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WBV ON THE UPPER LIMB PERFORMANCE IN COMPLETE SPINAL CORD INJURY

Uriel Sena Lopes Gomes da Silva[1i],
Hernán Ariel Villagra[2],
Laura Luna Oliva[3],
Nádia Fernanda Marconi[4]
[1]PhD candidate, Department of Education,
Physical Activity and Human Motor Control,
Autonomous University of Madrid, Madrid, Spain
[2]Dr. PhD, Department of Education,
Physical Activity and Human Motor Control,
Autonomous University of Madrid, Madrid, Spain
[3]Dr. PhD, Department of Sciences,
Physiotherapy and Rehabilitation,
Universidad Rey Juan Carlos, Madrid, Spain
[4]Dr. PhD, Physical Therapy Department,
College of Health and Human Sciences,
Western Carolina University, Cullowhee, NC, USA

Abstract:

Background: individuals with spinal cord injury (SCI) need upper limbs during activities of daily living that include transferring and propelling a wheelchair. A single session of Whole-body Vibration (WBV) has shown positive impact on musculoskeletal performance. **Objective**: To investigate the effects of one single session of WBV over the upper limb function in complete SCI during the execution of functional tasks. **Design**: Individuals with SCI have performed three functional tasks: a timed push up test, grip strength and throw ball test before and after a session of WBV. **Participants**: 15 individuals with complete SCI were recruited for this study. **Interventions**: WBV was composed of one single session, five series of thirty seconds vibration with one-minute rest between. The push up test consisted of attempting a maximum number of repetitions during a fifteen second work period followed by a forty-five second rest period. Grip strength was assessed using a handheld dynamometer. Throw ball test

[i] Correspondence: email uriel_fisio@hotmail.com

consisted on launching a 2Kg medicine ball as afar as possible. **Results**: WBV statistically improved performance in all three functional tasks. **Conclusions**: one single session of WBV can improve upper limb performance in complete SCI.

Keywords: WBV, spinal cord injury, functional tasks, hand dynamometry, push up test, ball throw test

1. Introduction

Individuals with spinal cord injury (SCI) demonstrate strength deficits that can limit their functional ability to perform activities of daily living. Muscle-strength testing is used to document recovery or loss of motor function early in SCI, as well as measure improvements in strength and electromyographic signal in SCI[1, 2]. The shoulder is the most common site of upper extremity pain in patients with chronic SCI. Shoulder pain is associated with lower quality-of-life ratings and physical activity engagement in SCI[3]. Recently, whole body vibration (WBV) has become increasingly used as a neuromuscular training tool in several cases including SCI[4, 5, 6, 7]. A proposed mechanism for the acute effects of WBV training include neural adaptations related to increased excitatory input from vibrated muscle spindles[8, 9]. Vibration stimulation is proved to elicit tonic vibration reflex in muscles. It has also been demonstrated that intervention based on vibration stimulates the neuromuscular system and consequently increases muscle strength and physical performance acutely and transiently[10]. It seems that 25–30 Hz and 3–5 mm amplitude provides stimuli strong enough to elicit depolarization of muscle spindles and elicit one afferent excitatory inflow to the motor neurons through Ia afferent fibers. Alpha motor neurons, in turn, make excitatory synapses to the muscle fibers, eliciting tonic vibration reflex[10].

Some studies have found positive results of WBV in a short period (one single section)[11-17]. Field laboratory tests for assessing strength and power are well established; however, laboratory equipment can be costly and, sometimes constrain the performance of movement. Field-based tests can measure muscular performance with a high degree of reliability[18].

In addition, there are several studies investigating the effects of vibration on the upper extremity muscles performance. In most studies, the elbow extensors or flexors were stimulated holding vibrating dumbbells or wire in the hand[19-25]. All of them reported significant improvement in muscle strength, power, and EMG muscle activity except in Moran's et al. study[25].

