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Direct Application of Vibration to Stimulate Muscles of a Patient Post-Stroke: A Case Report

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Abstract

Background: Due to the high prevalence of strokes and the severe deficits they may cause, it is pertinent that simple methods are developed to attempt to increase functional mobility. Vibration is a potentially effective treatment to help individuals with strokes regain some muscular activation and cortical excitability. The purpose of this case report is to describe and explore the use of direct vibration on the lower extremity musculature of a patient experiencing hemiplegia post-stroke. **Case Description:** The patient was a 48-year-old male with a history of hypertension, who experienced left hemiplegia after having a stroke. He was a husband, father, and coach who had goals of returning to an active lifestyle. **Intervention:** Direct vibration was applied to the tibialis anterior and hamstrings of the patient to attempt to increase their activation and increase cortical excitability. This stimulation was provided once a day for a period of 2 weeks at different frequencies. **Outcome Measures:** The patient was tested with manual muscle testing, gross range of motion, and light touch sensory testing multiple times throughout the use of the vibration intervention. Assessing spasticity via the Modified Ashworth Scale may have also been beneficial, but did not take place. The patient also had vitals taken and was tested for DVT's with Homans test to screen for safety of the intervention. **Discussion:** This case report describes the direct application of vibration on muscles of the lower extremity in a patient with hemiplegia because of a stroke. Vibration combined with other interventions during regular therapy assisted the patient to be able to activate his lower extremity musculature.

Background

Each year, about 15 million people worldwide experience a stroke. Of these, about 5 million are permanently disabled. Strokes can be ischemic, causing a sudden stop of the flow of blood through the brain, or hemorrhagic, when a blood vessel bursts and bleeds into the brain. They can occur at any age and about 25% of the stroke cases in the United States occur in patients under the age of 65. Some risk factors of stroke include being of African American or Asian descent, smoking, high blood pressure, a history of atrial fibrillation, or being overweight. Of these risk factors, high blood pressure contributes to about 12.7 million of the 15 million strokes worldwide.[11]

Strokes can result in deficits such as muscle weakness, hemiparesis, spasticity, decreased mobility, decreased sensation, and poor balance.[6] According to the National Stroke Association, approximately 8 out of 10 stroke survivors experience some level of hemiparesis or weakness on one side of the body. For example, if a person were to have a stroke on the right side of the brain, left-sided weakness and neglect may result. This type of stroke may also affect the nonverbal communication and other types of behaviors, as this is dominated by the right side of the brain. Many people who experience these limitations seek out physical therapists and other practitioners to gain as much of their physical function back as possible.[12]

Some different therapy methods used to improve the function of patients who are post-stroke may include modified constraint-induced therapy (mCIT), electrical stimulation (Estim), cortical stimulation, use of assistive devices, stretching, heat, stimulation with tapping over the muscle bellies, or various medications and injections. mCIT is a method in which the therapist will restrict the use of the strong side of the patient, so they are more encouraged to use their weakened side. This can assist with improving the nerve function, but may take a considerable amount of time for the patient's full neuromuscular control to return. When using Estim, electrical pads are placed on skin overlaying the weakened muscles of the affected side of the body. The muscles receive an electrical signal directly from the machine, causing them to activate and contract. At the same time, the individual can try to volitionally contract the muscles. Estim can also help with sensory awareness. Cortical stimulation works similarly in that it stimulates part of the brain's cortex during rehabilitation exercises. Both interventions may be beneficial, but may also cause discomfort to a patient experiencing nerve hypersensitivity after having a stroke.

Assistive devices or orthoses can help a patient to have the support necessary to balance or to control various parts of the body. For example, an ankle-foot orthosis (AFO) can help prevent foot drop during ambulation. Assistive devices and orthoses are necessary in many cases, but are used in a compensatory manner if the patient is unable to regain full function of their body.[12] Stretching, heat, and tapping are easy to implement in therapy, but are limited by lack of research on their effects long-term. Other medical therapies include baclofen or botulinum toxin, but require more advanced education and skills to implement.[13] Because of the vast number of people who experience these functional deficits from stroke each year, it is vital that the effects of simple treatment methods are supported by evidence and research.

