European Journal of Physical Education and Sport Science

ISSN: 2501 - 1235

ISSN-L: 2501 - 1235

Available on-line at: www.oapub.org/edu

doi: 10.5281/zenodo.401402

Volume 3 | Issue 2 | 2017

EFFECTS OF WHOLE-BODY VIBRATION DURING WHEELCHAIR PROPULSION IN INDIVIDUALS WITH 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: Push the manual wheelchair is one of the most important activities to the wheelchair users like individuals with spinal cord injury (SCI). The excessive or bad use of the upper limb would lead to biomechanical issues and pain. Whole-body vibration applied by vibratory platform (WBV) has been showing great results increasing muscular performance of the upper limb. Although researches regarding the influence of WBV on activity of the upper limb muscles are unclear due to contradictory findings and dissimilar protocols. **Objective**: The aim of this study was to evaluate the effects of one single session of WBV increasing muscular performance during the propulsion of the wheelchair in SCI. **Methods**: Fifteen complete SCI were recruited and performed wheelchair propulsion test that consists in to push the manual wheelchair in a 10 meters path as fast as possible. Average speed, push frequency (cadence) and time of

[i] Correspondence: email uriel_fisio@hotmail.com

displacement were measured before and after WBV intervention. WBV consisted in 5 sets of 30 second vibration with 60 second rest between. The positioning on the platform consisted in supporting the elbows and forearms. **Results**: Results show a significant increase in average speed and time of displacement. There was no significant difference in push frequency. **Conclusion**: In conclusion, WBV is an effective tool increasing upper limb performance during propulsion of the wheelchair and it can be useful during the treatment of SCI individuals.

Keywords: spinal cord; upper extremity; wheelchair; vibration

1. Introduction

The correct functionality of the upper limbs is an essential condition for the autonomy of people with disabilities, especially for wheelchair users (1, 2, 3). Individuals with a spinal cord injury (SCI) demonstrate strength deficits and pain that can limit their functional ability to perform activities of daily living such propulsion of the wheelchair (4, 5, 6).

Recently, whole body vibration applied by vibratory platform (WBV) has been used as an efficient neuromuscular tool (7-12). WBV has slowly emerged as an alternative method of neuromuscular overload to enhance physical performance (13). Several mechanisms for the acute effects of WBV training have been suggested, including neural adaptation, related to increased muscle activation, caused by increased excitability input from muscle spindles exposed to vibration (13-15). Vibrations applied to the upper body showed enhancement of mechanical power and an increase in neuromuscular efficiency supporting the evidence that vibrations represent a strong stimulus for the neuromuscular system (16, 17). Acute changes in motor output, in fact, have been associated with increased sensitivity of muscle spindles, which would lead to facilitation in homonymous α motoneurons (13). Vibrations applied to the lower limb in SCI have not reported positive results (18). Some studies have found positive results of WBV in a short period: one single session (7, 8, 19-24).WBV applied to the upper extremity has been showing positive results in muscular performance and EMG signal (7, 17, 25, 26).

Propulse the wheelchair is one of the main tasks during daily living in SCI. The Wheelchair Propulsion Test (WPT) consists of wheeling 10 meters while time is recorded with a stopwatch, and the number of cycles and time are recorded by observation. The WPT appears to be a simple and inexpensive test with excellent measurement properties that can be used for people who use hand and/or foot propulsion (27).

The aim of this study was to investigate de effects of one single session of WBV in complete SCI during wheelchair propulsion. To the best author's knowledge, however, there are no studies investigating the upper limb muscle performance in complete SCI during exposure to WBV. Although researches regarding the influence of WBV on activity of the upper limb muscles and contradictory findings have been reported as result of dissimilar protocols (17). In this study, we have tried to adopt the parameters with positive results in literature to confirm its efficiency in SCI.

