Stroke Rehabilitation

Subjects: Clinical Neurology
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Because of the complexity of a stroke, various approaches to chronic stroke rehabilitation, such as facilitation technique, functional electric stimulation (FES), transcutaneous electrical stimulation (TENS), electromyography (EMG) biofeedback, exercise, physical and occupational therapy, robotics, and virtual reality, have been studied to help functional recovery from hemiplegia due to brain damage.

Keywords: Focal muscle vibration ; vibration parameters ; vibration protocol ; outcome measures ; stroke rehabilitation

1. Introduction

Stroke is the second leading cause of death and one of the most common causes of adult-onset disability worldwide. According to a recent study, 26% of individuals with stroke have a disability in activities of daily living (ADL), and 50% have reduced mobility due to hemiparesis [1]. The post-stroke disruption of the sensory system plays an important role in motor dysfunction of the hemiparetic limb [2]. Loss of proprioception impairing corrections to movement errors and loss of tactile sensation are common consequences of stroke and affect control of limb motion [3]. Another major problem affecting nearly 20–30% of stroke survivors is gait disorders [4]. These disorders further increase the risk of falls and loss of balance, reducing patients' social participation. According to National Stroke Association's post-stroke recovery guidelines, only 10% of stroke survivors recover almost completely; 25% recover with minor impairments; 40% experience moderate to severe impairments requiring special care; 10% require care in a nursing home or other long-term care facility; and 15% die shortly after the stroke [5]. While numerous therapies have been developed over the last 10 years to treat acute ischemic stroke, the stark reality remains that 95% of these patients continue intervention in the chronic stage and go on to live with significant disability for many years.

Because of the complexity of a stroke, various approaches to chronic stroke rehabilitation, such as facilitation technique [6][7], functional electric stimulation (FES) [8][9], transcutaneous electrical stimulation (TENS) [10][11], electromyography (EMG) biofeedback [12], exercise [13][14], physical and occupational therapy [15][16], robotics [17][18], and virtual reality [19][20], have been studied to help functional recovery from hemiplegia due to brain damage. The limitations of the aforementioned intervention strategies are their sustainability due to one or more of these challenges: the requirement of trained and licensed professionals to administer the right dose to ensure safety; lack of precision and accuracy of intervention; lack of consensus among the findings; lack of sufficient evidence to establish the effectiveness of the intervention strategies; awareness of and access to existing intervention strategies; the cost of administration; and other similar disparities [21][22][23][24]. One intervention strategy that has the potential for sustainable stroke rehabilitation is the use of mechanical vibration as a therapeutic intervention known as vibration therapy (VT) [25][26][27][28][29]. According to Murillo et al. (2014), VT as an intervention in rehabilitation can be dated back to 1969, when Hagbarth and Eklund observed tonic vibration reflex (TVR) in which the application of vibratory stimulus resulted in agonist muscle contraction and antagonist relaxation. Hagbarth and Eklund then used this observation as a basis to use vibration to decrease muscle spasticity in individuals with stroke [28][29].

There are two types of VT: whole body vibration (WBV), in which mechanical vibrations are transmitted from the feet to the rest of the body using a vibrating platform, and focal muscle vibration (FMV), where mechanical vibrations are applied to a localized point in muscles, generally the muscle belly or the tendon on the affected/paretic side. The potential mechanism behind using vibration as an intervention in the treatment of motor disorders in patients is that vibration stimulates the primary muscle spindle endings, causing Ia afferent impulses to be conducted to alpha motor neurons and Ia inhibitory interneurons in the spinal cord. This afferent pathway produces involuntary contraction in the vibrated muscle (that is, a tonic vibration reflex, TVR) and inhibits the antagonist muscle [30][31]. The effect of VT on the human body depends on the characteristics of the vibration applied, such as type of vibration (vertical, horizontal, or multidirectional), frequency, amplitude, and the protocol [27]. The effects also depend on the characteristics of the person, such as age, gender, and health condition [26][27].

