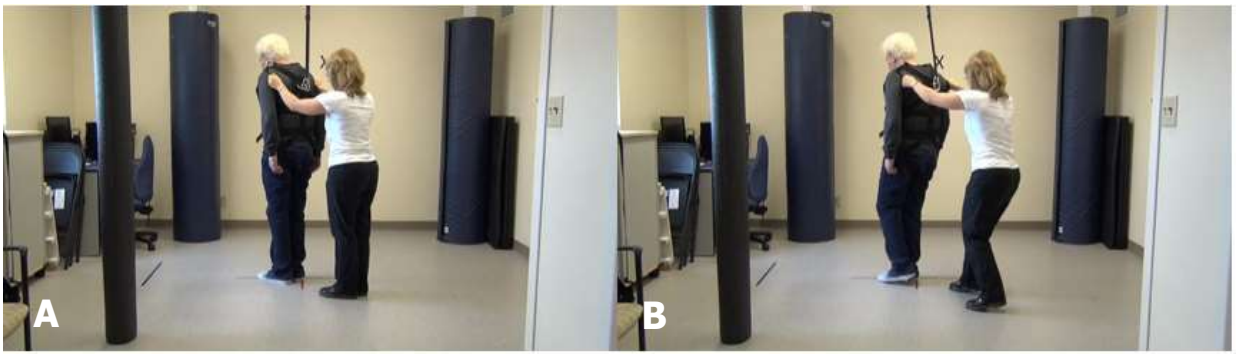


Figure 4.7. Backward-directed pull perturbation. The therapist uses the shoulders, hips, or harness to pull the client backward, requiring a reactive step to regain stability.

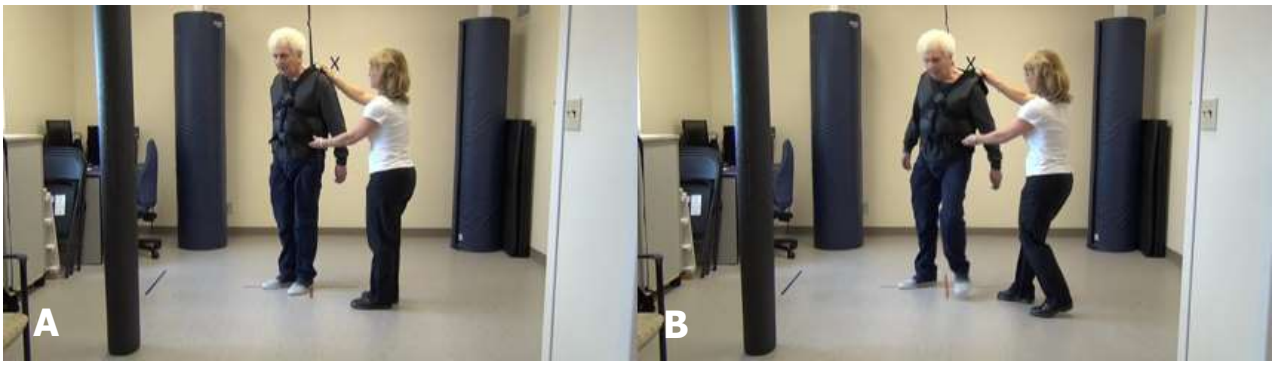


Figure 4.8. Lateral-directed pull perturbation. The therapist uses the shoulders, hips or harness, to pull the client to the right (or left), requiring a reactive step to regain stability.

4.3 Training principles

The following training principles are specific to RBT. Additional interventions and training strategies may be warranted to address underlying impairments that contribute to impaired anticipatory or reactive balance control (e.g., strength training).

4.3.1 The balance challenge should be greater than that experienced in daily life and during 'traditional' exercise

While individuals may experience some balance perturbations during daily life, the number and magnitude of perturbations during RBT should be greater than that experienced under typical circumstances. The perturbations themselves have to be ***intense*** enough to elicit stepping responses. It is important to allow for success, which is defined as independent recovery of balance with a response of 2 steps or less, some of the time. The rest of the time the perturbation should require a multistep reaction or need for assistance. Overall, the client needs to lose balance and the goal is to regain, rather than to maintain balance.

Table 4.1: Recommended frequency, intensity, time and type of reactive balance training. Note that optimal parameters are not known yet. Studies in apparently healthy older adults provide evidence that a single session of RBT with 24 repetitions is sufficient to improve reactive balance control and prevent falls.[62,63]

Frequency	• 1-2 sessions/week
Intensity	• Sufficient perturbation magnitude to elicit a reactive step • Not such a large magnitude that clients 'fall' (into the safety harness) all the time
Time	• ≥24 repetitions per session[62]
Type	• See Section 4.2 (Methods of perturbation) • Include a variety of perturbations and tasks

4.3.2 The program should be specific to the clients' problems with balance control

The RBT program must incorporate activities that evoke balance reactions. The client-specific training program should: 1) have specific focus on client's goals and expectations for recovery and community ambulation; 2) target client-specific problems with reactive balance control (see Table 2.2 and Appendix 2); and 3) target specific impairments in reactive balance control that could place the client at increased risk of falls (Table 2.2).[57]

4.3.3 As clients adapt and improve, the level of challenge should increase

The difficulty of the balance challenge should be progressed in order to achieve the desired intensity. Client-specific progression can be made by manipulating the motor task, sensory condition, cognitive requirements, or environment, or increasing the magnitude of external perturbations. See the accompanying videos for suggested ways to progress the intensity of training. Clients should be allowed to progress at their own pace.

