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A Conceptual Framework for the Progression of Balance Exercises in Persons with Balance and Vestibular Disorders

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Abstract

There is little information in peer-reviewed literature to specifically guide the choice of exercise for persons with balance and vestibular disorders. The purpose of this study is to provide a rationale for the establishment of a progression framework and propose a logical sequence in progressing balance exercises for persons with vestibular disorders. Our preliminary conceptual framework was developed by a multidisciplinary team of physical therapists and engineers with extensive experience with people with vestibular disorders. Balance exercises are grouped into six different categories: static standing, compliant surface, weight shifting, modified center of gravity, gait, and vestibulo-ocular reflex (VOR). Through a systematized literature review, interviews and focus group discussions with physical therapists and postural control experts, and pilot studies involving repeated trials of each exercise, exercise progressions for each category were developed and ranked in order of degree of difficulty. Clinical expertise and experience guided decision making for the exercise progressions. Hundreds of exercise combinations were discussed and research is ongoing to validate the hypothesized rankings. The six exercise categories can be incorporated into a balance training program and the framework for exercise progression can be used to guide less experienced practitioners in the development of a balance program. It may also assist clinicians and researchers to design, develop, and progress interventions within a treatment plan of care, or within clinical trials. A structured exercise framework has the potential to maximize postural control, decrease symptoms of dizziness/visual vertigo, and provide "rules" for exercise progression for persons with vestibular disorders. The conceptual framework may also be applicable to persons with other balance-related issues.

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Keywords

Balance; Exercise; Physical therapy; Progression; Rehabilitation; Vestibular

Introduction

When designing a vestibular rehabilitation program, experienced clinicians often progress balance exercises in a similar way, but there is limited literature to guide less experienced practitioners in the development of balance programs. In addition to the obvious concern regarding the quality of care provided to a client, the lack of a systematic progression framework for balance exercises also impacts how clinicians and researchers design, develop, and progress interventions or research trials. A structured exercise framework has the potential to maximize postural control, decrease symptoms of dizziness/vertigo, and provide “rules” for exercise progression for persons with balance and vestibular disorders.

While the mechanisms and measurement of balance are complex, the term balance has been described concisely as the body posture that prevents falling [1]. Balance is dependent upon the input of the visual, vestibular, and somatosensory systems [2], therefore any exercise that alters or removes the input of any of those sensory systems could be classified as a balance exercise. Balance exercises are part of a vestibular rehabilitation program, which is specifically indicated for individuals who have balance impairments of vestibular origin [3]. In addition to challenging our sensory inputs, rehabilitation for an individual with vestibular hypofunction utilizes the strategies of adaptation, habituation, or substitution [4]. A systematic review completed in 2007 concluded that there is moderate to strong evidence suggesting that vestibular rehabilitation is effective for adults with chronic dizziness [5]. Research shows significant improvements in postural control [6–11], functional balance [12, 13], vestibulo-ocular reflex (VOR) gain [7], subjective dizziness symptoms [6, 9, 10, 12], motion sensitivity [8], and quality of life [14]. The literature also indicates that this type of rehabilitation is appropriate for people who have peripheral [9, 13] or central etiology [13, 15], and/or unilateral [5, 11] or bilateral hypofunction [11, 16]. Not pertinent to progression, but within the realm of vestibular rehabilitation, are canal repositioning maneuvers, which are a type of treatment intervention used for individuals with the diagnosis of benign paroxysmal positional vertigo [4, 17].

There are examples of successful exercise programs used by clinicians that treat individuals with balance deficits, but these examples fall short of providing details regarding the rationale for how participants were progressed. For example, Gill-Body et al. (1997) described the results of rehabilitation programs for two individuals with cerebellar lesions in a case report; both patients had subjective and objective improvements in postural stability following a 6-week physical therapy exercise program focusing on stability challenges [18]. The experienced clinician prescribed a three phase treatment program with individualized treatment activities chosen based on each person’s specific impairments and one of the programs included eye-head coordination exercises. While all of the exercises are justified, they do not provide a hierarchy for progression for less experienced practitioners, or for standardized practice.