A review of the literature suggests that future research is needed to determine the therapeutic potential, adverse events and to establish WBV parameters tolerable for patients with SCI[7].

The purpose of this study was to verify the effects of one single section of WBV on upper limb function in individuals with SCI.

2. Material and Methods

For this study were selected fifteen individuals with complete SCI. They were asked to perform three tasks: push up, grip strength and, throw ball. These tasks were performed twice: before and after WBV. For each task, it was calculated the performance average to determine whether the WBV was effective in improving the upper limb performance in all three tasks.

2.1 Participants

For this study, 15 individuals with complete SCI were recruited. To be considered eligible to enroll to the study the subjects needed to meet the following criteria: have been diagnosed with complete SCI beneath T3 level; wheelchair users for more than one year prior to the intervention and; using a manual wheelchair more than one hour per day. Individuals were excluded from the study if: their injury was beneath T3 level; had been diagnosed with incomplete SCI; weren't manual wheelchair users; had any known orthopedic issues involving the upper limbs or any contraindication to WBV, such as epilepsy, active tumor or severe arthrosis. We chose the injury underneath T3 to ensure that all individuals would have the muscles of the upper limbs completely preserved.
This study was conducted at two centers for individuals with physical disabilities and was duly authorized by the ethics committee.

3. WBV Session

WBV intervention consisted of a single session composed of five series of thirty second vibrations with one-minute rest periods. The frequency employed was 30Hz while the amplitude was kept constant at 4mm. The vibratory platform model Galileo Advanced Novotec Medical had been used for this study. The position assumed on the platform was over the platform on elbows and forearms in a plank position (Figure 1). Trunk and lower limb had assumed the most comfortable position possible to respect each individual limitation.

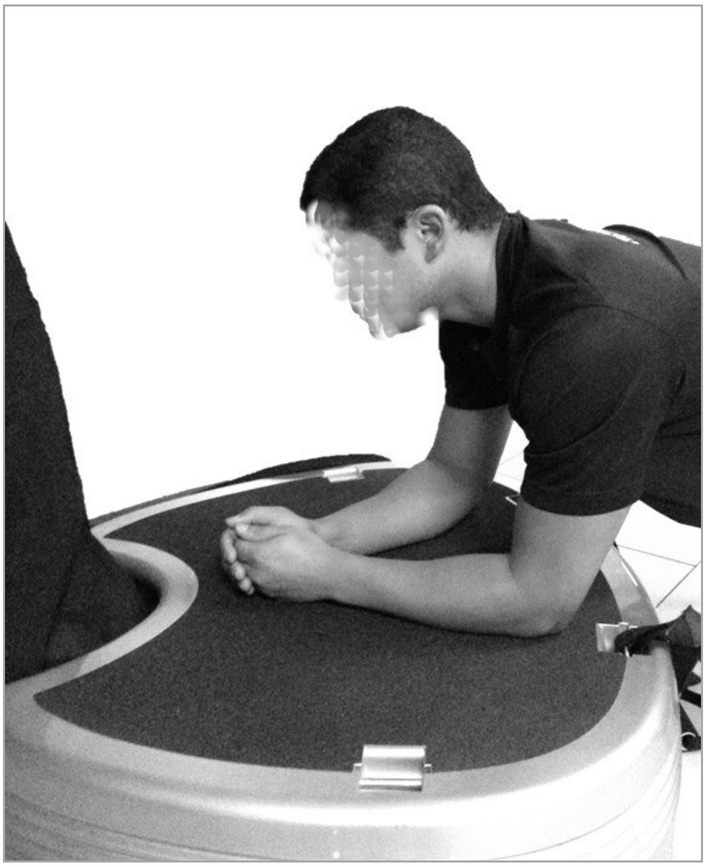

Figure 1: Representation of the positioning over the platform

3.1 Timed Push Up Test (Tput)

Based on Negrete's studies[26-28], this test this test consists of attempting a maximum number of pushups during a fifteen second work period followed by a forty five second rest period. This test was performed prone, reflecting a right angle at the elbow in relation to the humorous and the floor. Every individual had the freedom to follow their pace and make stops if necessary, but the time to perform the test would not be interrupted under any circumstances and would continue counting. The average of the three series was taken for the test results. For this test a simple digital stopwatch was used[10, 26, 28, 29].