If a client expresses fear or anxiety related to the perturbations, you should start with 'easier' perturbations (e.g., internal perturbations, small magnitude, cued/predictable perturbations). Gradually increase the difficulty of the perturbations as the client gets used to the training (see Section 3.4).

Progressions	
Perturbation type	• Lean/pull toward → Push away
Perturbation magnitude	• Small → Large
Perturbation direction	• Predictable → Unpredictable
Perturbation timing	• Cued → Unpredictable
Other challenges	• Motor tasks • Sensory (eyes closed/dim lights, stand on foam) • Cognitive tasks • Environmental

4.3.4 Short-term adaptation might not indicate long-term learning.
Consistent with motor learning research[64] apparent improvements in balance control within a session might not be retained long-term. Changes to the training program based on these apparent short-term improvements should not be made. Instead, the therapist should assess whether these improvements are retained in the next training session before making changes.

4.3.5 Consider incorporating variability in training parameters
Each training session should eventually require the client to react to a variety of different perturbation conditions. The following training parameters can be varied: 1) direction of perturbation (forward, backward, lateral, diagonal); 2) magnitude of perturbation; 3) type of perturbation (i.e., internal vs. external); 4) perturbation timing (e.g., cued versus unpredictable) and 5) additional motor, cognitive, sensory, or environmental challenges. Ideally, training parameters will be varied trial-to-trial, but it is not necessary to vary all parameters trial-to-trial. If trial-to-trial variability is not feasible then parameters may be varied in blocks. Perturbation trials should be included with non-perturbation trials to prevent anticipation or pre-planning of responses.

Variability and random presentation of tasks ***may depend on the stage of learning***. Clients who are earlier in the RBT training program may benefit from tasks that are consistent from trial-to-trial, and perturbation characteristics that are more predictable until they begin to have some success in executing the desired stepping reactions. As clients improve their balance control and confidence, more variable and unpredictable tasks can be included.

4.3.6 Support should be minimal
The safety harness should not provide any support to clients unless they are unable to recover balance using their own reactions or from therapist assistance. Therapists should use clinical judgement to

ensure the provision of adequate supervision and ability to provide physical assistance if required, while also allowing clients to attempt to regain balance without providing assistance prematurely (see the accompanying videos for more information).

4.3.7 Both verbal instruction and demonstration may be useful

Instruction should refer to the whole task, rather than part of a task (e.g., do not provide instructions regarding specific movement patterns). Instructions should be simple with just one instruction given at a time.

4.3.8 Promote an external focus of attention

Clients should be encouraged to focus on the effects of their movement rather than a specific movement pattern. Feedback and instructions should promote an external focus of attention. It may be useful to change the environment to achieve specific goals of training rather than providing instructions/feedback to focus on specific movement pattern; e.g., place an obstacle on the ground as a target to step over to encourage increased step length or limb clearance.

4.3.9 When to stop RBT

Some clients might not improve reactive balance control with RBT. We do not yet understand what factors determine if a client will or will not respond to RBT. Regularly assessing reactive balance control (see Section 2.3) can help determine if your client is improving. If a client does not appear to improve after repeated sessions, you could consider discontinuing RBT and focusing therapy time on other aspects of balance and mobility. Likewise, you should stop RBT if a client reaches a plateau or ceiling in reactive balance control; that is, if they improved initially but are no longer improving with repeated sessions, or if they are consistently able to respond to large magnitude perturbations in multiple directions with a single step.

4.4 Documentation

Documentation of balance training sessions should focus on: 1) client-specific problems; 2) ongoing progression; and 3) client safety. The Reactive Balance Training Log (Appendix 4) can be 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 client experiences a loss of balance) and balance reactions (i.e., balance recovered independently using 2 steps or fewer; balance recovered using more than 2 steps; or assistance provided by the safety harness or therapist to recover balance);
- Additional tasks/conditions;
- Number of rest breaks;
- Intensity of balance training (see below and Appendix 5); and
- Heart rate and/or blood pressure (if indicated).

