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Research Article

Immediate Effect of Vibration to Plantar Flexors on Functional Mobility in Stroke Patients

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Abstract

Background: Stroke is the most common cause of disability in adults. Stroke leads to problems such as muscle spasticity, weakness, abnormal gait, and balance dysfunction. This study investigates the immediate effect of focal vibration to plantar flexors on functional mobility in stroke patients.

Method: It was a quasi-experimental study (Pre and Post-intervention design) conducted in the physiotherapy department of a tertiary care hospital. A convenience sample of 38 stroke patients was recruited. Outcome measures used were Timed Up and Go Test (TUGT), Modified Ashworth Scale (MAS) and goniometry for ankle passive range of motion. Vibration was applied via a hand-held applicator for 15 minutes to the plantar flexors of the hemiparetic side. Pre- and post-intervention comparative analysis was done using Wilcoxon Signed Rank Test.

Results: Post vibration significant improvement was observed in Timed Up and Go test and ankle range of motion; whereas there was no improvement in plantar flexor spasticity.

Conclusion: Immediate effect of focal vibration on spastic plantar flexors shows significant improvement in functional mobility in stroke patients. Focal Vibration can be used as an adjunct to the on-going therapy to augment mobility and dynamic balance. We recommend future studies to further explore the effectiveness of focal vibration in therapy.

Keywords: Stroke; Vibration; Plantar flexors; Functional mobility; Spasticity; Ankle range of motion

Abbreviations: TUGT: Timed Up and Go Test; MAS: Modified Ashworth Scale; ROM: Range of Motion; MMSE: Mini Mental State Exam

Background

Stroke is the most common cause of disability in adults. The cumulative incidence of stroke ranged from 105 to 152/100,000 persons per year, and the crude prevalence of stroke ranged from 44.29 to 559/100,000 persons in different parts of India during the past decade. Stroke is defined as a rapid onset of focal neurological deficit, resulting from diseases of the cerebral vasculature and its contents. Because of sudden loss of function, patients experience difficulty in carrying out activities of daily living, ambulation, planning rate and rhythm of movements, maintaining static and dynamic balance, making postural adjustments and a general reduction in body awareness to carry out motor tasks and bring about functional mobility. They often experience problems such as muscle spasticity, weakness, abnormal gait, and balance dysfunction [1-10].

Balance impairment is common after stroke which increases the risk of falls [9]. A study found that 83% of patients with stroke had balance dysfunction [10]. Fall is a common complication observed in as high as 73% of patients with stroke [7]. which may contribute to serious injuries and life-threatening problems [8]. Thus, improvement of balance and reducing falls are one of the important goals in stroke rehabilitation. Patients with stroke usually present with sensory deficits and reduction in cutaneous sensation [10,11]. Muscle weakness and sensory dysfunction are factors influencing poor balance in patients post-stroke 14. Sensory deficits, therefore, may contribute to poor balance, and can have negative effects on the functional outcomes of patients with stroke. There are various strategies of physiotherapy interventions used for treating impaired balance in patients post-stroke [15-17]. The evidence for the efficacy of sensory stimulation modalities on balance in patients after stroke is limited [20-22].

Functional mobility is defined as the manner in which people are able to move around in the environment in order to participate in activities of daily living and move from one place to another. Being able to satisfactorily change directions while walking is a vital component of mobility. Stroke survivors demonstrate a significantly longer reaction time and lower accuracy in turning while walking, as compared to healthy individuals of a similar demography. Turning while walking is one of the commonest causes of falls post-stroke. Vibration stimulation is an effective modality which can be used in neurological rehabilitation [24]. Vibration based methods in either focal or wholebody vibration (WBV) form have been used in healthy and patient populations to improve functional outcomes [12]. A recent systematic review and meta-analysis included seven studies with 298 chronic stroke patients to assess the effects of WBV and found no beneficial effects of WBV on balance and gait performance [25]. However, studies on the effects of focal vibration applied to the plantar region in elderly women [27] and application of vibration to the feet via vibrating insoles in young and elderly participants [28] have demonstrated beneficial effects on balance control. Recently, a study used clinical measure of Mini-Balance Evaluation Systems Test (Mini-BESTest) to investigate the effects of plantar vibration on balance in patients suffering from stroke and found improvements in balance, ankle plantar flexor spasticity, and ankle dorsiflexion passive range of motion (PROM) [23]. There are no further studies addressing the effects of plantar vibratory stimulation on balance control in patients post-stroke [19]. Due to limited studies and conflicting outcomes we aimed to determine the effect of focal vibration on functional mobility of stroke patients.

