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Original article

Proactive use of perturbation training for balance and posture control in geriatric rehabilitation: An experimental study

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Abstract

Background: Aging is a complex process involving several variables that interact to cause deterioration of various physiological functions, such as low motor function and slow protective reflex.
Objectives: This study aimed to determine the effect of perturbation training on balance and postural control upon center of gravity (COG) sway velocity in the older population using the modified clinical test of sensory integration on balance (m-CTSIB) component of the Neuro Com Balance Master® and Timed Up and Go (TUG) test.
Methods: An experimental study, using a pre-post intervention model, involving 30 individuals aged 65–85 years with mild to moderate fall risk, was conducted at the Pune Tertiary Hospital from August 2022 to January 2023. Perturbation training was given using a tilt board along with conventional exercises for 3 days per week for 4 weeks (12 sessions). Pre–post assessment was done using the M-CTSIB test on the Neuro Com Balance Master® and the TUG test. The paired samples *t*-test was used for comparing the pre and postintervention measures.
Results: Pre- and postintervention measures on the TUG test and M-CTSIB test on the Neuro Com Balance Master® showed a statistically significant improvement in the TUG values ($P < 0.0001$) and COG sway velocity under all conditions except on the firm surface with eyes open, with FIEO ($P = 0.1208$), FIEC ($P = 0.0011$), FOEO ($P = 0.0013$), FOEC ($P < 0.0001$), and composite COG sway velocity ($P < 0.0001$).
Conclusion: To achieve postural control along with conventional exercises, perturbation training can be effective on proprioception, thus promoting the muscle recruitment pattern, which minimizes loss of balance and increases sway velocity, thereby eventually reducing episodes of fall.

Keywords: Balance, geriatrics, postural control, rehabilitation.

Aging is a complex process involving several variables that interact to cause the deterioration of various physiological functions. Loss of sensitivity of the peripheral sensory system contributes to impaired balance control and a high fall risk, leading to a poor quality of life, injuries or death. [1] Fall is a serious problem that increases with age as 50.0% of adults aged 80 years and above experience a fall every year. There are several modifiable risk factors for falls, including muscle weakness, problems with balance and gait, poor vision, psychoactive medications, and home hazards.

Multiple neurological pathways communicate to maintain balance, which is a highly integrated system. The somatosensory, vestibular, and visual physiological systems are involved in maintaining balance in old adults. [2] Balancing is the process by which postural stability is maintained. Postural stability is the ability of an individual to maintain their center of gravity (COG) within the base of support (BOS), which is controlled by many complex physiological and neurological processes.[3] To maintain posture, the sole, the sacroiliac joint, and the cervical spine provide proprioceptive input because these areas have a high density of mechanoreceptors. [4]

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The perturbation-based balance training is emerging as a viable option to improve a person's resilience for fall reduction. Inducing repeated disturbances to the alignment of Com relative to the BOS is enhances fall-resisting skills in older adults. Perturbation-based balance training uses external, repeated mechanical destabilizing disturbances to elicit rapid reactions to regain postural stability in a safe and controlled environment, ultimately leading to the activation of specific recovery strategies. [5]

As these recovery strategies convolutional, it is best to train compensatory responses through unexpected external perturbation exercises performed while standing. [6] These techniques may induce compensatory muscle activation patterns in old adults. The goal is to retrain the body's inherent neuromuscular protection mechanisms to prevent a fall following a postural perturbation.

The training is an effective way to re-educate proprioception, improve mechanoreceptor function, and restore normal neuromuscular coordination through controlled movement and perturbing stimuli.[6] When appropriately trained, older adults can quickly adapt to large postural perturbations by altering their biomechanics. There are various multicomponent programs for muscle strengthening, Tai chi, and functional and balance exercises, but they lack specificity.[7] Thus, it is imperative to integrate supervised perturbation training to elicit prompt responses and restore postural stability within a secure and monitored environment. The aim of this study was to determine the effect of perturbation training on balance and postural control upon COG sway velocity in older adults using the modified clinical test of sensory intregation on balance (M-CTSIB) component on the Neuro Com Balance Master® and Timed Up and Go (TUG) test.

