The Effect of the Lumbar Vibratory Belt on Static and Dynamic Postural Stability

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Abstract

Background: Loss of postural control has been recognized as a major health problem in post-stroke hemiplegic patients. Vibratory somatosensory stimulation (VSS) is a novel method with considerable promises for improving postural stability in these subjects.

Objective: The aim of this study was to evaluate the effects and feasibility of local vibration through a lumbar belt on static and dynamic postural stability in post-stroke hemiparetic subjects.

Methods: Eighteen stroke subjects participated in this study. Subjects were checked by Berg balance scale and then were asked to wear the vibratory belt which applies mechanical vibration on both sides of the posterior lumbar region. Balance control of the patients was tested in static and dynamic modes with open and closed eyes, in separate sets with and without vibration.

Results: There was statistically significant stability improvement in overall stability index during applying vibratory belt ON. No significant evidence was shown the preferential balance improvement of the vibratory belt in either dynamic vs. static state or open vs. closed eye condition.

Conclusions: Localized vibratory stimulation can improve the postural stability in patients with post-stroke hemiplegia.

Keywords: Vibratory somatosensory stimulation; Static; Dynamic; Postural stability; Post-stroke hemiplegia

Introduction

Post-stroke hemiplegia is a major disability which disturbs the patients’ ability to maintain the center of body mass over the base of support. Hemiplegia leads to loss of functional movements by making the patients to sway in static stance and have asymmetry in weight distribution on lower extremities and decrease dynamic stability [1]. Loss of postural control has been recognized as a major health problem in individuals with stroke resulting in a high incidence of falls, further trauma, injury, functional deficits and even death both during rehabilitation and thereafter. In addition, postural control is the best predictor of achieving independence the primary goal in rehabilitation [1-3].

Special sensory data from vestibular, visual and proprioceptive systems are essential requirements for providing postural balance. Thus, a wide range of therapeutic interventions such as repetitive task training, high-intensity therapy, physical fitness training and biofeedback have been developed in recent decades to provide better motor recovery in hemiparetic stroke subjects. Sensory stimulation as an intervention on balance recovery by acupuncture or transcutaneous electrical nerve stimulation, functional electrical stimulation, electromyographic feedback, and force feedback or body weight supported treadmill training applied to post-stroke hemiparetic patients. However, there is limited evidence for their effectiveness [1-3].

Vibration is a relatively novel somatosensory stimulation (SSS) method that shows considerable promises for rehabilitation in recent studies. It is shown that low amplitude and high frequency mechanical vibratory stimulation has considerable effect on proprioceptive sense and can increases muscle strength, postural control, motor performance and activities of daily living in patients with different causes of balance disturbance such as stroke [4-8]. Vibration is a stimulation characterized by oscillatory motions which excite the spindle Ia afferents leading to reflex muscle contraction. Stimulated muscle contracts and relaxes at approximately the same frequency of vibratory stimulus [1,2]. Its impact on motor neuron excitability and/or fast-twitch fiber recruitment [9] and its activating effect on the
spindle II afferents and improvement of motor units synchronization is suggested as well [10].

Whole body vibration (WBV) has been the common vibratory modality that provides systemic SSS for balance improvement in stroke and some other neurologic diseases [9,11,12]. Local stimulation has been applied in limited studies and there is little, but, interesting scientific evidence about its effectiveness. Randomly vibrating shoe insoles had been effective in enhancement of dynamic balance activities in older adults with sensory loss [13]. Functional vibratory stimulation is useful for patients with stroke through improving gait speed [14]. Neck and lumbar muscle vibration were used successfully in Parkinson’s disease (PD) [5,15].

The effect of local stimulation in stroke patients has yet to evaluate and based on the early evidence of effectiveness on balance of Parkinson patients, it probably shows similar effects in stroke patients. This study was conducted to evaluate the effects and feasibility of local vibration through a lumbar belt on static and dynamic postural stability in post-stroke hemiplegic patients.

Methods

The vibratory belt

This vibratory belt applies mechanical vibration on both sides of the posterior lumbar region. For the purpose of this study we made a vibratory belt that consists of a soft belt with adjustable Velcro that applies four 3-12 V DC vibratory electro-motors embedded in plastic shield bag within the belt layers; two motors placed on each side vertically, a 7.5 V DC adaptor, and a tuner which connects the belt to the adaptor.