2. Materials and Methods

2.1 Participants

For this study, 15 individuals with complete SCI (46±20 years) were recruited. All subjects had their injury level beneath T3 and they were all wheelchair users for more than one year prior to the intervention. To participate in this study, they should be manual wheelchair users more than one hour per day and have no orthopedic issues concerning the upper limb. They also cannot have any contraindications to WBV such as epilepsy, active tumor or severe arthrosis. None of the subjects was experienced with WBV training. This study has the approval of the local Ethics Committee and informed consent was obtained from all participants.

2.2 Experimental procedures

2.2.1 Wheelchair propulsion test (WPT)

WPT is a valid method to assess upper extremity performance in a wheelchair (27). It consists:

A. <u>Equipment and set-up</u>: Means of recording the time (to the nearest second). A 10m path at least 1.2m wide on a smooth level surface, with at least 2 m before the starting line and at least 2m beyond the finish line. The starting lines and path width were clearly indicated.

B. <u>Starting position</u>: Wheelchair user seated in wheelchair at rest, with the wheel locks off, behind the starting line, facing forward. The casters were oriented as they will be for moving in the selected direction. The tester positions himself where it is best possible to view the limb being used to record the number of cycles and to view the leading wheel as it crosses the finish line.

C. Safety: The tester is attentive to and in a position to spot for rear tips or forward falls from the wheelchair, especially during the starting and stopping stages of the test.
D. Instructions: • The test subject may do a practice attempt to familiarize him with the instructions and to provide the tester with an indication of what limb should be used for counting the cycles and propulsion method. • Orally or in writing, the tester instructs the test subject as follows: "*When you are ready, please propel your wheelchair to the finish area using your usual method and speed*". The tester should indicate the finish area beyond the finish line.
E. What the tester records: The tester used the form on the appendix to record the following data:

1. Success at completing the 10m task: always "yes" individuals.
2. Direction of travel: only forward.
3. Limbs contributing to propulsion, steering or braking: only with both arms.
4. Limb monitored for timing propulsion cycles: dominant one.
5. Time (to the nearest second) from when the leading wheels cross the starting line until they cross the finish line.
6. Total number of propulsive cycles in 10m (to nearest full cycle). A cycle was defined as beginning when the limb being monitored makes the initial contact with the hand-rim (if an arm) or the ground (if a leg). The end of the cycle is when this event occurs the next time.
7. All subjects have used both arms to push the wheelchair the way they used to do in their daily life tasks.
8. F. What the tester assessed: The tester has calculated the following derived parameters:
9. Average speed: in 10 meters (m/s).
10. Push frequency (or cadence): cycles in 10 meters.
11. Effectiveness: time spent to displace 10 meters (27).

2.2.2 WBV session

WBV intervention was composed of one single session, five series of thirty second vibrations with one-minute rest between. The frequency employed was 30Hz while the amplitude was kept constant at 5mm. The vibratory platform model *Galileo Advanced Novotec Medical* had been used for this study. The position assumed on the platform was to support the upper limbs over the platform with elbows and forearm (Figure 1). Forearm had been completely supported over the platform with elbows opened underneath shoulders. Hands were kept together with the eyes looking to the horizon.

Trunk and lower limb had assumed the most comfortable and possible position to each subject respecting personal limitations.