Materials and methods

The study was approved by the institutional ethical committee DYPCPT/ISEC/42/2022. In this pre–post interventional study, a cohort of 67 individuals aged 65–85 years was considered for inclusion based on power analysis with an expected medium effect size (d) of 0.5, a significance level of 0.05, and a power of 80.0% according to specified inclusion and exclusion criteria. Older adults (including both males and females) with a mild to moderate risk of fall on the functional reach test with a score of 6–10 inches [8], walking independently without any assistive devices (such as walker, sticks or crutch) with a cognition level of 26 and above on the Montreal cognitive assessment (MOCA) were used as participants. Subjects with a history of recent fracture and surgeries of the lower limb and spine in the past 6 months, any neurological and vestibular impairments (Parkinson's, stroke, and vertigo), any uncorrected visual or hearing impairments, and those under medications that interfere with balance (antihistamine and antidepressants) were excluded from the study. Subsequently, 32 participants meeting the criteria were identified and recruited into the study. A written informed consent was obtained from each study participant before the commencement of the study.

A total of 30 subjects completed the study because 2 individuals were dropped out due to loss of contact as they went out of state. The study was conducted at DY Patil College of Physiotherapy, Pune, from August 2022 to January 2023. The study was explained in detail (including duration and possible risks and benefits) to the subjects (using vernacular language to the best of their understanding) and those who willingly opted to take part in the study were included upon signing a written consent.

A detailed assessment was taken by interviewing the subjects about their demographic details, vital signs (heart rate, blood pressure, respiratory change, oxygen saturation, and temperature), functional ability in the independence of activities of daily living (ADLs) and instrumental activities of daily living using the Katz Index of Independence in ADL [9], use of any assistive devices, hearing or visual impairment, MOCA score ≥ 26, nutritional status, medical history, comorbidities such as diabetes, osteoporosis, urinary incontinence, dementia, vertigo, and if the subject was undergoing any treatment or had any history of fall.

Pre-assessment using the TUG test and Neuro Com Balance Master® was taken using the M-CTSIB–COG sway velocity. In the TUG test [10], the participant was asked to sit comfortably in a firm chair with arms and back resting against the chair, and feet on the floor. He/she was then instructed that, on the command "go," he/she was supposed to get up and walk 3 m as soon as it was safe and feasible, step across a line drawn on the floor, turn back, and recline on the chair. The participants were asked to wear regular footwear. They walked under supervision. The time taken for the exercise by the participant was noted.

The participants were then taken on Neuro Com Balance Master® for evaluation of their postural control. The equipment was calibrated prior to assessment. On the Neuro Com Balance Master®, the test chosen was M-CTSIB.

M-CTSIB had 4 conditions, including 2 conditions on the static surface and the other 2 on the dynamic surface. Each condition had 3 trials.

1. Standing on the force plate-firm surface with eyes opened.
2. Standing on the force plate-firm surface with eyes closed.
3. Standing on the force plate-Compliant (foam) surface with eyes opened
4. Standing on the force plate-Compliant (foam) surface with eyes closed.

COG sway velocity (mean of shift in COG alignment in mediolateral and antero-posterior directions in time degrees per second) was recorded pre-intervention for all the subjects using the balance master. [11]

Procedure

Along with perturbation training, all subjects participated in a conventional exercise program (including strengthening, stretching, proprioceptive, and balance retraining exercises given three times a week for 4 weeks) to prevent falls .

Perturbation training

The program involves practical implementation of perturbation training administered to individuals by a physical therapist using a tilt board.

- Dimensions/specifications- The surface of the tilt board measured 7.5 cm × 7.5 cm, and the amount of tilting during perturbations ranged from 2.5 to 7.5 cm.
- Position: During the perturbation training, the tilt board was placed between the parallel bars for safety purposes and the subject stood on it with bilateral lower-extremity support, feet shoulder width apart, hands across the side and eyes looking straight. If the subject felt any instability/imbalance/fear of falling, he/she could hold the parallel bars to maintain an upright position.
- Method: Heart rate was monitored along with the Borg scale to record the rate of perceived exertion during the perturbation training to minimize unpleasant episodes. The erect posture of the subject was manually disturbed by applying arbitrary front-to-back tilting perturbations. The intervals between the perturbations ranged from approximately 1 to 5 s. Tilting perturbations could be applied quickly or slowly and gradually, depending on the situation. the response was expected to involve taking up the bipedal upright stance position on the board. If the participants got up from the board, the therapist would provide supplementary assistance. The same steps were performed to alter the medial and lateral tilting.
- Intensity and duration: The number of perturbations prescribed per session ranged from 32 to 64. The typical parameters had a perturbation session lasting for 60–90 s with 30–60 s rest break for tissue recovery. The total duration of each session ranged from 30 to 45 min. Training was given three times per week for 4 weeks (12 sessions).
- Progression- progression was made by gradually increasing the duration of the session by 2 min every week, adding dual task training such as talking and upper extremity activities, and delivering perturbation in unpredictably varying from a quick application to a slow, gradual application of tilting at random intervals of time, thus providing a greater challenge.