![Figure 1: Descriptive data of Biodex index (1=SOO: Static Open Eyes without Vibration Overall Index; 2=SCO: Static Closed Eyes without Vibration Overall Index; 3=DOO: Dynamic Open Eyes without Vibration Overall Index; 4=DCO: Dynamic Closed Eyes without Vibration Overall Index; 5=SOOV: Static Open Eyes with Vibration Overall Index; 6=SCOV: Static Closed Eyes with Vibration Overall Index; 7=DOOV: Dynamic Open Eyes with Vibration Overall Index; 8=DCOV: Dynamic Closed Eyes with Vibration Overall Index; Not vibration: vibration off condition/Vibration: vibration ON condition; Higher index indicates poorer balance; The highest OSI mean score is belonged to the SCO condition and SOOV condition has the least mean score).](image)

The tuner has two output sockets with the same output voltage, one as tester socket used for frequency evaluation by laser photo tachometer to adjust suitable voltage based on 7.5 V main power which leads to the desired frequency (97 Hz) marked on tuner switch screen and the other for belt supply (Figure 1).

Experiment protocol

In this experimental study, Biodex balance system was used for performing static and dynamic postural balance assessments and training. It consists of a balance platform that provides up to 20° surface tilt in a range of 360°, 12 dynamic stability levels and a locked state for static stability measurements. The platform is interfaced with computer software (Biodex, Version 3.1, Biodex Medical Systems, USA product) that enables the device to serve as an objective assessment of balance. The measure of postural stability includes the overall (OA), the anterior/posterior (AP), and the medial/lateral (ML) stability scores. A higher score in the OA index indicates poorer balance. Biodex measures the patient’s ability to control his center of gravity (COG) and limits of stability (LOS) during static and dynamic postural stability testing as provided by its clinical resource manual.

Subjects

Patients who have had only one stroke attack, be able to maintain independent unsupported stance for at least 20 s, understand the goal and be able to cooperate with the methods of the study were included. Patients who had an orthopedic impairment with significant impact on standing balance, severe spasticity interfering with standing balance, cerebellar or brainstem induced balance impairment, history of vestibular balance impairment or severe peripheral neuropathy and cardiac pacemaker were not included (Figure 2).

A total of 18 interviewed ischemic or hemorrhagic stroke patients (12 men, 6 women, and mean age 53.9 years) met the inclusion criteria during May to September 2016, referred to the outpatient stroke rehabilitation center at least one month after their stroke attack to pass the acute phase period and be able to stand. The study was approved by ethics committee of Iran University of medical sciences. All of them signed the informed consent before participation.
Study protocol

The level of Biodex platform stiffness was 12, in dynamic phase “the most stable level” and static in static phase. The frequency of vibration was set on 97 Hz and the vibration amplitude was about 0.5 mm [5,13]. To consider the impaired limb proprioception of hemiplegic patients, the vibratory belt was placed in the lumbar region [5] (Figure 3).

The study was performed in bare feet; only socks were permitted to save the study from unpredictable effects of different shoe types on standing or postural balance. First of all, patients were evaluated with Berg balance scale (BBS). Then patients were asked to wear the belt with motor parts located in direct contact on waist skin over paraspinal muscles, step on the platform and assume a comfortable upright position on bilateral stance, look straight ahead with hands on both sides (Figure 4).

The feet position were fixed throughout the test session and recorded by platform foot position markers on the test sheet. The test was explained to each patient to stand still in the entire test situations, keep the postural balance as they can and not to fall. To adapt to the machine, training tests provided for 20 min in both static and dynamic modes before the practical tests.

Two different conditions of eye-open and eye-closed were examined. In each condition, the quality of balance was assessed in two situations of vibratory belt: motors ON and motors OFF, each in two static and dynamic levels. The patients were not provided with any cues or instruction during the practice tests. An average of three trials for each condition was done and the duration of each test was 20 s with 2 min inter-trial rest in sitting position. Due to the probable long-lasting effect of vibration, we played all motor OFF situations first and motor ON situations latter. In motors ON mode, the vibration provided through all trials but not in resting time. Final indices were trials data provided by the Biodex system in the test sheet and the stability index represents displacement from a level platform position (Figures 5 and 6). We compared the overall stability index, in similar conditions. A high score in the overall stability index indicates poor balance [15].
Statistical analysis

The data was analyzed by SPSS 24 in repeated measures three-way ANOVA method. The complementary analysis Bonferroni adjusted alpha was used in order to avoid an increase in alpha in different comparisons.