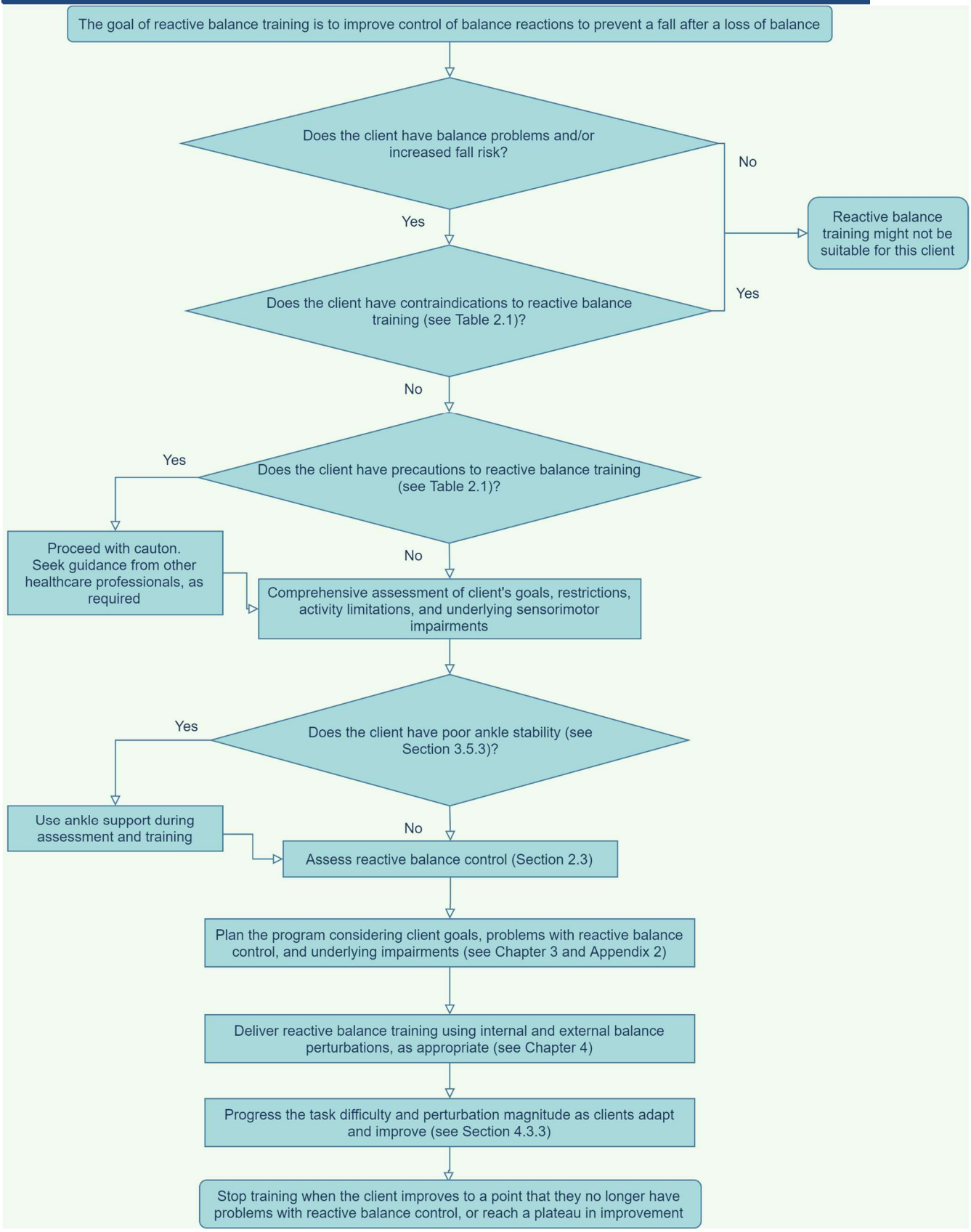
The training log in Appendix 4 is provided as a suggested way to document training sessions. Use of this specific training log might not be compatible with health record keeping at your institution/organization. You might prefer to use another method to document RBT sessions.

There are a few rating scales available to allow clients to rate their perceived intensity, or level of challenge/difficulty, of balance training. None of these scales have been validated for the intensity of

RBT, but you may still find them useful to document clients' perceived training intensity. These scales are included in Appendix 5.

1. The OMNI Perceived Exertion Scale is a generic scale used to rate perceived exertion of any type of exercise.[65] Clients rate their perceived exertion on a scale from 0-10. OMNI Perceived Exertion Scale scores correlate with challenge of anticipatory balance training.[66]
2. The Rate of Perceived Stability scale is a balance-training specific scale that asks clients to rate their perceived stability on a scale from 0-10.[67] The Rate of Perceived Stability scale is a valid measure of intensity of anticipatory balance training.[66] As the goal of RBT is to evoke balance reactions, but not falls, you should aim for scores of 10 when using this scale in RBT.
3. The Balance Intensity Scale asks clients to score effort during balance training on a scale from 1-5.[68] Balance Intensity Scale scores correlate with challenge of anticipatory balance training.[69]

5.0 SUMMARY FLOWCHART



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