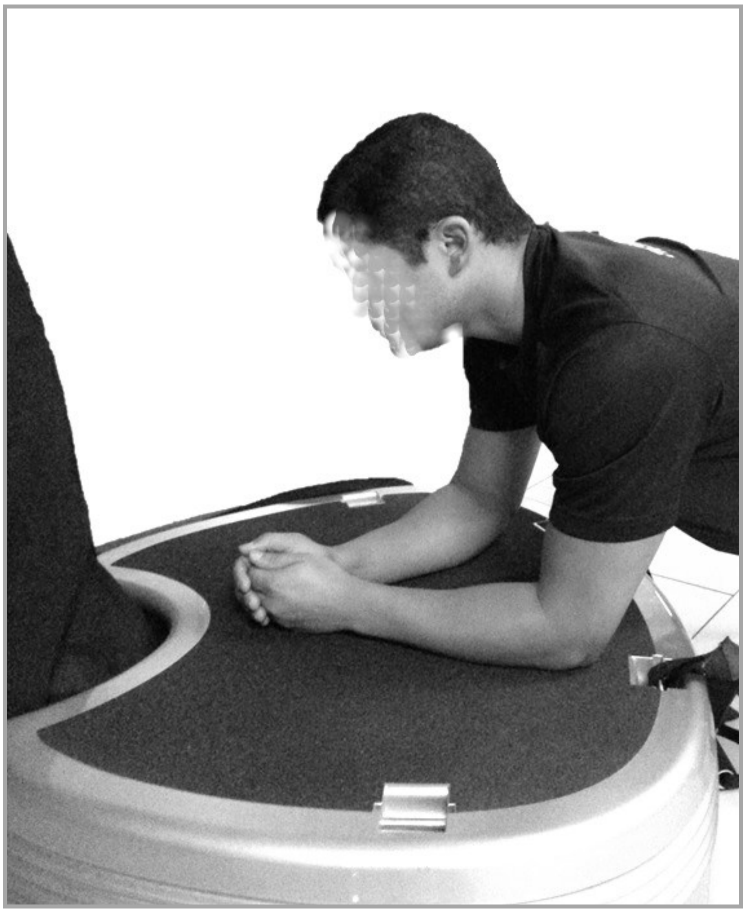

Figure 1: Positioning of the upper limbs on the platform

2.3 Data analysis and statistics

The pattern of normality of the data was analyzed using Shapiro Wilk test (less than fifty individuals). As variables average speed and propulsion followed the normal pattern, T-student test for independent samples matched was applied to compare the average before and after WBV. Variable time did not follow the normal pattern; Wilcoxon test was applied to compare the average before and after WBV.

Statistical significance level was assumed if $p < 0.05$. *IBM-SPSS* software version 22 package for Windows (Chicago, IL, California) was used for all statistical tests.

3. Results

3.1 Time of Displacement

Time of displacement was measured in seconds using a chronometer while SCI propulse the wheelchair. Thirteen of the fifteen subjects have performed a better/faster wheelchair propulsion reducing the time spent during the test. The mean average before WBV was 6.30 seconds. The mean average after WBV improved to 5.47 seconds (an increase of 0.83 second). It shows a better/faster performance after WBV. Table 1 shows the time spent during displacement for each individual before and after WBV.

Individual	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**mean**
Pretest	5.15	7.75	5.46	4.93	4.35	5.81	6.73	6.52	6.52	6.72	5.16	12.7	4.92	5.52	5.04	6.30
Posttest	4.27	6.42	5.04	4.71	4.36	5.02	6.18	5.69	5.77	5.07	4.02	11.45	3.38	5.61	5.06	5.47
Difference	0.88	1.33	0.42	0.22	*0.01*	0.79	0.55	0.83	0.75	1.65	1.14	1.25	1.54	*0.09*	*0.02*	**0.83**[a]

Table 1: Time of displacement during wheelchair propulsion for each individual, in seconds. Individuals 5, 14 and 15 were the only ones that have performed a slower propulsion after WBV. [a] Significant increase. Baseline measurement comparing pretest and posttest ($p < .001$; Confidence interval: 99% with Z = 2.58).

3.2 Push Frequency

Push frequency represents the total cycles during the 10 meters displacement. There was no significant difference, that is, individuals have performed a faster displacement without to change cadence. Table 2 shows push frequency of each individual before and after WBV.

Individual	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**mean**
Pretest	7	10	6	6	8	6	8	10	10	8	10	12	7	6	8	8.13
Posttest	8	10	7	7	7	6	8	9	10	6	8	10	8	7	9	8
Difference	+1	0	+1	+1	-1	0	0	-1	0	-2	-2	-2	+1	+1	+1	**-0.13** [b]

Table 2: Push frequency of each individual before and after WBV. Negative values represent the cycles that have decreased in the posttest and positive values represent an increase of cycles. [b] There was no significant difference in the average of individuals. Baseline measurement comparing pretest and posttest ($p < .001$; Confidence interval: 99% with Z = 2.58).