Results

Basic characteristics

This study assessed 18 post-stroke hemiplegic patients, 6 female and 12 male, aged 35-75 years. Participants' characteristics are shown in Table 1. Five participants (27.8%) had left sided hemiplegia and 13 (72.2%) of them had the right sided one.

| Variables | Min. | Max. | Mean | Standard Deviation |
|-----------|------|------|------|--------------------|
| Age (year)| 36   | 75   | 53.94| 9.66               |
| Weight (kg)| 62  | 90   | 75.33| 9.17               |

Table 1: Basic Characteristics of Study Patients (*BBS: Berg balance scale, BMI: Body Mass Index).

Vibration

According to repeated measures ANOVA analyses significant decreased in overall stability index was observed when the vibratory belt was ON. It has been revealed that vibration improved standing balance and stability independent of eyes or platform condition (F=12.32, significance<0.003) (Table 2 and Figure 1).

Source | Type III Sum of Squares | dF | Mean Square | F | P-value |
|-------|------------------------|----|-------------|---|---------|
| Vibration | 13.201                  | 1  | 13.201      | 12.328 | 0.003   |
| Error(Vibration) | 18.204                  | 17 | 1.071      |   |         |
| Static/Dynamic | 2.103                  | 1  | 2.103      |   |         |
| Error(Static/Dynamic) | 99.928                  | 17 | 5.878      | 0.358 | 0.558   |
| Open/Closed | 27.04                  | 1  | 27.04      |   |         |
| Error(Open/Closed) | 6.195                  | 17 | 0.364      | 74.202 | 0      |
| Vibration* Static/Dynamic | 0.84                  | 1  | 0.84      |   |         |
| Error(Vibration* Static/Dynamic) | 14.585                  | 17 | 0.858      | 0.979 | 0.336   |
| Vibration* Open/Closed | 0.188                  | 1  | 0.188      |   |         |
| Error(Vibration* Open/Closed) | 4.202                  | 17 | 0.247      | 0.76 | 0.396   |
| Static/Dynamic* Open/Closed | 1.914                  | 1  | 1.914      |   |         |
| Error(Static/Dynamic* Open/Closed) | 11.421                  | 17 | 0.672      | 2.848 | 0.11    |
| Vibration* Static/Dynamic* Open/Closed | 0.203                  | 1  | 0.203      |   |         |
| Error(Vibration* Static/Dynamic* Open/Closed) | 4.818                  | 17 | 0.283      | 0.715 | 0.41    |

Table 2: Summarized results of repeated measure ANOVA.

Open vs. closed eyes

Our data demonstrated a statistically significant difference in overall stability index by eye condition (F=74.2, significance<0.000). The greater overall stability index in the eye-closed state indicates that the eyes-open condition improved patient's stability (Table 2 and Figure 1).

No interaction between vibration and eyes condition suggests that the overall stability index (OSI) improvement in vibration ON condition is independent of eyes to be open or close. Similar to our expectation, the stability index was higher in eyes-closed condition (Figure 2).

Dynamic vs. static state

Our findings have demonstrated no statically significant difference between static and dynamic state, including both eye-open and eyes-closed conditions and vibratory belt ON or not (F=0.358, significance<0.558).

As mentioned above, the positive effect of vibration on improving overall stability index is shown to be independent of dynamic or static test conditions (Figure 3).
Discussion

To our knowledge, this is the first study exploring the effect and feasibility of local vibration through a lumbar belt on static and dynamic postural stability in post-stroke hemiparetic subjects. A large body of previous evidence examined the effects of whole-body vibration among people with central nervous system disorders [16]. Here, in accordance with the previous study of Ghoseiri et al. which reported the effects of vibratory orthosis on balance in idiopathic PD [5], we used mechanical vibration on both sides of the posterior lumbar region, and studied the effects of localized somatosensory vibration input on balance control in stroke patients.