Direct vibration is a simple and potentially effective treatment for patients with hemiplegia following stroke. Vibration stimulates different cutaneous and musculo-tendinous receptors and can lead to cortical excitability. The stimulation triggers cutaneous mechanoreceptors connected with myelinated afferent nerves that join the peripheral nerves and follow various pathways to the brain. Vibration also triggers Ia afferents which end in spinal motoneurons to elicit the tonic vibrator reflex, causing the local muscle to contract.[8] The patient can then try to volitionally contract the muscles. These effects have the potential to increase function and quality of life in patients with deficits due to stroke. Vibration may be a valuable topic of further exploration in scientific study. Therefore, the purpose of this case report is to describe and explore the use of direct vibration on the lower extremity musculature of a patient experiencing hemiplegia post-stroke.

Case Description

The patient was a 48-year-old right-handed male employed as a coach who was sent to inpatient rehabilitation in July 2017 status post right thalamic intraparenchymal bleed extending into the right ventricle and basal ganglion. He was at home showering when he experienced dizziness and left-sided weakness causing him to fall towards his left side. EMS was called and patient was taken to the emergency room where he had a CT showing his stroke. His systolic blood pressure at the time was 220mmHg.

The patient's pertinent medical history included untreated hypertension and ADHD for which he took Adderall. The patient's father has a history of diabetes and hypertension. He was a non-smoker, drank alcohol socially, and exercised regularly with his athletes. The patient was on 2 liters of oxygen at the time of the physical therapy initial evaluation. The patient reported only having slight back pain. He was alert and oriented to person, place, and time and could follow directions 100% of the time. His speech was age appropriate, but his physical vocalization was slightly difficult to understand. He had extreme weakness on the left side of his body, absent deep tendon reflexes, Babinski sign present on the left, and light touch sensory altered on the left side of his body. The patient and family's stated goals for physical therapy were to sit, stand, return to coaching, play with his children, and learn to walk again.

The patient's stroke diagnosis was made clear by the imaging completed when the patient was brought to the emergency room. This CT scan and the patient's signs and symptoms ruled out other relevant differential diagnoses. The specific signs and symptoms making the patient appropriate for vibration were his strength deficits, as well as his minor spasticity in his left lower extremity. There is evidence to support that each of these physical limitations may be benefitted using direct vibration.

The patient was also examined to determine if vibration was a safe intervention. The patient was screened for Homan's sign to determine if he had a deep vein thrombosis (DVT).[4] If vibration was used on an extremity with a DVT, the clot could come loose and travel through the circulatory system and to the heart. This would likely be fatal, so screening for DVTs was vital.[8] The patient's vitals were also taken due to his history of hypertension. Blood pressure and heart rate were taken before physical therapy to ensure he was stable enough to participate.

Due to the deficits the patient acquired from his stroke, he was sent to inpatient rehabilitation to gain back as much function as possible. The patient was a good candidate for vibration on his lower extremity musculature for multiple reasons. First, he was young and very active previously. As a 48-year-old track and field coach and prior Olympian, he had maintained a physically active lifestyle and was very coordinated with his movements. This helped with his understanding of neuromuscular re-education and the reason why vibration as a stimulus may be helpful. This was also beneficial because the patient knew what it meant to have good control of his body even if he did not have that capability at the time. Second, the patient was suffering from a physical deficit, hemiplegia, that prevented him from fully activating the muscles on the left side of his body. The vibration assisted with the disconnect between the brain and peripheral nervous system in this case. Third, the patient was a very motivated individual. He was determined to return to his career, as well as his duties as a father and husband. For this reason, he was willing to participate in any intervention the physical therapists thought would benefit him.

The patient was tested in multiple different ways to confirm he was appropriate for the use of vibration on his muscles. First, the patient was assessed with the functional independence measure (FIM). The FIM 18-part scale that helps to assess the level of motor and cognitive disability of a patient in a rehabilitation settings using a 7-point scale. This instrument is explained in Tables 1a and 1b. According to sources, the FIM has excellent reliability for stroke patients at 0.88 on admission and 0.91 at discharge. The validity varies based on what the FIM has been compared to. One applicable comparison is the construct validity of the FIM with correlation to length of hospital stay, which is adequate at a value of $r=-0.39$.[10] Only 3 of the 18 items in the FIM were used by physical therapy in this rehabilitation setting; the locomotion (ambulation and wheelchair), stairs, and bed to chair transfers. These values were measured each week for the patient. He began as a 0 for ambulation locomotion and stairs as they were not tested initially. He was a 1 with bed to chair transfers which means he could

do less than 25% of the work in each area or required assist of at least 2. Finally, for wheelchair locomotion he was a 4 because he required some steering assistance. The FIM values related to the patient's ability to respond to vibration because the vibration may have helped him to learn to contract his left lower extremity musculature and the ability to activate his muscles allowed the physical therapist to begin to initiate gait training. Because gait training was initiated, the ambulation and stair values were eventually able to be determined.