3.3 Average Speed

Average speed was measured in meters per second (m/s). Table 3 describes the average speed of each individual during the test. The fourth row shows the speed improvement comparing pre and posttest. All individuals, but number 5, have increased their speed after WBV.

Individual	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**mean**
Pretest	1.94	1.29	1.73	2.02	2.29	1.72	1.48	1.53	1.53	1.48	1.93	0.78	2.03	1.53	1.98	1.68
Posttest	2.34	1.55	1.98	2.12	2.29	1.99	1.61	1.75	1.73	1.97	2.48	0.87	2.95	1.78	1.97	1.95
Difference	0.4	0.26	0.25	0.1	0	0.27	0.13	0.22	0.2	0.49	0.55	0.09	0.92	0.25	0.01	**0.27** [c]

Table 3: Average speed of each individual pre and posttest. All individuals (but number 5) have increased their average speed. [c] Significant. Baseline measurement comparing pretest and posttest ($p < .001$; Confidence interval: 99% with Z = 2.58).

4. Discussion

Wheelchair propulsion is an alternative form of mobility that can facilitate community participation and functional independence for people with mobility impairments. Reliance on wheeled mobility ranges from complete - as often is the case for people with paraplegia or tetraplegia resulting from spinal cord injury. WPT is a very simple and effective test to measure objectively the performance of the upper limb in SCI; some studies have been demonstrated the viability of this test and the need of further investigations (1, 17, 27, 29). Few studies have examined biomechanics of wheelchair propulsion at a self-selected velocity over surfaces commonly encountered in the community (28). Differences in parameters and positions in WBV would explain such different results literature (18).

Masani (18) have studied the effects of 40 weeks WBV on lower limbs of SCI with no results. When WBV is applied on upper limbs, it gets great results over neuromuscular system (7, 12, 25, 26, 30). Our study agrees to the literature increasing muscular performance in upper limb using WBV (7, 12, 25, 26, 30).

Bosveld (8) have studied the effects of ***one single session*** of WBV on quadriceps of motor-incomplete SCI. This one single session was enough to increase quadriceps force-generating capacity and suggest further studies in this area. Our study also has used one single session with positive results but in upper limb muscles.

Ashnagar et al (17) also have studied the effects of one single session of whole body vibration over the upper limb adopting the modified push up position but in a healthy population. They also used the same positioning and parameters applied in this study (30Hz, push position, 5 sets of 30-second vibration, 5mm). EMG signal has increased significantly on Upper Trapezius, Serratus Anterior, Biceps Brachii and Triceps Brachii. We have used the same parameters of Ashnagar due to the positive results. One single session of WBV was enough to get positive results in both studies. It proves that these parameters and positioning over the platform are correct and can lead to an increase in neuromuscular response of upper limb in both healthy and SCI individuals. These findings have clinical utility when they can be reproduced and used by professionals that treat SCI.

In our study, one single session WBV applied to the upper limb was able to increase the time of displacement and the average speed during wheelchair propulsion test in SCI. Cadence have not changed in this study. It means that SCI were able to increase speed and timed of displacement using the same cycles.

The vibration exposure to wheelchair users exceeds international standards when the vibration is applied directly to the wheelchair (31); due to this, vibration was applied right to the arms. Based on Ashnagar study (17), modified push up position over the platform stimulates upper extremity muscles.

The sample was small to achieve the same strict characteristics between individuals and get the most reliable results. Parameters and positioning were the same used in previous studies; it can explain the positive results. Considering the reduced mobility of the SCI, the adopted position over the platform was able, comfortable and safe. Wheelchair propulsion test is a valid, reliable and easily reproductive test to assess the upper extremity performance (27).

