Effect of Vestibular Stimulation on Postural Stability and Mobility in Elderly

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Abstract

The Galvanic vestibular stimulation (GVS)is proven to be a promising tool to improve vestibular functioning. Decline in vestibular functioning in the elderly results in decreased capacity to identify weak signal which may lead to postural instability. Postural sway is produced when GVS is given over mastoid process. In this study our aim is to determine whether GVS can be utilized to maximize the effect of balance training programme among elderly individuals. Ambulatory community dwelling elderly (N=150, age 65.67±3.4 yrs) were randomly assigned to a control group (Group A, n=50, age 65.54±3.4 yrs), Placebo group (Group B, n=50, age 65.5±3.3 yrs) and an experimental group (Group C, n=50, age 65.98±3.5 yrs). Group A was not given any intervention while group B was given placebo stimulation along with balance training and group C was given noisy galvanic vestibular stimulation along with balance training program. Pre, mid and post data were recorded for overall stability index (OSI) (Biodex Balance Master) and Timed up and gotest (TUG) and analyzed. Compared to control group there was a significant improvement in overall stability and mobility in placebo and experimental groups. Significant difference was observed in improvement in experimental group compared with placebo group for both,OSI and TUG. Early improvement in stability and mobility was also observed in experimental group but similar results were not obtained in control and placebo groups. The outcome of this study suggests that GVS can be utilized therapeutically to optimize the efficacy of balance training clinically.

Keywords: *Fall, Postural Stability, Mobility, Vestibular Stimulation.*

Introduction

Older individuals constitute over 7.4% of the total population of India, and the elderly are a rapidly growing demographic.[1] Falls and fall associated secondary injuries in elderly are a serious concern, and a foremost cause of mortality and morbidity in them.[2] About one-third of community-dwelling elderly have a tendency to incur a falls, and 50% of those who fall have recurrent falls.[3–5] The Fall Mortality Rate is 2.1 in India.[16] Multiple factors contributing to fall risk, including physical, environmental, and behavioral have been identified. The role of the vestibular system for maintenance of upright posture is well understood. Age associated changes such as loss of muscle girth, loss of vestibular hair cells, degenerative musculoskeletal transformation or the onset of chronic diseases and their consequences are closely related with reduction in static and dynamic balance, and likely to cause falls.[7–9] Early identification of vestibular deficits and instability, with appropriate intervention may help in reducing the incidence of falls and associated risk.

Balance training exercises are designed to improve postural stability, mobility, and activities of daily living. Balance programme includes exercises helps to

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control equilibrium. Balance exercises are repetitive and progressed gradually to help to improve balance by reducing postural sway and irrelevant motor responses.[10] The maintenance of upright posture involves complex sensory systems including the vestibular system. Vestibular system is the main processing unit to maintain postural stability. As the age progresses, reduction in function of the vestibular system is well identified. Physical therapy is an established treatment for vestibular system dysfunction.[11]. However recent studies on noisy Galvanic Vestibular Stimulation (nGVS) are proven to be a promising treatment. During Galvanic Vestibular Stimulation, a small electrical current is delivered through surface electrodes over the mastoid process.[12] This transcutaneous electric current activates and induces continuous firing of the vestibular afferents.[13] In response to GVS, the capacity to identify a weak signal or to process incoming sensory information may be enhanced by adding white noise.[14]

Stimulating an individual's vestibular afferents during standing causes leaning in different directions depending upon the polarity of the electrodes.[13] Induction of a change in the electrical excitability of the vestibular nerves stimulates the vestibular nuclei and networks of the right hemisphere when the anode is attached to the left mastoid and the cathode on the right (known as LGVS), while the reverse electrode positioning (RGVS) leads to a bilateral activation.[15] Specifically, anodal and cathodal currents can be used to artificially decrease and increase the firing rates of the vestibular afferents. A standing subject tends to sway towards the anodal stimulus and/or away from the cathodal stimulus.[16] Another study shows that the sway response increases in direct proportion with the stimulus intensity when constant galvanic current is given.[17] Bilateral activation of vestibular cortices is obtained by applying left-cathodal/right-anodal GVS.[18]

Previous studies show that M1 a-transcranial direct current stimulation along with treadmill based gait training reduces the anterior posterior and medial lateral sway that significantly improved static balance along with functional performance in cerebral palsy children.[19] GVS when delivered to adults in quite-standing with open eyes, results in reduction in sway length and sway velocity.[20,21] It also produces similar results in bilateral vestibulopathy during quite-standing with closed eyes.[22,23]