Participants had refrained from eccentric exercise training for at least one day before data collection. This test was performed before and after WBV.

3.2 Grip Strength (GS)

A thorough review of the literature revealed that holding a dynamometer is a suitable alternative to traditional manual muscle testing as it exhibits good to excellent reliability, provides objective ratio data, and has portability, allowing it to be used in multiple environments. Hand-held dynamometry is a reliable method to determine grip strength[2, 30-33].

Considering the hand-held dynamometers ease of use, portability, cost, and compact size, compared with isokinetic devices, this instrument can be regarded as a reliable and valid instrument for muscle strength assessment in a clinical setting[32]. For this test was used Camry Electronic Hand Dynamometer Grip EH101-37 manual pressure with high pressure up to 90Kg. Individuals flexed their fingers with maximum force and speed possible while maintaining the position of the dynamometer in relation to the forearm. The individual did not begin testing until the observer said "go". The test ended when the subject had reached his/her maximum degree of finger flexion.

The display was clearly visible during the test and the subject was not allowed to let it touch any part of the body. The best result of two attempts with each hand was collected and the mean of these values were adopted as the final score[30, 32]. This test was made before and after the intervention of WBV and individuals have made it in their own manual wheelchair.

3.3 Throw Ball Test (TBT)

Based on Negrete's studies[26-28], this test was performed with individuals seated in the wheelchair. A two kg medicine ball was held with the dominant hand while the non-dominant hand was placed on the anterior aspect of the dominant shoulder (figure 2). This position minimizes the use of the trunk during the test. The trunk could not be used during the launch of the ball; only the upper limb could be used. Individuals were instructed to throw the ball as far as possible, simulating the Olympic weight launch. They made three attempts. The distance was measured by the observer using a meter. For analysis purpose, the average of the three attempts was used[26, 27].

Figure 2: Representation of the positioning to perform TBT

For this study were selected all individuals who had met all criteria for inclusion from two centers for the impaired.

Variables that were analyzed in this study were: 1. the number of repetitions of pushups, 2. the grip strength measured by a dynamometer and 3. the distance throwing the ball.

3.4 Statistical methods

The pattern of normality of the data was analyzed using Shapiro Wilk test (less than fifty individuals). As it followed the normal pattern, T-student test for independent samples matched was applied to compare the average of the tests (TPUT, GS, TBT) before and after WBV. Statistical significance level was assumed if $p < .05$. IBM-SPSS software version 22 package for Windows (Chicago, IL, California) was used for all statistical tests.

4. Results

Thirteen individuals were unable to participate in this study because of their incomplete SCI; two other individuals with complete spinal cord injury were unable to participate due to orthopedic injuries in the shoulder and another did not want to participate without giving reason. The average age of the fifteen SCI participants was 46±20 years.

Regarding the TUPT, a single session of WBV lead to an increase of 2.74 repetitions or an increase of 21.5% that represents a significant increase in the push up exercise (P<.001. Confidence interval: 99% with Z = 2.58. Table 1).

Table 1: TUPT. Maximum number of pushups during a fifteen second work period

SCI	Level of injury	Pretest	Posttest	P value
1	L1	9.3	11.3	
2	L5	14.6	17.3	
3	L1	12.3	12.6	
4	T4	13.0	17.3	
5	T11	15.6	18.3	
6	T12	14.6	17.0	
7	T5	15.3	16.3	
8	T6	15.6	19.3	
9	L1	11.3	15.3	
10	T4	11.0	16.0	
11	T11	16.6	19.3	

12	T8	19.0	22.3	
13	T10	7.3	10.6	
14	L1	6.3	9.3	
15	T10	6.3	7.0	
	Mean	**12.5 ± 4**	**15.2 ± 4[a]**	**.001**

Baseline measurement comparing pretest and posttest (mean ± SD).
TUPT = Timed up pushup test. SCI = individuals with spinal cord injury.
Unit used is repetition.
[a] significant.
P value indicates the comparison of pretest and posttest means.
Confidence interval: 99% with Z = 2.58.