Alsalaheen et al. (2013) examined chart reviews for 114 patients receiving vestibular rehabilitation for dizziness and imbalance following a concussion to determine the prescription of exercises based on pre-determined categories [19]. The most commonly prescribed exercises were eye-head coordination, standing static balance, and ambulation exercises [19]. This report also indicated the presence of "preferred prescription patterns" and further discussed the importance of understanding patterns used by experienced clinicians to improve quality of care in managing persons post-concussion [19].

It is evident that some balance exercises are more challenging than others, however there currently is not an accepted hierarchy or sequence to follow related to the level of difficulty for a specific exercise, which considers all of the possible variables that contribute to balance. Some of the variables to consider include whether or not the exercise is: static or dynamic; completed with a specific foot stance (feet apart, feet together, semi-tandem, tandem, or single leg stance); performed on a firm, foam, or ramped surface; performed with visual input (i.e., eyes open or closed); implemented during ambulation (multitude of variations); or performed with a gaze stability challenge [20]. The aim of this research is to develop a preliminary conceptual framework for progressing balance exercises. The justifications for the chosen sequences are based on established principles of exercise, theories of motor control, and consideration of how variations in sensory input alter the degree of challenge for any given exercise.

Methods

The theoretical framework described below is the product of a collaborative team of physical therapists and engineers with extensive experience in the realm of vestibular rehabilitation. Because a subset of the exercises has not yet been studied experimentally for progression validation, clinical expertise guided aspects of the progressions within the framework. Most of the rankings, which are ranked in order of degree of difficulty, were primarily based on information collected from a scoping literature review, interviews and focus group discussions with physical therapists and postural control experts, as well as pilot studies involving repeated trials of each exercise. Hundreds of exercise combinations were discussed and research is ongoing to validate the hypothesized hierarchy.

Theories of postural control and motor learning were also considered when determining exercise progressions. As we ranked the exercises in order of increasing balance difficulty, we were cognizant of biomechanical principles that determine postural stability, specifically, the difference of center of pressure (COP) and center of gravity (COG) [1]. For clinical application, it has been hypothesized that people who have larger COP-COG differences in static standing are at greater fall risk than individuals with smaller values [21]. However, large COP-COG differences are needed to maintain balance for perturbed standing, therefore small COP-COG differences during dynamic standing tasks place a person at greater fall risk [21]. This notion is important to consider as an exercise adds variables that make it more dynamic.

Results

We propose incorporating six different exercise categories when developing a balance program aimed at improving postural control: static standing, compliant surface standing, weight shifting, and modified center of gravity, gait, and gaze stabilization or VOR training. These categories correspond to the six different balance control systems that are included in the Balance Evaluation Systems Test (BESTest) [22]. Within each category there are variants with modifications that distinguish each exercise (Figure 1) and affect the level of exercise difficulty. The progression framework ranks each exercise in order of difficulty within each category (Tables 1 – 5).

Foot Stance

We ranked the following five stances in order of increasing difficulty as the base of support becomes narrower: feet apart, feet together, semi-tandem Romberg, tandem Romberg, and single leg stance. Meulbauer et al. (2012) studied healthy young adults while maintaining stability in four stances including feet apart, staggered stance, tandem stance, and single leg stance. Participants stood on a firm computerized balance platform with eyes open and as the base of support was reduced, the center of pressure displacements significantly increased [23]. In this framework, each of the exercise categories applies the principle of increasing the challenge of an exercise by narrowing the base of support except for the weight-shifting exercise category, where the feet apart stance was maintained throughout the progression.

Surface

Several studies have shown that balance is more challenged when standing on compliant compared to firm surfaces [24, 25]. Additionally, an increase in the surface slope adversely affects postural stability during standing [26]. When a person stands on a sloped surface the risk of falling increases because of the high friction force between the feet and the surface [27]. Redfern et al. (1993) compared the effect of downhill and uphill walking on postural stability and found that people tend to slip more often while walking downhill due to the increased friction force at heel strike [28]. Persons with bilateral vestibular loss demonstrated very large and fast postural sway compared to individuals without vestibular deficits when standing on an inclined surface with eyes closed, which reflects difficulty interpreting surface orientation based on somatosensory inputs alone [29].

This information, along with the input from clinical experts, led us to hypothesize that the degree of difficulty and the amount of postural sway increases in the following order for surface progression: firm, firm with incline, firm with decline, and foam. This sequence was used for the modified center of gravity exercise category and the firm to foam progression was used in the VOR and weight shifting categories.