In another study stochastic vestibular stimulation during walking resulted in increase in the gait speed and changes in stride length in healthy adults.[24,25] Sensitivity of the vestibular system to normal vestibular inputs can be increased by adding noise to subthreshold stochastic vestibular stimulation. This increase in the sensitivity is important to postural stability in more challenging situations. Studies suggested that noisy vestibular stimulation alters visuomotor activity and motor circuit functioning in Parkinsonism. This sensorimotor integration and performance might be associated to change in oscillation related to processing of information and error.[26]It has been shown that more erect posture is maintained after mechanical perturbation when appropriate galvanic current is given over the mastoid process.[27]

Thus the objective of this study was to determine the effect of noisy Galvanic vestibular stimulation on postural stability and mobility among elderly by performing a randomized control trialand to determine whether GVS can be utilized to maximize the effect of balance training programme among elderly individuals.

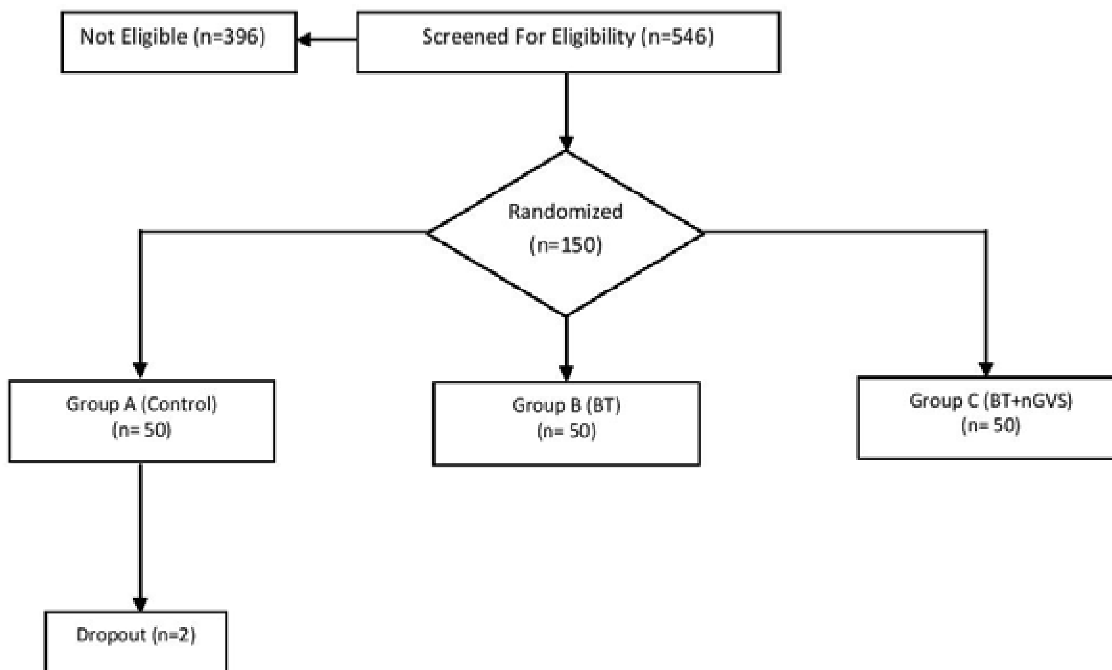
Method

This study employed a repeated measure design and a randomized controlled trial. A total of 150 participants were recruited from various Physiotherapy Centers in Noida, India and randomly allocated to three groups.

Inclusion criteria included individuals of both gender with age between (60 – 75) years, can walk in the community independently, able to perform the balance tests without assistive device and able to participate in a series of balance classes. All participants provided with patient information sheet.

Our study excluded subjects with the history of, any orthopedic surgery in the lower limbs, psychoactive medication in past six months, persons with progressive neurologic disorder that could affect balance and gait, orthostatic hypotension, unstable medical condition, diabetes for more than five years, vision less than 6/6 in either eye (even if corrected),fall in past 6 months and patient with high risk of fall (Tinetti<19)

Figure 1: Recruitment of study participants



A total of 546 volunteers were initially screened for the study out of which 150 who met the inclusion criteria were included in the study. Participants were randomly assigned into three groups after being fully informed about the nature of the research and taking written informed consent. (Fig 1) The first group was the control group A that included 50 subjects, 48 subjects (2 dropouts) were retested at the interval of 3rd and 6th weeks without any intervention.