WBV has been widely studied, and the evidence agrees on the pros and the cons of its application in patients with stroke [32][33][34][35][36][37][38][39][40]. The application of FMV for patients with stroke has been less widely studied [28][29]. Only one review specifically focused on FMV in stroke [28]. The authors summarized eight studies and concluded that FMV showed some evidence in reducing hemiplegic upper extremity spasticity in patients with stroke, and additional randomized controlled trials were needed to study the effects on FMV on spasticity in individuals with stroke [28].

Multiple studies have been conducted on the use of FMV for stroke rehabilitation in upper and lower limb impairments. These studies showed some improvements in functionality and reduction of muscle spasticity. However, there is a lack of consensus regarding its clinical application. The other gaps include the lack of protocol (frequency and amplitude of vibration, number of days and duration of intervention and overall study, etc.), standardized outcome measures, and recommended vibration devices. The purpose of this review was to focus on the current FMV devices in use, the vibration parameters applied, and protocols of FMV therapy and outcome measurements in post-stroke rehabilitation.

2. Focal Muscle Vibration for Stroke Rehabilitation

FMV therapy may reduce spasticity in both upper and lower extremities and improve function in individuals with stroke [28][29]. The positive effect of FMV in inhibiting hemiplegic upper and lower extremity spasticity in patients with strokes was confirmed with other reviews [25][28][29].

Included studies were primarily quasi-experimental design and RCTs. Most studies did not justify the choice of target muscles for vibration or provide the rationale behind the vibration protocols. Blinding of participants and therapists was poor, although the assignment of control and experimental groups was randomized. There was overall a lack of follow-up post FMV intervention to determine how long the improvements would last. Marconi et al. (2011) and Jung Sang-mi et al. (2017) examined the effects of FMV therapy after two weeks of intervention and reported that, even though the changes on the main outcome measures were less than observed immediately post interventions, patients were still better than baseline [41][42]. This finding indicates that the benefit of FMV therapy might last for two weeks. Caliandro et al. (2012) and Calarbo et al. (2017) checked the participants one month after the FMV therapy, and there were no significant differences on the outcome measures [43][44]. In addition, the included studies did not compare FMV therapy with other interventions, except for traditional physical therapy (PT). There was agreement with our review and others that a wide variety of FMV devices with different vibration frequencies, amplitude, targeted muscles, vibration protocol, and outcome measures were used [25][28][29].

Seven different vibration devices were used in the 19 studies that reported the vibration devices. The technical details of those devices were ambitiously described, but their availability for clinical and home use were not clear. In the 22 included studies, participants visited the clinics for the vibration interventions, which could lead to poor compliance for sustainable usage of the FMV therapy.

Recently, newer wearable FMV technologies were developed, including the Equistasi® (Equistasi S.R.L. Via C.Porta, 16 20064 Gorgonzola, Italy), VibraCool® (Pain Care Labs, 195 Arizona Ave LW08, Atlanta, GA 30307, USA), and Myovolt (Myovolt Limited 146a Litchfield Street, Christchurch 8011, New Zealand). Equistasi® uses nanotechnology fibers to deliver frequency as high as 9000 Hz with very low amplitude less than 0.002 mm. It has been used to treat Parkinson's disease [45][46][47], multiple sclerosis [48], and ataxia [49][50]. However, due to the much higher frequency and the lower amplitude, the mechanism of Equistasi® might not be the same as that of the FMV discussed in this study. In addition, Equistasi® has not been used for patients with stroke to our knowledge. VibraCool® uses proprietary high-speed vibration frequencies and intense cold for pain relief and to treat muscle tension and myofascial trigger points. Research evidence on VibraCool® appears unavailable, and its technical specifications were not reported on their website. Myovolt combines therapeutic vibration together with a gentle warming effect to massage and relieve muscle soreness and stiffness. Studies conducted using Myovolt reported improvement in muscular power performance [51] and alleviation of muscle soreness in healthy adults [52] and improved muscle function in patients with peripheral artery disease [53]. All of these wearable FMV technologies showed promise but with limited application or evidence in stroke rehabilitation. Future studies are warranted to explore their benefits with individuals with stroke.