Visual Input

Vision affects postural control across all populations [30]. In a study of elite athletes, increased postural sway was observed with eyes closed activities compared to eyes open [25]. During visual sway referencing experiments it has been shown that older adults have increased postural sway compared to younger adults, indicating that older adults have greater visual dependence [31]. For a person with vestibular loss, the effect of removing visual input results in decreased postural control, especially when standing on an unstable surface [29]. Because of the negative correlation between visual input and performance, we deemed activities completed with eyes closed to be more challenging than activities with eyes open in the proposed framework. This consideration can be applied to all categories except for the VOR category, as the exercises in this category necessitate that the eyes are open.

Static vs. Dynamic Standing

Within the framework highlighted in Tables 1–5, we consider the effects of dynamic weight-shifting and upper extremity movements that lead to changes in center of gravity. Existing literature and clinical experience informed our hypothesis that weight-shifting activities in the medial-lateral direction are easier than the anterior-posterior direction with feet apart. This was predominantly based on the work of Winter et al. (1996), which concludes that during quiet stance with feet apart, the hip muscles primarily control postural stability in the medial-lateral direction, where as the ankle muscles control balance in the anterior-posterior direction [32]. Because the base of support during feet apart stance is greater in the medial-lateral direction, a larger COP displacement is required to disrupt postural stability in this direction. Theoretically this would make this activity less challenging than maintaining COP in a smaller base of support where a smaller displacement may cause imbalance due to movement beyond the base of support. Additionally Chou et al. (2009) have demonstrated that subjects show better directional control in the medial-lateral direction than in the anterior-posterior direction when tasked with reaching to targets displayed on a screen during weight shifting assessments using the Neurocom Smart Balance Master ® system [33]. Not surprising, it has been shown that ankle range of motion is an important factor related to balance and functional ability [34, 35] and increased risk of falling is related to poor medial-lateral control [32, 36]. Although postural stability has not been analyzed during weight shifting at different speeds and distances, we propose that postural sway will increase when the speed of the movements is decreased. Additionally, we propose that postural sway increases as the center of mass extends beyond the base of support [37].

In the development of the BESTest, Horak et al. (2009) investigated the type of balance control system that is associated with different balance diagnoses and results showed that individuals with somatosensory deficits had worse anticipatory postural adjustments [22]. One activity used to assess anticipatory postural control in the BESTest is lifting a weight to shoulder level. In our framework, we chose to include bilateral shoulder flexion, with and without weight, to achieve exercises that modify COG. We hypothesized that completing this task with heavier weights will elicit greater postural sway compared to completing the task with a lighter weight or no weight. Based on our clinical experience, we hypothesize that lifting the weight at slow speeds will cause more sway compared to faster speeds.

Head Movements

Head movements often provoke visual blurring, dizziness, imbalance and path veering in patients with peripheral vestibular hypofunction, resulting in limited head movements while walking [14]. Cohen et al. (2014) found that both healthy controls and individuals with vestibular hypofunction were able to maintain postural stability for longer durations in trials completed with no head movement compared to trials completed with yaw and pitch head movements [24]. In subjects with vestibulopathy, visual acuity degrades as a consequence of head movement, presumably because the VOR cannot stabilize the gaze [38]. Mamoto et al. (2002) found that patients with unilateral and bilateral vestibular involvement adopted head stabilization as a strategy to maintain gaze stability [39]. It has also been shown that patients with vestibular disorders had a higher percentage of lower (worse) scores on the Dynamic Gait Index in the yaw plane compared to the pitch plane during gait [40]. We therefore proposed that head movements in the yaw direction are more challenging than balance activities incorporating head movements in the pitch direction. No head movement was subsequently deemed the easiest condition of the three variations. In our framework, head movement considerations were used for progressing static standing, compliant surface, gait, and the VOR exercise categories.