WBV was also able to significant increase in grip strength on the GS HD test comparing pre and post intervention scores. The average improvement was a 1.6Kg (P<.001. Confidence interval: 99% with Z = 2.58. Table 2).

Table 2: GS. Grip strength of the hand assessed using a handheld dynamometer

SCI	Level of injury	Pretest	Posttest	P value
1	L1	35.5	36.5	
2	L5	36.2	37.5	
3	L1	58.3	57.0	
4	T4	61.1	61.9	
5	T11	62.9	66.0	
6	T12	43.6	47.1	
7	T5	46.5	48.8	
8	T6	60.4	62.3	
9	L1	20.5	22.9	
10	T4	37.5	38.0	
11	T11	57.7	58.9	
12	T8	49.7	50.3	
13	T10	35.7	37.9	
14	L1	30.9	34.2	
15	T10	10.9	12.5	
	Mean	**43.2 ± 15**	**44.8 ± 15[b]**	**.000**

Baseline measurement comparing pretest and posttest (mean ± SD).
GS = Grip strength. SCI = individuals with spinal cord injury.
[b] significant.
Unit used is Kilograms.
P value indicates the comparison of pretest and posttest means.
Confidence interval: 99% with Z = 2.58.

There was a significant increase the distance on BTT by 10.4% (0.34 meters) after WBV. ($P < .001$. Confidence interval: 99% with $Z = 2.58$. Table 3).

Table 3: TBT - Launching a 2Kg medicine ball as afar as possible

Individual	Level of injury	Pretest	Posttest	P value
1	L1	2.96	4.17	
2	L5	3.92	4.20	
3	L1	2.51	2.60	
4	T4	3.52	3.73	
5	T11	4.43	4.60	
6	T12	4.54	4.71	
7	T5	4.80	5.41	
8	T6	3.66	4.16	
9	L1	1.61	1.79	
10	T4	3.30	3.49	
11	T11	3.39	3.60	
12	T8	3.70	3.96	
13	T10	2.30	2.86	
14	L1	2.04	2.39	
15	T10	2.00	2.10	
	Mean	**3.24 ± 1**	**3.58 ± 1** [c]	**.000**

Baseline measurement comparing pretest and posttest (mean ± SD).
TBT = throw ball test. SCI = individuals with spinal cord injury.
[c] *significant.*
Unit used is meters.
P value indicates the comparison of pretest and posttest means.
Confidence interval: 99% with Z = 2.58.

None of the individuals discontinued participation as a result of the intervention. In addition, there was no problem or discomfort regarding the use of the vibrating platform in the upper limbs or the posture assumed.

5. Discussion

This study had shown that one single session of WBV was able to increase three tasks: pushups, grip strength and throwing ball. These tasks were chosen due to their importance in daily living tasks in SCI such propulsion of the wheelchair, manual abilities and strength, transfers, etc. Only individuals with complete SCI were recruited to get a group with the same characteristics and increase the reliability of the results.

This was the first study that applied the WBV under the upper limbs in individuals with complete SCI. Individuals were able to improve in all of the three proposed tasks.

As a limitation of this study, we do not know the long-term effects; we only know the immediate effects of WBV. Having enrolled only individuals with complete SCI increased the strength of the results within a very specific population; Because of this specificity, and rigorous inclusion and exclusion criteria, the sample had proven to be sufficient to achieve statistical significance and relevance.