Conventional exercise program

The conventional exercise program included strengthening and stretching exercises. The strengthening exercises targeted the knee extensors, knee flexors, hip abductors, ankle plantarflexor, and ankle dorsiflexor with 8–10 repetitions per session. Progression was achieved by increasing the weight of the ankle cuffs or the number of repetitions. The stretching component involved hamstring stretches, tendoachilles (TA) stretches, and quadriceps stretches, each performed for three repetitions with a 10-s hold per stretch.

Statistical analysis

The collected data were checked for normality using the Shapiro–Wilk's test of normality. The paired samples *t*-test was used to test for significant differences pre- and post-intervention in the baseline parameters (age, BMI according to Asian classification, gender, and heart rate). Quantitative data were presented as mean ± standard deviation (SD). $P < 0.05$ was considered as statistically significant.

Results

Thirty participants with a mean age of 69.3 ± 4.8 years (16 males/14 females) were enrolled in the study. The mean body mass index (BMI) and mean heart rate of the participants were 25.9 ± 4.1 kg/m^2 and 80.2 ± 7.1 beats per minute, respectively.

Table 1. Comparison of pre and post effect of perturbation training on balance using TUG values and postural control with COG sway velocity on M-CTSIB.

Component	Pre mean + SD	Post mean + SD	Mean difference	*P* – value
Timed up and go test (seconds)	13.9 ± 2.7	11.2 ± 2.0	2.8	< 0.0001*
Firm EO	0.4 ± 0.2	0.3 ± 0.1	0.1 ± 0.2	0.1208
Firm EC	0.4 ± 0.2	0.3 ± 0.1	0.1 ± 0.2	0.0011*
Foam EO	0.6 ± 0.2	0.4 ± 0.2	0.2 ± 0.3	0.0013*
Foam EC	0.8 ± 0.4	0.5 ± 0.2	0.3 ± 0.3	< 0.0001*
Composite (average/mean of all 4 conditions)	0.6 ± 0.2	0.4 ± 0.1	0.2 ± 0.2	< 0.0001*

EO, Eyes open; EC, Eyes closed; * P < 0.05.

There was a significant reduction in TUG scores ($P < 0.0001$, **Table 1)**, indicating improved mobility and quicker response time. COG sway velocity on M-CTSIB varied, with a significant reduction in sway velocity under all conditions except on the firm surface and at the time of eyes open ($P = 0.1208$). The composite score, averaging all conditions, also showed a significant improvement ($P < 0.0001$).

The significant improvement across all conditions reflects the overall effectiveness of the perturbation training in enhancing both the speed of movement and postural control under various sensory conditions, thus, reducing the risk of falls in older adults.

Discussion

Our findings show perturbation training in conjunction with conventional exercises improved balance using TUG and postural stability using sway velocity, which might help in minimizing the risk of falls. These results suggest that perturbation exercises performed on a destabilizing surface provide sensorimotor learning, which helps to elicit automatic postural stabilization, as shown by improvements in postural stability on the COG sway velocity parameters under various conditions. It also effectuates reactive balance-correcting responses and prompts postural strategies, such as ankle strategy, hip strategy, and stepping strategy, which constitute muscle coordination to maintain postural control. [12]

Perturbation training includes repeated externally applied mechanical perturbations on an unstable platform with incremental speed that produce quick responses to regain postural stability in a confined space as it fosters feed-forward /proactive control of stability, which yields a recovery stepping response.