Dual Tasks

Improved performance would be expected with focused attention toward the task when compared to an activity that is completed with a cognitive or manual dual task challenge [41]. Silsupadol et al. (2006) included examples of both cognitive and manual dual task challenges in their case report which investigated dual task training in older adults with balance impairments [42]. Examples of cognitive tasks include, but are not limited to, naming words within an identified category, counting backwards, arithmetic, memorization, and spelling tasks for cognitive tasks. Reaching, throwing/catching a ball, kicking a ball, and carrying an object are some examples of manual tasks [42]. We included dual tasks within our framework in each of the categories except for weight shifting.

Redfern et al. (2004) found that patients with well-compensated vestibulopathies require increased attention compared with healthy controls when performing a balance task concurrently with a cognitive task. The effect of the cognitive task had a greater negative impact on performance as the difficulty of the postural task increased [43]. When choosing balance and gait related tasks, the clinician needs to consider whether the elements of the task demand voluntary movement, an autonomic postural response, or an anticipatory postural adjustment. Patients need to be challenged with a combination of all three conditions for optimal recovery [44]. During the development of this framework, the expected postural response elicited by each exercise was deliberated with the goal to encompass each type of response in the framework.

Environment

We acknowledge that many different environmental variables can alter performance and impact the degree of challenge for an exercise. Some of the considerations include whether the exercise is completed in settings that are: quiet or loud; empty or crowded; high or low visual contrast; and predictable or unpredictable [45, 46]. Additionally, the following factors can affect performance: the type of compliant surface (foam density, carpet type, outdoor surface type, consistency of surface type); the lighting (fluorescent, iridescent, natural light, and amount of light); the presence or absence of physical assistance (from the support of a physical therapist, family member, assistive device, or even a wall or other stable object/ surface for support); and the tone/ inflection of the tester in providing instructions or commands [45]. Our framework varies the type of surface to increase the difficulty of the exercises. The adoption of this type of framework in the clinical setting should also consider the additional variables that simulate the real world environment for the client.

Gait

The goal of gait training is to assist the patient in mastering walking on level surfaces and then challenge the patient with progressive variations in the task or environment, while working toward the same quality of independent controlled locomotion [47]. Patients with vestibular involvement typically ambulate with a wide base gait, decreased gait speed, and limited head movement [39,48,49]. All of the considerations discussed so far can be applied to gait exercises to alter the challenge. Additionally, we included the speed at which someone walks in our framework, where the literature and clinical experience guided our decision to progress from self-selected to fast and finally to slow speeds in order to increase the difficulty level [50,51]. We also propose based on clinical experience that walking backward is more difficult than walking forward. Although not included in our framework we recognize that additional gait variations can be included to challenge a patient such as: changing gait speeds within a given trial, incorporating quick stops/starts, stepping over objects of different sizes, sidestepping, braiding, marching, completing 180 and 360 degree turns, walking on toes, or walking on heels [52].

Special Considerations for Eye/Head Exercises

The VOR, when functioning normally, acts to maintain stable vision during head motion and consists of two components: the angular and linear VOR [53]. The angular VOR is controlled by the semicircular canals and is primarily responsible for gaze stabilization. The critical stimulus for recalibration of the dynamic VOR response following unilateral vestibular loss is the presence of motion of images on the retina during head movements. Adaptation of the VOR gain is a dynamic process that requires visual experience for its acquisition [54].

Gaze stabilization exercises are an example of adaptation exercises used to improve the gain of the VOR [55]. This exercise progression begins with the VOR X 1 viewing paradigm involving the use of a stationary target at a distance of 1 meter against a plain background while performing either pitch or yaw head movements. The patient is instructed to keep his/her eyes fixed on a target and move his/her head from side to side as fast as possible while maintaining the target. Patients are instructed to slow the speed of their head if the target is moving or blurring consistently. Examples of exercise variations include changing the stance position, the stance surface, the distance of the target, and the background from plain to complex [55].

Additionally, VOR exercises can be completed via VOR X 2 viewing where the target and head both move, but in opposite directions. In this case, the target and head velocity are equal, but opposite in direction, thereby requiring an angular VOR eye velocity twice as large as head velocity, stimulating a large change in the angular VOR [55]. There is evidence that the VOR gain can increase with gaze stability exercise in individuals with vestibular hypofunction [55]. Herdman et al. (2003) found that significant improvements in dynamic visual acuity occurred in adults with unilateral vestibular hypofunction who completed VOR exercises [55].