50 subjects were allocated to Placebo group B who received placebo stimulation along with balance training and the remaining 50 subjects were allocated to the Treatment Group C who received noisy Galvanic Vestibular stimulation (nGVS) along with balance training.

A structured interview was conducted to collect socio demographic information including age and gender. Medical history was obtained by a physician who also recorded the presence of any symptoms associated with balance dysfunction.

All the study participants after group allocation were assessed pre, mid and post for postural stability on the Biodex Balance System and Timed Up and Go. Three trials of 20 seconds each were conducted for postural stability and mean of which was considered the final reading (as recommended in the manual described by the developers of the tool). Interval of one minute was given between each trial. Subjects sway over a fixed plate was monitored to calculate Overall Stability Index (OSI). During each trial participants were instructed to remain standing without support with eyes open. Value of OSI depends upon the rate of oscillation of the platform, lower values indicate good stability as lesser the oscillation lower will be degree of sway. For TUG every participant was given first practice trial which was not timed and then mean of three trials were considered as final value.

The intervention given in group B and C included a sixweek program of active stretching, postural control, endurance walking, and repetitive muscle coordination exercises. The actual frequency, repetitions, and resistance intensity of the exercises were adjusted according to individual ratings of perceived exertion.[28] During first week, subjects were made to exercise at a fairly low level (equivalent to 11 on the 16-point Borg ratings of perceived exertion scale). In follow up training, exercise at a moderate level of intensity (equivalent to 13 on the ratings of perceived exertion scale) were given. Balance exercises were given thrice a week for 6 weeks.

Group C Participants additionally received bi-polar binaural (left-cathodal/right-anodal) noisy Galvanic

Vestibular Stimulation of subliminal intensity for duration of 20 minutes during postural, dynamic stability and coordination exercises.

The tap water was used as a medium for lint cloth over the electrodes (60mm_40mm) and fastened with the elastic band over each mastoid to stimulate the vestibular afferents.

Statistical Analysis: All statistical analysis for Time-up and go procedure and Stability index parameters were performed with SAS 9.4 version software. Normality assumptions were tested using the Shapiro-Wilk test. All individual data parameters were tested for normality, and test variables followed a multivariate normal distribution in the population (as per the assumptions of Repeated measures ANOVA (RMA), as n>=25). The model considered here was based on an interaction effect between the treatment group and visits for between and within groups and for Least square mean estimates based on individual visits. Tukey's-Kramer method was used for adjusting p-values for multiple pair-wise comparisons for post-hoc analysis.

Summary statistics for demographics presented was based on the descriptive statistics N, Mean and standard deviation with three quartiles (Q1, Q2 and Q3) with minimum and maximum values. All statistical analysis was performed within 95% confidence interval,with alpha fixed at 5% level of significance for acceptance.

Results

All Male and Female subjects considered for this study were clustered between 60 to 74 years of age. The Mean & SD of the demographic data was comparable in the three groups. The average age was 65.5 and there were 47% females and 53% Males in the study. The average BMI was 26.44 (1.685), 26.01 (1.319), 25.99 (1.321) for Control, placebo and Treatment groups.

Time-Up and Go Test scores: The Least squares Mean values for Time-up and go (TUG) test showed a decline from Day-1 to Day-42 in both Treatment and Placebo groups compared to control group, suggesting an improvement from baseline to the end visit. There was a significant decrease in the TUG Score in treatment group **(0.604±0.017)**and in placebo group **(0.424±0.023)** at Day 42 compared to Day-1 (p<0.0001) and the post-hoc pair wise comparison test was statistically significant (p<0.0001).