Conventional strengthening exercises (knee extensor, knee flexor, hip abductor, ankle plantarflexors, and dorsiflexors) and stretching exercises (hamstring, TA, and quadriceps) with postural perturbation also optimize muscle recruitment and recover balance, which changes when the muscular power of the lower extremities grows, and achieve postural control and minimizes risk of fall. [10]

Our results show that balance was improved with TUG score; slow to fast perturbation gave rise to postural instability, which shifted COG from the base of support and challenged motor strategies, and in response to balance correction postural strategies, and prevents the shift of COG and maintaining dynamic balance. The vestibular signal is used in an anticipatory manner, whereas proprioceptive control mechanisms primarily manage modifications to the body on the support.[13] Perturbation-based balance training seems to lower the chances of falling both in older adults and people with neurological disorders.[14]

The recalibration process of the central nervous system uses motor adaptations and generalizes them to untrained situations based on prior experience and knowledge in a feed-forward manner. This establishes a new functional BOS, which enables individuals to regain stability. [15]

The ability to anticipate changes and coordinate muscular action in response to disturbances of stability is known as dynamic balance. Our findings indicate that the effect of perturbation training on balance, as measured by TUG, was highly significant, which could be due to an increase in improved dynamic balance, which increases the confidence of an individual thereby increasing the speed of gait and reducing the time to cover the specified distance.

Postural sway, a measurement of a person's center of pressure, is used to assess postural stability during

static balance. Greater postural sway is linked to higher postural instability, which raises the risk of falling.Visual conflict increases postural sway (measured using M-CTSIB) and even gets challenged if one moves from a stable to an unstable surface, such as foam.[16]

During recovery from rapid disturbances caused by perturbations, hip motion is increased until ankle joints and hip motion are more equally responsible for balance.[17] This pattern is named alternating ankle and hip strategy. By constraining ankle torque to levels associated with keeping heel contact with the platform and limiting ankle movement, this strategy allows the body to stay within the possible balancing configuration. The hip flexion and ankle extension movements encourage center of mass recovery after perturbations.[11]

Nichols TR, *et al*. posit that "force-feedback" is a possible explanation for the coordinated muscle reaction to disruptive forces acting on a joint. Muscles that would resist the perturbation stretch and become activated when a force perturbing a joint is applied. Additionally, the reflexively inhibited muscles pull in the opposite direction from the perturbation's usual direction. [18]

The muscles antagonistic to those that resist the perturbing force experience less of the unwanted stretch reflex due to the inhibitory influence, but not entirely. Overall, this causes the perturbed extremity muscles to coordinately coactivate to tighten the joint and maintain stability. In this study, we observed that following perturbation training, there was a reduction in incidences of falling, as indicated by subjective incidents reported during telephonic interviews.

In this study, COG sway velocity measured using the modified M-CTSIB on Neuro Com Balance Master® post-probability training showed that there was a significant improvement in sway velocity in all parameters except Firm EO, which exhibited a clinically significant effect but not a statistically significant one. This may be attributed to the adaptation and involvement of the individual on a firm stable surface with visual input in their daily life, showing no statistically significant improvement after the intervention.

As older adults use their primary visual input for balance maintenance, their ability to maintain balance in the external environment is hindered when visual input is reduced. Additionally, older adults have enhanced balance when they stand on a firm surface than on a compliant surface. Clinicians can find means and ranges for every condition using the assessment of patients on the M-CTSIB.

Elderly perturbation helps with balance and reduces future risk of falling, allowing better task goal suppressing a step response and tendency to rely more on hip strategies. In line with this, our results revealed that elderly people's balance had improved and their risk of falling had decreased.

The main limitations of this study were that there was no follow-up on whether the participants continued the exercises or not, and on whether the effects of perturbation training were retained, and the intensity/magnitude of the perturbation was not well defined and could vary among subjects.

Further studies can be done focusing on different forms/modes of perturbation training and delving into optimizing the intensity and duration of perturbation training sessions, to account for individual variation and preferences. Additionally, longitudinal studies could provide insights into the long-term effects of perturbation training on reducing the risk of falls and enhancing the overall functional capacity in older adults.

Our findings suggest that perturbation training in conjunction with conventional exercises is a valuable strategy for improving postural control and reducing the risk of falls in older adults. Clinicians should consider adopting these targeted interventions, emphasizing the importance of supervised and secure settings for effective outcomes in geriatric rehabilitation.

Conclusion

We conclude that perturbation training in conjunction with conventional exercises of balance is an effective intervention to enhance postural control and the capacity of elderly people to avoid falling when they lose their balance. Thus, it can be given to older adults to enhance their physical function, decrease their fear of falling, increase their walking speed, and improve their fall-related self-efficacy.

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Conflict of interest statement

Each of the authors has completed an ICMJE disclosure form. None of the authors declare any potential or actual relationship, activity, or interest related to the content of this article.

Data sharing statement

All data generated or analyzed during the present study are included in this published article. Further details are available for noncommercial purposes from the corresponding author on reasonable request.

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