Substitution exercises are used to treat patients with bilateral peripheral vestibular hypofunction [56]. In this treatment approach, patients are taught to primarily rely on visual and somatosensory cues to maintain postural stability in place of absent vestibular inputs. When there is bilateral peripheral vestibular weakness, but not complete loss, both adaptation and substitution exercises are utilized to maximize function. In a study involving saccade and VOR motor learning, it was concluded that both saccade and VOR systems are adaptable and can work together to optimize gaze stability in persons with bilateral vestibular loss [57].

Therefore, we believe that corrective saccades are an important substitution exercise for patients with bilateral and unilateral vestibular loss. Exercises are used to promote saccadic eye movements for gaze stability by teaching patients to move their eyes to a target while the head is stationary. General guidelines for vestibular exercises to improve gaze stability and balance exercises to improve postural stability following unilateral and bilateral peripheral vestibular hypofunction have been outlined by Herdman et al. (2001), but there are limited reports on how vestibular physical therapists translate the principles into practice [58]. Most exercise programs are customized to the deficits of the patient [12, 59]. Customized exercise appears to be superior to handing patients a standard written exercise handout [8].

Not described specifically in our progression, but sometimes utilized, are exercises for visual vertigo [60]. Vittae et al. [61], Szturm et al. [7], and Pavlou [59] have suggested that exposure to increasingly more complex visual scenes can promote changes in the VOR gain. Recently, optokinetic stimulation has been used with persons with mal de debarquement [62]. Any of the exercises already described can be augmented with these visually complex backgrounds, such as virtual reality [63, 64], head-fixed visual stimuli apparati [65], or optokinetic scenes [7, 59].

Discussion

Ultimately, the goal of balance rehabilitation is to improve patients’ daily lives. However, improvement is contingent on intense, challenging, and progressive task-specific training [66]. Furthermore, motor learning is necessary if betterment of functional performance is desired. Karni et al. (1998) have shown that motor learning is achieved following practice on the order of minutes [67]. If a few minutes of practice are required for skill acquisition, and

30 second training segments are used with the proposed framework, we propose completing 4 – 6 repetitions of each exercise, however specific volume parameters have not been established [68]. Evidence indicates that balance training 2 – 3 times per week is recommended for healthy adults and older adults [68–70].

When adopting a balance progression framework into clinical practice, the timing of progressing to the next exercise is important. We believe that this should occur when the individual's postural control is stable enough that they perceive the challenge of the task to be minimal and the postural sway is consistently within the limits of stability during multiple repetitions of the exercises. Mastery of static postural control involves maintaining balance in a position with minimal sway without loss of balance and without use of external supports [47]. Therefore, an exercise would not be considered to have been mastered if an individual steps out of the stance position, touches the wall or other surface to maintain balance, or requires hands on assistance from the physical therapist for safety or to prevent falling. Additionally, we suggest that the patient's perception of their performance should be considered in the determination of when to progress to a more difficult exercise.

For clinical application it is important to realize that people undergoing any type of exercise program may plateau. In efforts to avoid boredom with repeated attempts at a particular exercise, or frustration associated with failure of an exercise, we propose that an individual who is unable to pass a particular exercise should revisit the preceding exercise within the category. If they succeed, they should retry the initially failed exercise. If they again fail to master that task, they should move ahead to the next exercise to see if this difficulty is secondary to that specific individual, or may be due to an error in our proposed progression schema.

An additional clinical application consideration is related to the method by which the clinician ensures that their patient is performing the exercise at the appropriate speed. This could be related to cadence during ambulation, speed of head movement with dynamic head turning or VOR completion, weight shifting speed, or extremity movement speed for the modified COG. We suggest the use of a metronome or verbal cues from the clinician to achieve the desired speed.

In 2011, the American College of Sports Medicine (ACSM) published guidelines aimed to inform individualized exercise prescription. The ACSM guidelines used data from randomized controlled trials to support the optimal volumes, patterns, and progressions they proposed for performing aerobic and resistance exercises. However, these specific recommendations are stated as "not known" for neuromotor exercise prescription [68]. Guidelines for aerobic exercise progression include increasing volume of metabolic equivalents or pedometer step counts at a pattern of certain minutes per day with progression of duration, frequency, and intensity increases [68]. Within the resistance exercise guidelines for progressing, percentages of the one-repetition maximum is used, with increasing sets and repetitions, and progressions of greater resistance, increased repetitions, and increased frequencies [68].