Table 1: Pre, Mid and Post by shift difference - within Group – Time Up and Go Test

	Estimate	SE	95% CI	P-value
Treatment With Group Difference				
Pre-Mid vs. Mid-Post Difference	-0.100	0.016	[-0.13;-0.07]	<0.0001
Mid-Post vs. Pre-Post Difference	-0.352	0.019	[-0.39;-0.32]	<0.0001
Pre-Mid vs. Pre-Post Difference	-0.252	0.016	[-0.28;-0.22]	<0.0001
Placebo With Group Difference				
Pre-Mid vs. Mid-Post Difference	-0.200	0.016	[-0.23;-0.17]	<0.0001
Mid-Post vs. Pre-Post Difference	-0.312	0.020	[-0.35;-0.27]	<0.0001
Pre-Mid vs. Pre-Post Difference	-0.112	0.016	[-0.14;-0.08]	<0.0001
Control With Group Difference				
Pre-Mid vs. Mid-Post Difference	0.015	0.012	[-0.01; 0.04]	0.2222
Mid-Post vs. Pre-Post Difference	0.010	0.013	[-0.02; 0.04]	0.7262
Pre-Mid vs. Pre-Post Difference	-0.004	0.012	[-0.03; 0.02]	0.4226

A table (Table 1) shows the evaluation of Time-up and go test for the three treatment groups, shift difference between visits. The Pre-Post Difference is high in Treatment group compared to Placebo and control groups. The pairwise comparisons between the three shift difference tests is statistically significant, for within group shift difference from Baseline to stimulated points for Treatment and Placebo groups (P<0.001).

Both the Treatment and Placebo groups show shift difference more in “Mid-Post vs. Pre-Post Difference” and Treatment group is more when compared to placebo. The shift in the within group difference among these shift pairs shows statistical significance in both Treatment and Placebo groups.

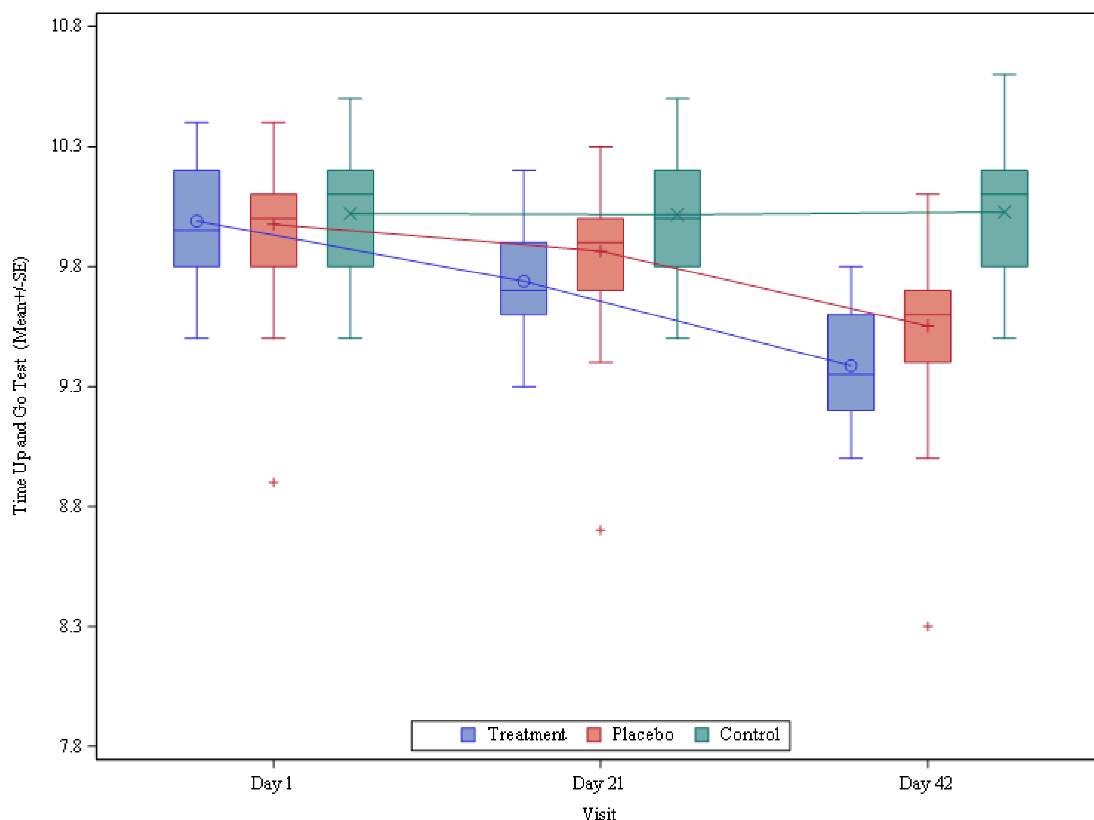


Figure 2: Box plot – By groups across the visits – Time Up and Go Test

A box plot presented in the Figure 2 compared the range and distribution of the Time up and Go Test at baseline (Day 1) and stimulated points (day 21 & Day 42). We observe that there is a greater variability for Treatment group and over time there is decrease at Day 21 and a visible decrease from mid-point to end of study in Treatment group compared to placebo and there is slight shift in increase in control group. The placebo group also has some outliers existing at all the three time points. Since the notches in the boxplots do not overlap, one can conclude with 95% confidence that the true medians do differ.