The patient was tested with manual muscle testing (MMT) in the muscles of his right and left lower extremities to determine if vibration as a potential intervention should be considered. MMT is rating scale out of 5 used to test the strength and function of muscles and muscle groups by testing them in an against-gravity or gravity-eliminated position. According to a literature review on the reliability and validity, manual muscle testing reliability ranged from 0.63 to 0.98 for individual muscle groups and from 0.57 to 1.0 for a total MMT score. The review did not give specific values of the validity of MMT, but stated that the observational cohort studies demonstrated good external and internal validity.[3] His right lower extremity tested as a 5/5 for all muscle groups, while the left side was much weaker. The patient had trace muscle contraction (1/5) on his left tibialis anterior muscle and his left hamstrings, muscles very important in functional gait. Due to the weakness present in his left lower extremity musculature and lack of control he had with the motions, vibration was an appropriate intervention to consider. Refer to Table 2 for specific values.

Gross Range of Motion (ROM) was also evaluated in the patient to ensure he had the range necessary for function. This was done by taking each joint of the patient's lower extremities through their passive range of motion. The purpose of using vibration was to try a method that could help him relearn to activate his muscles so they could eventually become strong enough for ambulation. If the patient did not maintain the necessary ROM, he would not be able to ambulate effectively. Because the gross ROM was not used to assess a numerical value, but instead to screen for extreme ROM limitations, a validity and reliability measurement was not obtained. The specific number was not used in this case because the use of vibration on the patient was only limited by extreme ROM limitations.

The patient was also initially assessed with light touch sensory testing to determine any sensation deficits he might have had in his lower extremities. He was first shown what light touch should feel like on the right side of his body. The therapist lightly stroked the right cheek of the patient to demonstrate. Next, the patient was asked to close his eyes and tell the therapist where he felt he was being touched. The therapist then lightly touched various areas on the left side of the body. The patient could identify where he was being touched about half the time the therapist asked while touching the left, and it was documented that his light touch sensation was a 1 in his left lower extremity, meaning it was altered. According to sources, quantitative sensory testing such as light touch has a reliability of 0.53, but more research studies are needed to determine the validity.[9] Another sensory test that may have been beneficial to assess would have been proprioception, but this was not completed for the patient. However, it became apparent throughout the physical therapy sessions that there were some proprioceptive deficits.

Minor spasticity was also present in the patient's lower extremity musculature. This was tested by taking the patient through lower extremity passive range of motion into ankle dorsiflexion, knee flexion, and knee extension at an increased velocity. According to a source, the Modified Ashworth Scale (MAS) could have been used to further assess the level of spasticity in the patient, but was not used in this case. This may or may not have been beneficial, however, because according to a review, the MAS reliability and validity are questionable primarily with use for the lower extremities.[7]

Based on the findings during the examination of the patient, it was determined he was appropriate for the use of vibration on his lower extremity musculature. First, the patient was unable to fully activate his tibialis anterior and his hamstrings. As mentioned above, the patient started with only trace activation for the tibialis anterior and hamstrings bilaterally. For this reason, the patient could benefit from the muscular stimulation that can be provided by direct vibration. In addition, based on the research behind the use of vibration to benefit spasticity and sensory deficits in stroke patients, these limitations, no matter how minor, could improve. Finally, vibration had already been used on the

patient's upper extremities during his occupational therapy sessions. The intervention had been beneficial in assisting his upper extremity musculature, so it was worth assessing to see if the vibration would help with his lower extremity function as well. The patient had direct vibration applied to his tibialis anterior and his hamstrings each day for a period of two weeks. This amount of time was chosen by the therapist because after two weeks, the patient was able to dorsiflex his ankle slightly with faciliatory strategies. If the intervention was successful, he could have increased activation in this musculature.