Our study agrees to the literature concluding that WBV, under the same parameters of this study, is effective increasing upper limb performance in SCI. It confirms that different parameters and methods can lead to despair results and that WBV is an efficient tool to treat the upper limbs of SCI.

5. Conclusions

One single session of WBV is able to improve the time of displacement and the average speed of the upper limb in SCI during wheelchair propulsion. Push frequency has not change significantly. WBV can be an additional tool during rehabilitation of upper limb in SCI.

References

1. Dellabiancia F, Porcellini G, Merolla G. Instruments and techniques for the analysis of wheelchair propulsion and upper extremity involvement in patients with spinal cord injuries: current concept review. Muscles Ligaments Tendons J. 2013; 3 (3): 150-6.
2. QI L, Wakeling J, Grange S. Effect of velocity on shoulder muscle recruitment patterns during wheelchair propulsion in nondisabled individuals: Pilot study. JRRD. 2012; 49 (10): 1527-36.
3. Requejo PS, Lee SE, Mulroy SJ, Haubert LL, Bontrager EL, Gronley JK, Perry J. Shoulder Muscular Demand During Lever-Activated Vs Pushrim Wheelchair Propulsion in Persons With Spinal Cord Injury. J Spinal Cord Med. 2008; 31 (5): 568-77.

4. Sisto SA, Dyson-Hudson T. Dynamometry testing in spinal cord injury. J Res Dev. 2007; 44 (1): 123-136.
5. Gutierrez DD, Mulroy SJ, Newsam CJ, Gronley JK, Perry J. Effect of fore-aft seat position on shoulder demands during wheelchair propulsion: part 2. An electromyographic analysis. J Spinal Cord Med. 2005; 28 (3): 222-9.
6. Mulroy SJ, Newsam CJ, Gutierres DD, Requejo P, Gronley JK, Haubert LL, Perry J. Effect of fore-aft seat position on shoulder demands during wheelchair propulsion: part 1. A kinetic analysis. J Spinal Cord Med. 2005; 28 (3): 214-21.
7. Hong H, Mayachela T, Abraham M, Moland1 J. Sullivan. Acute effects of whole body vibration on shoulder muscular strength and joint position sense. J Human Kinetics. 2010; 25: 17-25.
8. Bosveld R, Field-Fote EC. Single-dose effects of whole body vibration on quadriceps strength in individuals with motor-incomplete spinal cord injury. J Spinal Cor Med. 2015; 38 (6): 784-91.
9. Alizadeh-Meghrazi M, Masani K, Popovic MR, Craven BC. Whole-body vibration during passive standing in individuals with spinal cord injury: effects of plate choice, frequency, amplitude, and subject's posture on vibration propagation. PM R. 2012; 12: 963-75.
10. Nitin B. Jain, MD, MSPH, Laurence D. Higgins, MD, Jeffrey N. Katz, MD, MS, Eric Garshick, MD. Association of shoulder pain with the use of mobility devices in persons with chronic spinal cord injury. PM R. 2010; 2: 896-900.
11. Segal NA, Glass NA, Shakoor N, Wallace R. Vibration Platform Training in Women at Risk for Symptomatic Knee Osteoarthritis. PM R. 2013; 5: 201-209.
12. Hadi SC, Delparte JJ, Hitzig SL, Craven BC. Subjective experiences of men with and without spinal cord injury: tolerability of the juvent and WAVE whole body vibration plates. PM R. 2012; 4: 954-962.
13. Giombini A, Menotti F, Laudani L, Piccinini A, Fagnani F, Di Cagno A, Macaluso A, Pigozzi F. Effect of whole body vibration frequency on neuromuscular activity in ACL-deficient and healthy males. Biol. Sport. 2015; 32: 243-247.
14. Abercromby AF, Amonette WE, Layne CS, McFarlin BK, Hinman MR, Paloski WH. Vibration exposure and biodynamic responses during whole-body vibration training. Med Sci Sports Exerc. 2007; 39 (10): 1794-800.
15. Cardinale M, Bosco C. The use of vibration as an exercise intervention. Exerc Sport Sci Rev. 2003; 31 (1): 3-7.