There are conflicting results of acute effects of the systemic vibratory stimulus on patients who suffer from neurological diseases. Rehn et al. in a review article showed that whole body vibration has moderate to strong positive effect on lower extremity muscle function in unfit persons and older women [17], but the Nordlund et al. concluded that it has no or little effect on muscular function, balance control and bone mass in comparison to other interventions [18].

A systematic literature review toward the whole-body vibration effects in patients affected with PD reported that whole body vibration may help improve balance and postural control of patients suffering from PD [10]. Moreover, Olama et al. who studied stability maintenance after whole body vibration in children with hemiparetic cerebral palsy concluded that whole body vibration increases maintenance of balance function and stabilizes the neural network which leads to improvement of the specific postural control mechanism essential for keeping the balance through stepping [19].

Same balance improvement of patients with fibromyalgia syndrome is reported by Sanudo et al. following whole-body vibration training [20]. Yang et al. studied Effects of controlled whole-body vibration training in improving fall risk factors among individuals with multiple sclerosis and concluded that the vibration-based interventions could possibly reduce fall-related costs exerted on the health system and improve the quality of life in people with MS [21]. Whole body vibration therapy in stochastic(nonsinusoidal, random) vibratory pattern which is referred to as stochastic resonance (SR) and the treatment as stochastic resonance therapy (SRT) suggested as a potential novel treatment option for Parkinson disease patients suffering from postural instability by Kaut et al. [22]. In contrast, Hwang et al. applied whole body vibration at different vibration frequencies (10 and 40 Hz) to chronic stroke patients and examined its immediate effect on their postural sway and showed that The 40 Hz WBV increased postural sway in the ML direction [23]. Some other studies on localized vibratory stimulation like the study of Priplata et al. which randomly vibrating shoe insoles could help older adults to overcome their age-related sensory loss and postural instability by enhancing their performance of dynamic balance activities [13]. Moreover, Valkovic et al. had demonstrated that localized neck vibration can improve the postural control in the patients with PD [15]. In this regard, Novak et al. revealed their study in which a planar surface step-synchronized vibration resulted in a better walking speed in PD patients [24]. There are also other studies which have shown the beneficiary effects of other forms of somatosensory stimulation and other aspects of stroke-induced defects and disabilities like the effect of peripheral nerve stimulation on motor function performance [25]. One study in 2013 suggested that local vibration applied on lower limbs may improve postural sway and even gait parameters [26].

Similar to above-mentioned reports, our data generally indicate that applying vibratory belt leads to a significant improvement in overall stability index. These findings suggest that providing additional sensory stimulation by vibration can augment the central and peripheral balance control processes in hemiplegic patients and can help them to maintain their postural control. A limitation of the current study was the small sample size, heterogeneous on age which may affect the overall statistical significance of stability score changes in different test situations. The study group was mostly homogenous in balance scale (Berg Balance Test) and BMI which suggests less impact of age heterogeneity on the findings of this study.

Contrary to our expectations, standing balance shows no significant difference between static and dynamic modes, regardless of either eye-open or eye-closed. We also demonstrate a significant stability improvement in eye-open condition rather than eye-closed one due to the critical role of visual feedback in balance control of post-stroke patients.

 Altogether, the device used in the present study as a new performance requires more studies to evaluate its impact and effectiveness on different situations in neurological disorders. Long-term studies need to be designed to assess the long-term efficacy and feasibility of the device. More investigations with other frequencies may help to find the frequency with the maximum effectiveness. As participants of this study were mildly disabled post-stroke patients, it is proposed to study the effectiveness of applying vibratory belt on rehabilitation of the post-stroke patients with severe motor impairments. In contrast to whole-body vibration, vibration belt is much cheaper and can be used easily in daily life. The devices also may help to reduce fall risk in geriatric patients as well as patients with risk of stress fractures in osteoporosis. Further studies may help to clarify these applications.

Conclusion

In general, this study revealed that localized vibratory stimulation of lumbar region can improve the postural stability control in patients with post-stroke hemiplegia. Additionally, we demonstrated no relationship between the static or dynamic situation on the improvement of overall stability index of participants. This could suggest applying vibratory belt as a promising approach in post-stroke rehabilitation to help maximize recovery of affected patients.

Declaration Interest

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