Methods

It was a quasi-experimental study (pre and post-intervention design) conducted in the physiotherapy department of a tertiary care hospital. A convenience sample of 38 stroke patients was recruited. Sample size was estimated to be n=38 based on a previous study mentioned in Journal of Exercise Rehabilitation1. Institutional ethics committee approved the design and conduct of the study. The procedures followed protocol and accord with the ethical standards of the institutional review board. Informed written consent was obtained from the participants before their enrollment in the study. The study included ambulatory stroke patients with unilateral hemiplegia aged 20-60 years, plantar flexor spasticity with grade 1,1+ or 2 on MAS and able to understand verbal instructions. Exclusion criteria set was i) presence of conditions other than stroke affecting balance; ii) perceptual or sensory deficits; iii) cognitive impairments (MMSE<24); iv) symptomatic musculoskeletal conditions which can affect mobility; v) fixed ankle contractures.

Timed up and go test

The subject was explained and demonstrated the task, including instructions to rise from the sitting position, walk around the cone placed on the floor 3 meters away, turn, return and sit down on the chair. The task comprised the following steps:

1. Begin the test with the subject sitting correctly in the chair.
2. Timing of the assessment starts on the command "GO".
3. The timer is stopped when the subject is seated back in the starting position.

Notes on the performance of TUG Test:

- The subject was allowed to use their arms to stand up, if they wished.
- The subject was instructed to walk at a comfortable and safe pace.
- The subject was allowed to use their usual walking aid and footwear.
- There was no time limit.
- The subject could stop and rest (but not sit down) if required.
- If physical assistance was needed at any time during the assessment such as assisting the subject to stand up from the chair, stabilizing the subject in standing or when walking, then the assessment was to cease and the test was to be scored as zero.

Materials required

- HandHeld Electrical Vibrator (50-60 Hz)
- TUG test: Armchair, Tape measure, Cone, Stopwatch
- Modified Ashworth Scale (MAS)
- Goniometer

The investigator checked passive range of motion for ankle dorsiflexion with goniometer and assessed plantar flexor spasticity on the Modified Ashworth scale on the affected side. The participant then performed a Timed Up and Go Test. Vibration was applied to Gastrocnemius musculotendinous junction of affected leg in side-lying position on a plinth for 15 minutes via a handheld applicator. Immediately post application investigator assessed passive ankle range of motion and plantar flexor spasticity followed by Timed Up and Go Test. The assessments were conducted in a standardized and similar manner at both the times.

Results

We employed completed analysis, thus the sample for analysis was 38 stroke participants. Table 1 shows the demographic characteristics of the participants (Table 1).

In this experimental design, vibration served as an independent variable and functional mobility, spasticity and ankle ROM as the dependent variables. Data for TUGT and ROM did not pass the normality test whereas spasticity is an ordinal type of data. Thus, nonparametric test i.e. Wilcoxon Signed Rank test was employed for statistical analysis. Comparative analysis was done for all the three dependent variables pre- and post-intervention. (Table 2) After vibration, a significant improvement in the average TUGT and dorsiflexion range was observed whereas the difference in MAS was statistically not significant (Table 2).

Table 1: Demographic characteristics of the participants

Age (in years)	Mean	44.10%
	S.D.	6.01
Gender	Males	60.52%
	Females	39.47%
Hemiplegic side	Right	57.89
	Left	42.1
Duration of stroke (in months)	Mean	13.57
	S.D.	5.88

Table 2: Comparison between Pre-intervention and Post-intervention measures

Variable		Pre-Intervention	Post-Intervention	Statistical Test	P Value	Interpretation
TUGT	Mean	26.21	21.73	Wilcoxon Signed Rank test	$P < 0.0001$	Significant
	S.D.	14.16	13.01			
Dorsiflexion	Mean	10.42	12.97	Wilcoxon Signed Rank test	$P < 0.0001$	Significant
	S.D.	3.13	3.42			
MAS	Mean	2	2	Wilcoxon Signed Rank test	$P > 0.05$	Not significant
	S.D.	0	0			

Discussion

The present study found that direct focal vibratory stimuli at 50-60 Hz applied to the musculotendinous junction of spastic gastrocnemius muscle for 15 minutes in a single session improved functional mobility and dynamic balance as measured by the TUGT and ankle PROM in a sample of patients post stroke. Vibratory stimulation is a simple, noninvasive therapeutic method for the treatment of motor disorders and to reduce spasticity. To facilitate the paretic muscle, application of vibration to the muscle selectively stimulates the Ia or primary spindle endings and Ia inhibitory interneurons which causes a tonic vibration reflex thereby induce non-voluntary contraction in the vibrated muscle and inhibits the muscle antagonistic to the activated muscle. Therefore, vibratory stimulation is traditionally applied to the agonist muscles in order to decrease the tone [26].