Table 2: Between the groups shift difference–Treatment estimates–Time Up and Go Test

	Estimate	SE	95% CI	P-value
Between Treatment group effects				
Treatment Pre-Mid vs Placebo Pre-Mid	0.140	0.021	[0.10; 0.18]	<0.0001
Treatment Pre-Mid vs Control Pre-Mid	0.247	0.021	[0.21; 0.29]	<0.0001
Placebo Pre-Mid vs Control Pre-Mid	0.107	0.021	[0.07; 0.15]	<0.0001
Treatment Mid-Post vs Placebo Mid-Post	0.040	0.021	[-0.00; 0.08]	0.0547
Treatment Mid-Post vs Control Mid-Post	0.362	0.022	[0.32; 0.40]	<0.0001
Placebo Mid-Post vs Control Mid-Post	0.322	0.021	[0.28; 0.36]	<0.0001
Treatment Pre-Post vs Placebo Pre-Post	0.180	0.021	[0.14; 0.22]	<0.0001
Treatment Pre-Post vs Control Pre-Post	0.610	0.022	[0.57; 0.65]	<0.0001
Placebo Pre-Post vs Control Pre-Post	0.430	0.021	[0.39; 0.47]	<0.0001

We also intend to identify the shift pairs between the treatment groups in Table 2, and in this table for "Treatment Mid-Post vs Placebo Mid-Post" had an Estimate difference of 0.040 with 0.021 Standard error with [0.00, 0.08] 95% confidence limits. This doesn't show statistical significance (P>0.005) and can conclude that these two shift difference groups show some significant difference. The other pair difference shows statistical significance and thus conclude that there is no significant difference between the considered paired shift differences and thus it justifies the previous table that the difference from Mid to post (Day 21- Day 42) for both Treatment and Placebo are tending near to same, with maximum difference between the stimulated points

Stability Index: Likewise, for TUG score, the Least squares Mean values for overall stability index (OSI) test showed a decline from Day-1 to Day-42 in both Treatment and Placebo groups, suggesting an improvement from baseline to end visit. There was a significant decrease in the Stability Index scorein treatment group **(0.604±0.017)** and in placebo group **(0.424±0.023)**at Day 42 compared to Day-1 (p<0.0001) and the post-hoc pair wise comparison test also project a statistical significance (p<0.0001).

Table 3: Pre, Mid and Post by shift difference - within Group - Stability Index

	Estimate	SE	95% CI	P-value
Treatment with Group Difference				
Pre-Mid vs. Mid-Post Difference	-0.100	0.016	[-0.13;-0.07]	<0.0001
Mid-Post vs. Pre-Post Difference	-0.352	0.019	[-0.39;-0.32]	<0.0001
Pre-Mid vs. Pre-Post Difference	-0.252	0.016	[-0.28;-0.22]	<0.0001
Placebo with Group Difference				
Pre-Mid vs. Mid-Post Difference	-0.196	0.016	[-0.23;-0.16]	<0.0001
Mid-Post vs. Pre-Post Difference	-0.308	0.021	[-0.35;-0.27]	<0.0001
Pre-Mid vs. Pre-Post Difference	-0.112	0.016	[-0.14;-0.08]	<0.0001
Control with Group Difference				
Pre-Mid vs. Mid-Post Difference	0.010	0.012	[-0.01; 0.03]	0.3894
Mid-Post vs. Pre-Post Difference	0.008	0.013	[-0.02; 0.03]	0.8631
Pre-Mid vs. Pre-Post Difference	-0.002	0.012	[-0.03; 0.02]	0.5238

Table 3 presented, to understand the pairwise comparisons between the three-shift difference and three groups been identified among shift points and groups for Stability Index score. The "pre-post" difference shows more difference among the other paired combinations in both Treatment and placebo groups.