Intervention

The patient was treated in an inpatient rehabilitation facility where he received three 30-minute sessions of physical therapy and occupational therapy each and two 30-minute sessions of speech therapy each day. The initial physical therapy rehabilitation for the patient was focused on strategies to increase functional mobility with the deficits present post-stroke. For the first several treatment sessions, the treating therapist continued with the treatment the patient had worked on in acute care, as well as other interventions to increase function of his left side. They worked on bed mobility, sitting tolerance and balance, transfers, wheelchair mobility, and reactivation of left-sided musculature in a side-lying position. The patient was instructed in strategies using the right side of his body to move around in bed and push up to a seated position. He was also instructed to rest on his right elbow, with legs hanging off the bed and push into a seated position without over-shooting to the left side. The patient picked up on these movement strategies very quickly. In a subsequent therapy session, the patient was instructed on a squat-pivot wheelchair transfer strategy with the assistance of the treating therapist. This was completed in both the right and left directions. In the wheelchair, the patient was instructed on using his right extremities to propel the wheelchair, which he did effectively. The patient propelled the chair to the rehabilitation gym, was assisted with a squat-pivot transfer to a large mat table and was placed in a right side-lying position. A large powder board was placed between the patient's lower extremities, with the left lower extremity sitting on top. A four-wheeled skate was secured around the patient's shin, so he could practice moving his leg with more ease. The therapist began with hip flexion and extension, using tapping of the hip flexors and extensors to assist with the movement. Tapping is a strategy used for muscle facilitation as it creates a quick stretch of muscle fibers which helps to increase their contractility.[5] Although hip flexion and extension were weak in a gravity-eliminated position, the patient was still able to consistently flex and extend his hip with minimal compensation for 10 repetitions. The therapist then worked on knee flexion and extension, as well as ankle dorsiflexion and plantarflexion, again tapping the muscles to assist with the motion. This worked well for the quadriceps and allowed for a fair amount of knee extension. Due to the weakness of the hamstrings and tibialis anterior, the patient was unable to overcome the slight spasticity present in the co-contracting muscles (the quadriceps and the gastrocnemius/soleus respectively) to flex the knee or dorsiflex the ankle. Different strategies were discussed to assist the patient with his knee flexion and ankle dorsiflexion activation.

In addition to physical therapy, the patient had been attending occupational therapy sessions. The occupational therapists focused primarily on the activation of the upper extremity muscles. They used a strategy of direct muscular vibration to facilitate the muscles elbow and wrist and it was successful for the patient. For this reason, the treating physical therapist decided to initiate the same strategy on his lower extremities.

Direct vibratory stimulation was used for one 30-minute physical therapy treatment session each day for a period of 2 weeks. This time was all that was necessary before the patient could activate the lower extremity

Figure 1. The Magic Wand HV 260 Personal Massager was used for the direct vibratory stimulation.[14]

muscles on his own. The tool used for the direct vibration was called the Magic Wand HV 260 Personal Massager (Refer to Figure 1).[14] The vibration was placed directly on the medial/lateral hamstrings and moved in a distal to proximal direction for a period of 3-5 seconds. The frequency used for each short bout of vibration was 6000 cycles per minute or 100 Hertz. The patient was asked to focus on activating the muscles being facilitated as the vibration occurred. This was repeated 5-10 times. The patient was then asked to activate the muscles without the vibratory stimulation. This was successful at multiple treatment sessions. For activation of the tibialis anterior, the patient was asked to move to a prone position. With the knee held into flexion, the therapist applied vibration in the same manner as mentioned above, to the tibialis anterior. The patient could actively dorsiflex his ankle in a gravity-eliminated position with the use of this vibration strategy. Although weakness was still present, after about two weeks, the patient could actively dorsiflex his ankle in a supine position without faciliatory strategies.

Other interventions used on the patient to help facilitate the muscles after stopping vibration included Functional Electrical Stimulation (FES) and contracting the muscle with manual resistance. FES was used on the patient's tibialis anterior muscle. FES has been found to promote increased muscle mass, motor recovery, decrease muscle tone, and can at times promote a faster return to walking.[1] The patient could obtain a contraction with this method, but it was used only once due to the discomfort the patient experienced. The manual resistance strategy was used by holding the ankle in a position and asking the patient to move against the resistance in each ankle direction. This intervention was primarily used on the tibialis anterior muscle and is worth mentioning as the patient stated he felt this strategy is what helped him to really connect with the movement of his ankle again.

After the patient could activate his lower extremity muscles, gait training strategies were initiated. The treating therapist first worked on standing tolerance in the parallel bars. After 4 days of working on standing tolerance during a 30-minute session each day, a Rifton gait trainer was used to help the patient ambulate through the hallways of the hospital. His physical therapy treatment sessions were decreased to two 30-minute sessions each day to work on gait training and continuing strength of his lower extremity muscles.

Outcome Measures

The patient was seen for 2-3 sessions a day for a 10-week period and demonstrated improved functional mobility in the muscles of his lower extremity. The initial treating therapist was unable to be present up to the discharge of the patient, but obtained objective values after the 2 weeks of direct vibration treatment and after 8 weeks of inpatient rehabilitation.