It was found in this study that sensory vibratory stimulation applied to the plantar region of adult post stroke improved ankle PROM; an important factor for balance and fall risk. Balance is influenced by multiple factors. Normal muscle tone and sufficient ankle ROM are two important factors that allow the individual to have balance and postural stability during gait. Upper motor neuron syndrome such as stroke, can result in disturbed motor control and joint immobilization which can gradually lead to soft tissue contracture and increased muscle stiffness [29]. Hyperactive stretch reflexes together with increased passive stiffness due to mechanical changes in muscles, if untreated, can worsen the condition. Spastic muscle fibers have been demonstrated to be almost twice as stiff when compared to normal fibers [30]. Plantar flexor muscle stiffness has been also reported to be abnormally high on the paretic side [32].

A significant positive effect on the TUG test was identified. The TUG test is a measure of mobility and dynamic balance that improved after the intervention. Improvement in the TUG test might be explained by increased ankle PROM, and perhaps enhanced sensory information provided by vibration. Several factors contribute to slow walking speeds in individuals with chronic hemiplegia. Weakness of the paretic plantar flexor muscles during the push-off phase of the gait cycle is considered to be of primary importance [33]. Recent findings, however, highlight the importance of dorsiflexor muscles strength on the paretic side in determining gait velocity [34]. Indeed, dorsiflexor weakness causes inadequate foot clearance during the swing phase of the gait cycle, thereby increasing the swing time and reducing gait speed [35]. Trains of high-frequency, low-amplitude mechanical vibrations, applied to a muscle–tendon unit, generate Ia afferent fiber discharges because of the activation of muscle spindles [36]. The modulation of Ia inputs alters the excitability of the corticospinal pathway [37] as well as the activation of cortical motor regions. Although a small reduction in the mean TUG test score may be clinically acceptable and relevant following a single treatment applied for 15 minutes, a study reported a change of at least 23% in TUG score must be observed post stroke to indicate a real, clinical improvement [31]. This study showed a difference of 6% pre- and post-intervention session. The reduced percentage change can be attributed to a single treatment session and duration of vibration for 15 minute might be the reasons for less than optimal changes that occurred in the TUG test.

Focal vibration has different effects according to the frequency applied at and duration it is applied for. Considering vibration frequency as the main factor, Homma identified variable effects of different frequencies. Low frequencies, 20 – 50 Hz, produce muscular relaxation. Although some studies suggest that lateral gastrocnemius and some other muscles contract as a response to 40 – 60 Hz frequencies. Other researchers consider that the 50 Hz frequency is more facilitatory than lower one (30 Hz) 38. Stimulation rates between 80 – 120 Hz elicit the classic tonic vibratory reflex, and frequencies between 100 – 200 Hz determine post vibratory facilitation [39]. Frequencies above 200 Hz can damage the skin; even those around 150 Hz may induce pain and discomfort. The most widely used stimulation rates are in the interval 100 – 150 Hz, they augment electromyographic activity of the muscle and the synchronization of motor units [40].

Tendon vibration was used on patients with chronic stroke and longstanding spasticity 100 Hz vibration of triceps brachialis lowered the biceps brachialis spasticity (agonist) and the association with physical therapies led to a better effect (higher and faster) both on spasticity reduction and on motor control augmentation. These results were noted for a minimum 48 hours [41].

However, we acknowledge several limitations in the present study. First, the Modified Ashworth Scale was used as a measure for spasticity. Other test measures such as the Tardieu scale can be used in its place for precise measurement. Secondly, no control or placebo group was included in the study to compare the post measures. Third, the assessor and the physiotherapist treating the participants were the same, introducing possible bias. Finally, participants were not followed-up to determine the long-term effects. In conclusion, vibratory stimuli at a frequency of 50-60 Hz applied to the musculotendinous junction of spastic muscle of leg in post stroke patients could have beneficial effects on the ankle PROM measured by goniometer, and dynamic balance assessed by TUG test. With regard to MAS, there was not significant improvement. Further research is necessary to characterize the effects and the optimal dose using a rigorous, double-blinded randomized controlled study design in a larger sample of participants. Based on the results, the vibration stimuli applied to the musculotendinous junction of the more affected foot may be added to the physiotherapy program to improve functional mobility and dynamic balance in patients with stroke.

Ethics Approval and Consent to Participate

An ethical approval was granted by the Institutional Ethics Committee of K. J. Somaiya College of Physiotherapy. The procedures followed protocols and accord with the ethical standards of the institutional review board. A written informed consent was taken from all the participants at the beginning of the study.

Consent for Publication

Not Applicable.

Availability of Data and Materials

All data generated or analyzed during this study are included in this article [and its supplementary information files].

Competing Interests

The authors declare that they have no competing interests.

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Author's Contribution

Both the authors Siddhi Sharma and Isha Akulwar Tajane have nearly equal contributions to the conception and design of the work; the acquisition, analysis or interpretation of data for the work; drafting the work, revising it critically for important intellectual content; and final approval of the version to be published. Specific contribution of Siddhi is in the acquisition of the data and Isha Akulwar contributed to the data analysis and interpretation. All authors have read and approved the manuscript.

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