The framework has some limitations that we have identified. We recognize that not every possible variable is depicted for each exercise category and, as discussed above, many environmental considerations may affect the complexity of a task. Additionally, personal characteristics may alter the challenge and/or tolerance for an exercise differently amongst individuals. Factors that may affect success of a vestibular physical therapy program include: age, distal sensation, medical co-morbidities, drug regime, visual deficits, magnitude of vestibular loss, cognition, psychiatric co-morbidities [71], and attitude about the exercise program. There is also the issue of consistency of performance within each subject's training program that is difficult to control (i.e., effects of stress on their daily performance). These stressors may include both positive and negative outside life events, subjective perception of being in the state of a "good" or "bad" day. Subsequently, individual personality differences and the type of coping mechanisms they use, may impact how the stressor impacts their performance. In addition to the magnitude of vestibular loss, we expect that the stage of recovery could also impact consistency (i.e., someone who is well compensated might not fluctuate in terms of balance as much as an individual who is uncompensated).

Another limitation is related to differences in baseline performance. It is necessary to complete some assessment exercises to determine where each individual should start within each category. The fact that some of the progressions have not been tested and validated presents added limitations to the framework. Finally, baseline strength differences may cause misunderstandings about how light and heavy weight affects the balance challenge within the modified center of gravity category. By defining standard amounts for the light weight conditions (one pound) and heavy weight conditions (three pounds), we may see the light weight is actually very challenging, or perceived as heavy, for one person and the heavy weight could be no challenge, or perceived as light, to another person.

The framework may also be used with technologies to support the development of telerehabilitation balance exercises programs, including programs that leverage home-based technologies such as the Wii Fit [72] and sensory augmentation [73]. Using a structured balance exercise progression in a telemedicine based program may be an alternative way to provide additional rehabilitative services for patients with balance impairments who have limited access to physical therapy secondary to insurance or geographical restrictions.

Conclusion

A theoretical balance exercise framework has been presented. The rationale for and structure of an exercise program that progresses from easier to more challenging exercises for a person with a vestibular disorder was discussed. The understanding and use of a balance exercise hierarchy has the potential to improve patient care and the quality of clinical research trials. We suggest that patients should be provided exercises based on their presenting complaints and deficits and progressed throughout the sequence within the given exercise category to optimally challenge their balance. High level exercises are included in this framework to allow for adequate intensity which aims to avoid an under-dosed exercise program. While much effort was spent hypothesizing the hierarchy of balance exercises in this framework, future research is needed to validate, or reorganize, the order in which individuals with balance and vestibular disorders are progressed. Instead of performing a handful of the same exercises repetitively, the proposed balance sequence enables patients to be challenged by a multitude of exercise variations. The novel exercises may stimulate improved exercise motivation and compliance supporting the overall goal of skill acquisition.

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Abbreviations

BESTest	Balance Evaluation Systems Test
COG	Center of Gravity
COP	Center of Pressure
EC	Eyes Closed
EO	Eyes Open
PA	Pennsylvania
USA	United States of America
VOR	Vestibulo-Ocular Reflex

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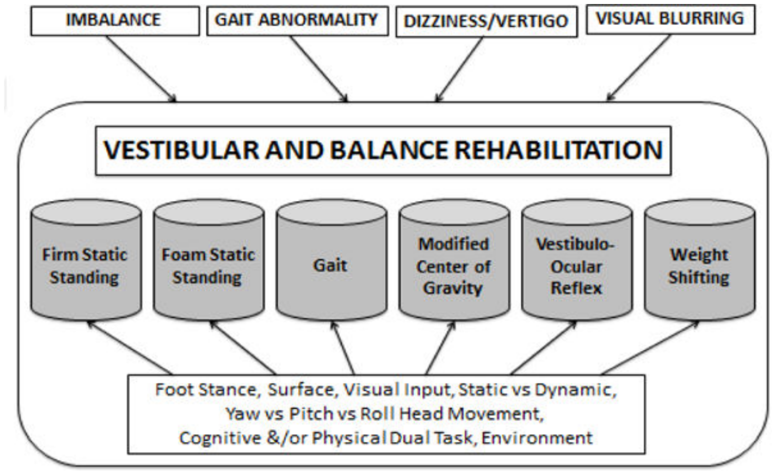

Figure 1.
Categorization of Balance Exercises and Considerations for Progression.