There were multiple components that may have contributed to the changes in FIM scores, including the direct vibration, other treatment strategies, and spontaneous recovery. After the 2 weeks of using vibration, the FIM score for ambulation and stairs continued to be a 0, as they were not yet tested. The bed to chair transfer score was a 3, as this had been practiced throughout physical and occupational therapy sessions. Finally, the wheelchair FIM score was a 5 as the patient required some supervision with steering. After 8 weeks, the FIM scores for ambulation, stairs, bed to chair transfers, and wheelchair were 4, 4, 5, and 6 respectively.

The patient maintained an altered light touch sensation and his gross ROM was within normal limits throughout his time in inpatient rehabilitation. MMT was again conducted after 2 weeks of vibratory stimulation and after the 8 weeks to assess progress. Refer to Table 2 for specific values. The patient continued to have weakness in the dorsiflexor muscles on the left in an against-gravity position, making it difficult to have a functional gait pattern. For this reason, he was fit for an ankle-foot orthosis and could ambulate with minimal assistance of 1 with a small-based quad cane. He was discharged to outpatient physical therapy to continue to make gains with functional mobility.

Discussion

The purpose of this case report was to describe and explore the use of direct vibration on the lower extremity musculature of a patient experiencing hemiplegia post-stroke. Initial treatment sessions

were focused more on the functional mobility of the patient, as well as increasing the activation of his lower extremity musculature. When reviewing the literature, there was evidence to support the use of direct application of vibration to assist with facilitation of muscles, which can help to increase functional mobility in patients with hemiplegia. Due to the accessibility, low risk, and growing research, vibration could at least be attempted in inpatient rehabilitation settings for stroke patients. The patient in this case study began with only trace activation of his hamstrings and his tibialis anterior muscles. After the application of direct vibration on these muscles, along with the use of other physical therapy interventions mentioned previously, the patient could actively flex his knee and dorsiflex his ankle. The level of activation after 2 and 8 weeks, however, was not quite adequate for independent functional ambulation. For this reason, the plan at 8 weeks was to discharge the patient to an outpatient facility to continue to improve his function. Further research may be necessary to explore if the results of this patient's case were correlated to the use of direct vibration or if they are attributed to some other intervention or mechanism.

Figures and Tables

Table 1a. Functional Independence Measure (FIM) rating scale. **1b.** FIM categories. The categories applicable to physical therapists in this inpatient rehabilitation setting are bolded.

1a.

Rating	Explanation
7	**Complete Independence**: all the task that involves an activity is performed with safety, without modifications or helpful resources, in reasonable time

6	**Modified Independence**: able to perform tasks with help of assistive device, needing more time, but performing with safety and totally independent
5	**Supervision**: individual needs only supervision or verbal commands or models to make the task without necessity of touch and help is only in the preparation of the task when necessary.
4	**Minimum Assistance**: need a minimum quantity of assistance, a simple touch, making it possible to perform the activity (perform 75% of the effort necessary in the task)
3	**Moderate Assistance**: needs a moderate amount of assistance, more than simply touching (do 50% of the effort necessary in the task)
2	**Maximum Assistance**: utilizes less than 50% of the effort necessary to complete the task, but does not need total help
1	**Total Assistance**: total assist is necessary or the task is not performed. Utilizes less than 25% of the effort necessary to make the task; Assist of 2
0	Not applicable or not tested

1b.

18 Items
1) Eating
2) Grooming
3) Bathing
4) Upper body dressing
5) Lower body dressing
6) Toileting
7) Bladder management
8) Bowel management
9) **Bed to chair transfer**
10) Toilet transfer
11) Shower transfer
12) **Locomotion (ambulatory or wheelchair level)**
13) **Stairs**
14) Cognitive comprehension
15) Expression
16) Social interaction
17) Problem solving
18) Memory

Table 2. The Manual Muscle Testing (MMT) values of the patient at initial evaluation, post-vibration and after 8 weeks of therapy. The only values taken post-vibration were the muscles in which vibration was used.

	Initial Evaluation	**Post-vibration**	**After 8 weeks**
Hip			
Flexion	0/5	-	3+/5
Abduction	1/5	-	3+/5

Adduction	2-/5	-	4/5
Knee			
Flexion	1/5	2+/5	3/5
Extension	1/5	-	3/5
Ankle			
Dorsiflexion	1/5	2+/5	2+/5
Plantarflexion	0/5	-	-

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