Box plot in Figure 3 is plotted for stability index scores to compare the range and distribution of the Index score at baseline (Day 1) and stimulated points (Day 21 & Day 42). We observe that there is a greater variability for Treatment group and over time there is decrease at Day 21 and a visible decrease from mid-point to end of study in Treatment group compare to placebo and there is slight shift in increase in control group.

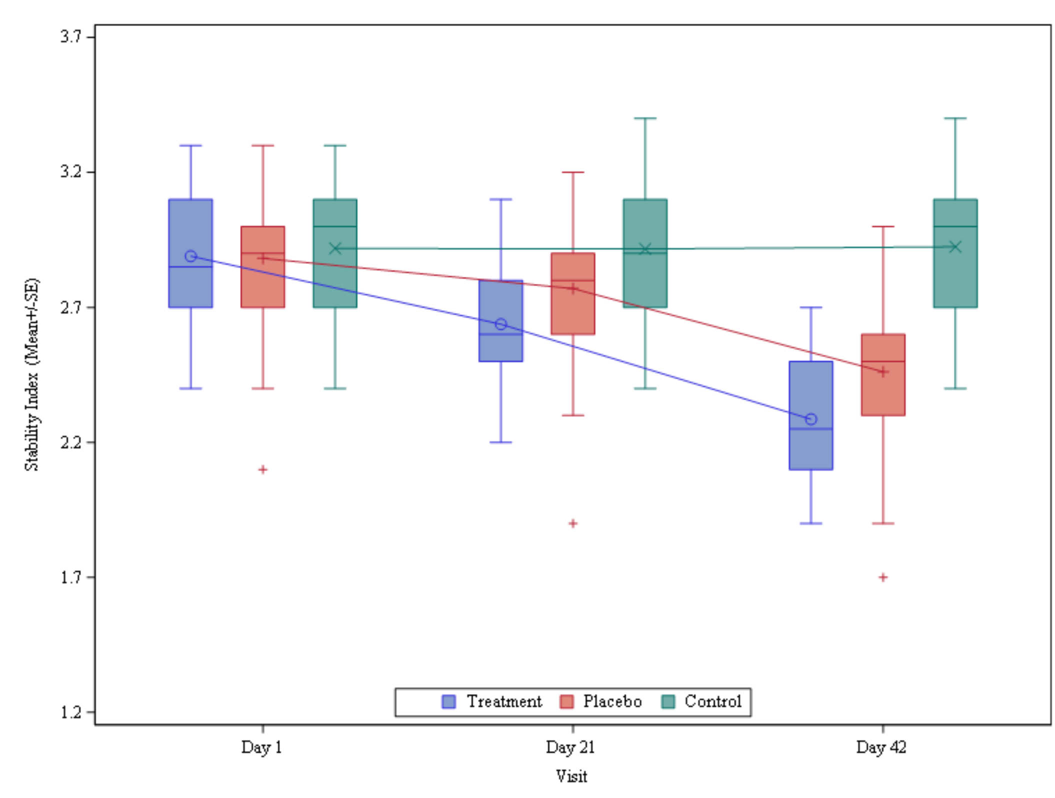


Figure 3 : Box plot – By groups across the visits – Stability Index

Table 4: Between the groups shift difference – Treatment estimates – Stability Index

	Estimate	SE	95% CI	P-value
Treatment Pre-Mid vs Placebo Pre-Mid	0.140	0.021	[0.10; 0.18]	<0.0001
Treatment Pre-Mid vs Control Pre-Mid	0.249	0.021	[0.21; 0.29]	<0.0001
Placebo Pre-Mid vs Control Pre-Mid	0.109	0.021	[0.07; 0.15]	<0.0001
Treatment Mid-Post vs Placebo Mid-Post	0.044	0.021	[0.00; 0.08]	0.0345
Treatment Mid-Post vs Control Mid-Post	0.360	0.021	[0.32; 0.40]	<0.0001
Placebo Mid-Post vs Control Mid-Post	0.316	0.021	[0.27; 0.36]	<0.0001
Treatment Pre-Post vs Placebo Pre-Post	0.184	0.021	[0.14; 0.22]	<0.0001
Treatment Pre-Post vs Control Pre-Post	0.610	0.021	[0.57; 0.65]	<0.0001
Placebo Pre-Post vs Control Pre-Post	0.426	0.021	[0.38; 0.47]	<0.0001

Table 4 shows the shift pairs between the treatment groups for "Treatment Mid-Post vs Placebo Mid-Post" had an Estimate difference of 0.044 with 0.021 Standard error with [0.00, 0.08] 95% confidence limits. This doesn't show statistical significance (P>0.005) and can conclude that these two shift difference groups show some significant difference. For stability score, the actual shift of improvement started from Mid (Day21) till Post(Day 42) for both Treatment and Placebo groups. "Placebo Pre-Mid vs Control Pre-Mid" had an Estimate difference of 0.109 which is slightly better than the "Treatment Pre-Mid vs Placebo Pre-Mid" also have estimated difference 0.140, however these are statistically significant and indicates that there is no significant difference between these two groups.