Table 1

Firm and Foam Static Standing Progression.

	Feet Apart	Romberg	Semi-Tandem Romberg	Tandem Romberg	Single Leg Stance
EO, No head movement	1	2	3	4	5
EC, No Head Movement	6	7	8	9	10
EO, Pitch Head Movements	11	13	15	17	19
EO, Yaw Head Movements	12	14	16	18	20
EC, Pitch Head Movements	21	23	25	27	29
EC, Yaw Head Movements	22	24	26	28	30

Activities are ranked numerically in order of increasing difficulty.

EO: Eyes open; EC: Eyes closed.

Table 2

Gait Progression.

	Walking Speed		
	Self-Selected	**Fast**	**Slow**
Forward, Firm, EO, No Head Movement	1	2	3
Forward, Firm, EO, Pitch head Movement	4	6	8
Forward, Firm, EO Yaw Head Movement	5	7	9
Backward, Firm, EO, No Head Movement	10		
Forward, On to/Over Foam, EO, No Head Movement	11	12	13
Forward, Firm, EC, No Head Movement	14		
Forward Tandem, Firm, EO, No Head Movement	15		
Backward, Firm, EC, No Head Movement	16		
Backward Tandem, Firm, EO, No Head Movement	17		

Activities are ranked numerically in order of increasing difficulty.

EO: Eyes open; EC: Eyes closed.

Table 3

Modified Center of Gravity Progression.

	Type of Weight; Speed of Arm Movements					
	No Weight, Fast	**No Weight, Slow**	**Light Weight, Fast**	**Light Weight, Slow**	**Heavy Weight, Fast**	**Heavy Weight, Slow**
EO, Feet Apart, Firm	1	4	7	10	13	16
EO, Romberg, Firm	2	5	8	11	14	17
EO, Semi-Tandem, firm	3	6	9	12	15	18

Activities are ranked numerically in order of increasing difficulty.

EO: Eyes open; EC: Eyes closed; Heavy weight = 3 lbs.; Light weight = 1 lb.

Repeat Sequence (1–18) with: Eyes Open, Toes Up (19 – 36); Eyes Open, Toes Down (37 – 54);

Eyes Open, Foam (55 – 72); Eyes Closed, Firm (73 – 90); Eyes Closed, Toes Up (91 – 108);

Eyes Closed, Toes Down (109 – 126); Eyes Closed, Foam (127 – 144).

Table 4

Weight Shifting Progression.

	Medial/Lateral Weight Shift	Anterior/Posterior Weight Shift
EO, Firm, Fast Speed, Medium Tilt	1	2
EO, Firm, Slow Speed, Medium Tilt	3	4
EO, Firm, Fast Speed, Maximum Tilt	5	6
EO, Firm, Slow Speed, Maximum Tilt	7	8

Activities are ranked numerically in order of increasing difficulty

EO: Eyes Open; EC: Eyes Closed; Medium Tilt = at approximately 50% of their maximum ability to tilt in either the medial/lateral or anterior/posterior direction;

Maximum Tilt = at their limit of stability.

Repeat sequence (1–8) with Eyes Closed (9–16).

Repeat sequence (1–16) with Foam (17 – 32).

Table 5

Vestibulo-Ocular Reflex Progression.

	VOR x1	VOR x2
Firm, Feet Apart, 1 meter, White Background	1	3
Firm, Feet Apart, 3 meter, White Background	2	
Firm, Feet Apart, 1 meter, Complex Background	4	6
Firm, Feet Apart, 3 meter, Complex Background	5	

Activities are ranked numerically in order of increasing difficulty.

VOR: Vestibulo-Ocular Reflex.

Repeat sequence with: Firm, Romberg (7 – 12); Firm, Semi-tandem Romberg (13 – 18);

Firm, Tandem Romberg (19–24); Foam, Feet Apart (25 – 30); Foam, Romberg (31 – 36);

Foam, Semi-tandem Romberg (37 – 42); Foam, Tandem (43 – 48).