Other studies have applied WBV on the upper limbs with positive results, including different populations. On the other hand, authors of previous studies had not reported similar results due to different protocols and sample[5, 10-17, 34].

Gyulai et al[10] also studied the use of WBV to increase upper limb strength, in healthy individuals, obtaining positive results. In this study, WBV session was composed of five sets of thirty seconds vibration, six mm of amplitude, 30 Hz, with the subjects assuming the push up position over the platform. This study gave us the theoretical basis related to the parameters, once the authors found out that WBV increased the upper limb strength. Both studies achieved positive results; that is because the same methodology even applied to different populations.

Hong et al[3] studied the effects of WBV over peak torque, time to peak torque, and power of upper limb in healthy individuals. Participants were instructed to place their arms on the vibration platform in a plank position (shoulder width apart), with their feet shoulder width apart on the ground. WBV session was composed of three sets of one minute vibration, with one minute of resting time between trials, an amplitude of five mm and a frequency of 30 Hz. The experimental group demonstrated a significant improvement in the internal rotation peak torque, time to peak torque and external rotation time to peak torque ($p<.05$) suggesting that short periods of vibration stimulation have a significant effect on shoulder muscle characteristics.

Marin et al[33] tested the effects of WBV on upper body performed in healthy individual but used a different testing protocol where individuals exercised on a vibrating platform. This study did not show positive results of WBV but it may be due to differences in methodology and parameters which may not have been adequate to increase upper limb physical qualities compared to other studies described. WBV session consisted in 50 Hz and 2,51 mm. Each individual performed 3 sets of elbow-extension exercise on a WBV platform under 3 conditions (independent variables): (a) acute effect, the elbow-extension exercise was performed during WBV on a vibration platform; (b) residual effect, the WBV stimulus (30 seconds) during the semi squat position was applied 60 seconds before the elbow-extension exercise (RE); control, the elbow-extension set was performed on a vibration platform without WBV (CTRL). The initial experimental session determined the individual's 1RM for the elbow-extension exercise using a pulley cable machine (Telju, Toledo, Spain). Each of the three exercise sessions were performed as one set of repetitions until muscular failure on the pulley cable machine. This study did not show positive results of WBV. It leads us to believe that this method and parameters are not adequate to increase upper limb physical qualities compared to other studies.

One single session was chosen to investigate the acute effects of vibration. Some studies have found positive results of WBV in a short period (one single section)[11-17]. Bosveld and Field-Fote[12] have studied the effects of one single session of WBV in the quadriceps of individuals with incomplete SCI. Similar to our results, this one single session was enough to increase muscle force-generating capacity.

All tests applied in this study are reliable and easily reproduced and the chosen WBV parameters were those which got the best results in previous studies. It can explain the positive results in all three functional tasks[1, 26-28, 32].

The functional tasks assessed in this study are very important to the daily activities of individuals with complete SCI. These tests can be easily reproduced by any health professional at any health center. To know established WBV parameters and applicability is important to guide health professionals in their interventions with SCI. According to results, one single WBV session improved upper limb abilities which may have a potential impact in improving quality of life and functional independence in individuals with SCI. WBV can be used in conjunction with standard multidisciplinary rehabilitative efforts to increase muscular performance and promote functional tasks.

The three chosen tasks are important in the functional performance of SCI: grip strength and musculature involved in the push up (pectoralis major, anterior deltoids, triceps brachial) are important in tasks such as, for example, pushing the wheelchair. Thus, the training protocol used in this study can be used by professionals to develop muscle strength of these demanded musculatures, and consequently, could improve functional tasks.

7. Conclusion

One single session of WBV increased upper limb performance in functional tasks in individuals with complete SCI. This study provides a foundation for further research and investigation regarding the benefits of WBV in individuals with SCI, and supports one single section, WBV parameters and positioning over the platform. Further studies are necessary to investigate the long-term effects of one single session of WBV.

8. Other Information

We declare that this study was done without any funding and that the centers, participants and investigators involved were volunteers.

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