Discussion

In this study we evaluated the effect of vestibular stimulation on postural stability and mobility in the

elderly randomized into experimental, control and placebo groups. We measured change in postural stability with overall stability index (OSI) and change in mobility with TUG. Significant improvement was observed in overall stability and mobility in the placebo group after the placebo stimulation and balance training while there was no difference in the control group. It was also observed that in the treatment group postural stability and mobility was significantly improved after the vestibular stimulation and balance training while there was no difference in the control group. TUG and OSI indices both were significantly improved in placebo and experimental group. There was a significant difference in improvement between placebo and experimental group which indicates the usefulness of vestibular stimulation along with exercises.

Similar studies show that when direct current is given to vestibular afferents, it passes through vestibular nucleus and vestibular thalamus resulting in added activation of brain areas linked with multisensory input.[15] This could be the underlying mechanism for enhancement in the function of vestibular afferents which results in improvement in postural stability.[29]

Findings of this study suggest that GVS can be used during balance training which help the elderly to gain better control over postural stability and mobility. The mechanism underlying might be extensive neuroplastic nature of the vestibular system.[30] These neuroplastic changes are dependent upon age, visual and vestibular experiences[31,32]. Vestibular end-organs send message to vestibular nuclei, which excite motor neuron of ipsilateral extensors and inhibit motor neuron of reciprocal flexor of the limb via lateral vestibulospinal tract.[33] Studies on animal model suggested that stimulation to vestibular afferents can induce long term potentiation and long term depression of the field potential of vestibular nuclei.[34]

Studies also suggest that the activation of brain areas involved in vestibulospinal relay and vestibular sensory input lead to the decrease in sway of center of pressure during single session of GVS stimulation in community dwelling elderly.[20]

Till date many studies have investigated and advocated the immediate effects of GVS over postural stability and mobility. Some also talked about change in sway during stimulation. Early improvement seen in this study in treatment group compared to placebo group can be explained on the basis of finding of one study which suggested the moderate additional improvement in postural stability after second stimulation session which last for few hours even after cessation of stimuli.[35]

Studies suggested that three hours of stimulation have a better effect in postural stability compared to thirty minutes of stimulation but the difference is relatively small,[35] this stimulation probably increases the activation of voltage-gated ion channels in vestibular system and prolong activation might cause decrease in activation of these channels.

So in this study we used twenty minute repeated sessions considering the adaptation of neural system but further investigation is required to find out factors which explain the appropriate duration to produce lasting effects on balance and mobility in different population and various balance disorders.

In this study we delivered multiple sessions of stimulation thrice a week every alternate day. Previous studies discovered that when low intensity direct current stimulation was delivered transcranially to motor cortex, then increase in the duration of post stimulation effects of the first stimulus was observed.[36] The study also determined that timing of stimulation of motor cortex can control plasticity. Adequate interval between consecutive sessions might be the cause of improvement in the treatment group in this study.

Long term effects, minimal invasion and absence of adverse effects prove appropriateness of subliminal GVS for repetitive stimulations in treatment studies for improving postural stability and mobility in elderly.[12] Further studies are required to find out the exact duration and intensity of stimulation for optimal results in improving the balance among elderly.

Conclusion

The present study suggests that vestibular stimulation can significantly improve balance and mobility in elderly individual when given along with exercise training program. Our results shows overall stability improved when nGVS delivered along with exercise training. Finding of this study also suggest improvement in dynamic stability. We can also conclude on the basis of finding that early changes in the stability can be achieved when nGVS is delivered along with balance training exercises. The findings also suggest these effects are not due to the placebo effect of the vestibular stimulation.

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Ethical Approval: The study procedure was approved by the Institutional Ethical Committee at Amity University Noida, Uttar Pradesh.

Declaration of Conflicting Interests: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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