16. Bosco C, Cardinale M, Tsarpela O: The influence of vibration on mechanical power and electromyogram activity in human arm flexor muscles. Europ J Appl Physiology 1999; 79: 306–311.
17. Ashnagar Z. Shadmehr A, Hadian M, Talebian S, Jalaei S. The effects of whole body vibration on EMG activity of the upper extremity muscles in static modified push up position. J Back Musculoskelet Rehabil 2016; Jan14 [Epub aead of printing].
18. Masani K, Alizadeh-Meghrazi M, Sayenko DG, Zariffa J, Moore C, Giangregorio L, Popovic ML Craven BC. Muscle activity, cross-sectional area, and density following passive standing and whole body vibration: A case series. J Spinal Cord Med. 2014; 37 (5): 575-81.
19. Amonette WE, Boyle M, Psarakis MB, Barker J, Dupler TL, Ott SD. Neurocognitive responses to a single session of static squats with whole body vibration. J Strength Cond Res. 2015; 29 (1): 96-100.
20. Di Giminiani R, Fabiani L, Baldini G, Cardelli G, Giovannelli A, Tihanyi J. Hormonal and neuromuscular responses to mechanical vibration applied to upper extremity muscles. PloS One. 2014; 9 (11): e111521.
21. Kordi Yoosefinejad A, Shadmehr A, Olyaei G, Talebian S, Bagheri H. The effectiveness of a single session of Whole-Body Vibration in improving the balance and the strength in type 2 diabetic patients with mild to moderate degree of peripheral neuropathy: a pilot study. J Bodyw Mov Ther. 2014; 18 (1): 82-6.
22. Boucher JA, Abboud J, Dubois JD, Legault E, Descarreaux M, Henchoz Y. Trunk neuromuscular responses to a single whole-body vibration session in patients with chronic low back pain: a cross-sectional study. J Manipulative Physiol Ther. 2013; 36 (9): 564-71.
23. Schlee G, Reckmann D, Milani TL. Whole body vibration training reduces plantar foot sensitivity but improves balance control of healthy subjects. Neurosci Lett. 2012; 506 (1): 7-3.
24. Erskine J, Smillie I, Leiper J, Ball D, Cardinale M. Neuromuscular and hormonal responses to a single session of whole body vibration exercise in healthy young men. Clin Physiol Funct Imaging. 2007; 27 (4): 242-8.
25. Gyulai G, Rácz I, Di giminiani I, Tihanyi J. Effect of whole body vibration applied on upper extremity muscles. Acta Phys Hung. 2013; 100 (1): 37-47.
26. Marín PJ, Herrero AJ, Milton JG, Hazell TJ, García-López D. Whole-body vibration applied during upper body exercise improves performance. J Strength Cond Res. 2013; 27 (7): 1807-12.

27. Askari S, Kirby RL, Parker K, Thompson K, O'Neill J. Wheelchair Propulsion Test: Development and measurement properties of a new test for manual wheelchair users. Arch Phys Med Rehabil. 2013; 94: 1690-8.
28. Cowan RE, Boninger NL, Sawatzky BJ, Mazoyer BD, Cooper RA. Preliminary outcomes of the smartwheel users' group database: A proposed framework for clinicians to objectively evaluate manual wheelchair propulsion. Arch Phys Med Rehabil. 2008; 89: 260-8.
29. Goosey-Tolfrey VL, Leicht CA. Field-Based Physiological Testing of Wheelchair Athletes. Sports Med. 2013; 43: 77–91.
30. Cochrane DJ, Hawke EJ. Effects of acute upper-body vibration on strength and power variables in climbers. J Strength Cond Res. 2007; 21 (2): 527-31.
31. Garcia-Mendez Y, Pearlman JL, Boninger ML, Cooper RA. Health risks of vibration exposure to wheelchair users in the community. J Spinal Cord Med. 2013; 36 (4): 365-75.