More than half of the studies used vibration frequencies from 85 to 120 Hz and vibration amplitudes of 0.01–2 mm. A reduction in spasticity was observed with various frequency ranges. Due to the variations in amplitude and treatment frequency and duration, and contradictory to what is stated in the recent review [28], we speculate that vibration frequency cannot be disregarded as a discriminative factor in FMV intervention. We believe that studies with rigorous design controlling for vibration amplitude and treatment protocol will be needed to investigate the impact of vibration frequency in FMV intervention. The vibration amplitude for stroke rehabilitation ranging from 0.01 mm to 2 mm was considered comparable to the vibration amplitude ranging from 0.005 mm to 10 mm in studies using FMV intervention for patients with spinal cord injury, multiple sclerosis, and other movement disorders [25][29][54]. About one third of articles on FMV did not report the amplitude delivered. The improvements observed in the outcome measurement scores were better in studies using FMV with amplitudes greater than or equal to 1 mm and frequencies in the range of 91–108 Hz or greater [55][56][57][58][59][42][60][61], unless FMV was paired with other forms of intervention such as robotic assistive device [44] or progressive modular re-balancing (RMP) [62]. FMV alone with lower frequencies of less than 90 Hz and lower amplitudes of less than 1 mm seemed to have a lesser change in the outcome measures. Given that frequency range 75–120 Hz was particularly effective on the central nervous network underlying motor control [63], and amplitude of 1–2 mm was sufficient to drive Ia spindle afferents while remaining safe for the tonic vibration reflex [64] and avoiding muscle fiber injury [65], these frequency and amplitude combinations could be recommended for future studies. The duration of intervention did not seem to have much effect on the total improvement, although the change scores were slightly greater in studies with longer durations of intervention, which could be because of the long-lasting effects on cortical excitability. In addition to exploring the impact of vibration frequency, it is necessary to conduct basic science research on how muscle spindles, neurons, and human tissues respond to the different amplitudes delivered by the vibration motor to understand the individual and the combined impact of the vibration parameters as well as to optimize vibration parameters for individual patients.

A single session of vibration while walking for 14 s was reported to improve the walking speed of patients with stroke [66]. Further, a single session lasting 5 min inhibited spasticity and improved muscle performance, as measured by EMG [55][67][56]. Although these studies were of high quality with larger sample sizes, the results were insufficient for generalization. These findings may implicate the acute effect of FMV in stroke rehabilitation, as also observed in professional athletes [51]. With more frequent and longer duration (5 min FMV + 30 min PT × 3/week × 8 week) and more FMV (30 min FMV × 3/week × 6 week), small to moderate effect sizes (0.11–0.52) were observed in studies with relatively high methodological quality [59][61]. Other studies with less FMV (30 min FMV + 60 min PT × 5/week × 2 week) also reported significant reduction in spasticity in the experimental group compared with the control group [68][57][69][42]. More FMV might lead to better outcomes, but there is a lack of evidence regarding the best vibration dosage and duration. Thus, future studies to investigate and standardize the protocol for FMV interventions are warranted. The overall lack of follow-up after the FMV interventions made it difficult to determine the long-term effects, even though some studies stated that FMV intervention effects could last as long as two weeks [41] and even four months after the intervention in elder adults [70].

3. Conclusions

In conclusion, FMV may reduce spasticity and improve function in individuals with stroke when it is applied to the antagonist muscles. However, the effects of FMV on stroke rehabilitation are not fully understood. The accessibility and the sustainability of existing FMV technology, effectiveness of treatment protocol, and dosage remain unclear. Furthermore, the included studies did not report details on the vibration devices, with highly varied muscles vibrated, vibration frequency and amplitude, treatment protocol, and outcome measures. These variations make it difficult to recommend the clinical application of FMV therapy. These findings illustrate the need for more research to understand the mechanisms of FMV in stroke rehabilitation, and the impact of characteristics of the vibration device on outcome measures. Further high-quality studies with large sample sizes are warranted.

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