Andrzej Myśliwiec*, Michał Kuszewski, Edward Saulicz, Adam Posłuszny, Anna Jagiełło, Izabela Mikołajczyk, Ewelina Kozioł and Paweł Linek

# The influence of vibration on the quality of gait in women with cerebral palsy

**Abstract**: In contrast to a normal gait, the locomotion of people with infantile cerebral palsy (ICP) is characterized by great variability. An experiment was conducted to determine if the use of whole-body vibrations changes the time of support by each of the extremities as well as the range of flexion of the hip and knee articulations. Three women with ICP were involved in the whole-body vibration experiment. The parameters of the vibration adopted during training were a frequency of 20 Hz and an amplitude of 2 mm. The BTS Smart system for three-plane movement analysis paired with a desktop computer was used for the evaluation of gait parameters. The vibration procedure improved the range of flexion in knee articulation but did not change the range of flexion in hip articulation. The equalization of time disparities in the load of both extremities was obtained after the first treatment procedure. In this investigated group, the vibration procedure may be a complement to the rehabilitation process.

**Keywords:** cerebral palsy; gait pattern; whole-body vibration.

DOI 10.1515/ijdhd-2014-0020
Received August 1, 2014; accepted October 2, 2014; previously published online April 16, 2015

***Corresponding author: Andrzej Myśliwiec,** Department of Kinesiotherapy and Special Physiotherapy Methods, The Jerzy Kukuczka Academy of Physical Education in Katowice, Poland; and Department of Physiotherapy, College of Strategic Planning in Dąbrowa Górnicza, Poland, E-mail: a.mysliwiec@awf.katowice.pl
**Michał Kuszewski and Paweł Linek:** Department of Kinesiotherapy and Special Physiotherapy Methods, The Jerzy Kukuczka Academy of Physical Education in Katowice, Poland
**Edward Saulicz:** Department of Kinesiotherapy and Special Physiotherapy Methods, The Jerzy Kukuczka Academy of Physical Education in Katowice, Poland; and The Academy of Business in Dąbrowa Górnicza, Poland
**Adam Posłuszny:** The Joseph Tischner Special Schools Complex Number 10, Jastrzębie-Zdrój, Poland
**Anna Jagiełło, Izabela Mikołajczyk and Ewelina Kozioł:** Graduate Studies, Department of Kinesiotherapy and Special Physiotherapy Methods, The Jerzy Kukuczka Academy of Physical Education in Katowice, Poland

## Introduction

Infantile cerebral palsy (ICP) is the most frequently occurring clinical gait disorder in children. In contrast to a normal gait, the locomotion of people with cerebral palsy is characterized by great variability. A central nervous system control disorder, it is reflected in the articulo-musculo-skeletal structure. The functional disorder results from long-lasting spasticity and pathological motor performance. Skeletal muscle atrophy and progressive limitations in the articular range of motion occur with age. Additionally, frequently increasing muscle and articulation pain limit everyday activity, which affects the intensification of symptoms and causes social exclusion and the development of cardiopulmonary disease symptoms [1, 2]. For these reasons, an experiment was conducted to determine if the use of whole-body vibrations changes the time of support by each of the extremities as well as the range of flexion of the hip and knee articulations.

## Methods

Three women with ICP, ranging in age from 22 to 30 years, were involved in the experiment. The inclusion criteria were the following:

- female
- aged between 20 and 30 years
- spastic quadriplegia
- able to move independently without any type of orthopedic equipment
- intellectual capacity enabling complete control of the therapeutic situation

During the time of the experiment, the participants were asked not to use any other forms of rehabilitation to carry out typical everyday functions. The experiment was performed in accordance with the principles of the Declaration of Helsinki. The women were informed about the process of the research, presented with the exact methodology of the research and advised that they could resign from the experiment at any time and without stating a reason.

The participants' biometrical data is presented in Table 1. Training was performed on a Fitvibe Excel (Fitvibe Coach Software, Gymna, Bilzen, Belgium) vibration platform at the Centre of The Foundation of Rybnik Power Plant. A preliminary analysis of the parameters

**Table 1:** Research participants' biometrical data.

| Participant | Age, years | Height, cm | Weight, kg |
|---|---|---|---|
| A | 22 | 170 | 57 |
| B | 23 | 153 | 49 |
| C | 30 | 160 | 60 |
| Mean | 25 | 161 | 55.3 |

was implemented before the start of training to optimally adapt the participants to the therapy. All participants were asked about their perceptions, and the parameters from the lowest (frequency 20Hz; amplitude 2 mm) to the highest values were applied. All participants indicated that the lowest possible parameters possible on a given machine were the most optimal for them. The lowest parameters of the platform were adopted during training, i.e., a frequency of 20 Hz and an amplitude of 2 mm. Twelve treatment sessions were performed during 4 weeks in April 2012. The treatment procedures were carried out on Mondays, Wednesdays and Fridays. One session consisted of two 1-min vibration procedures with a 10-min break between them. During the break, the participants could rest in any way they chose.

The research was carried out based on a precisely adapted schedule. It included gait analysis, which was carried out in a movement analysis laboratory at the Academy of Physical Education in Katowice. Two teams performed the experiment. The first team dealt with the methodology and organization of the treatment procedures. This team was responsible for coordinating transport issues for the participants and performing the vibration treatment procedure according to the intended parameters. The second team was responsible for the organization and methodology of the measurements. After drawing up the schedule for the experiment and determining the research and treatment procedures, the two teams were not in contact with each other on the subject of the research.

### Instruments

The BTS Smart system for three-plane movement analysis paired with a desktop computer was used for the evaluation of gait parameters. The system included a central unit connected with BTS specialist software, six infrared cameras that were adjustable on three planes and a module recording the IR signal from the markers placed on the bodies of the subjects. The cameras were equipped with lamps sending infrared signals toward the markers, from which the reflected signals got to the central unit. The flat, two-dimensional image recorded by the cameras was adapted by the BTS program. The Davis full clinical protocol was used for data analysis [3].

The system was calibrated before every measurement by means of the BTS equipment. The area for the static and dynamic test was determined. The path for the gait test was set at 4.5 m length, 2 m width and 1.7 m height. A horizontal 0.5-m-wide line was set as the beginning. This line was also set as the place for the static test.

The cameras were placed in such a way that it was possible to get the most precise recording. The device was calibrated before every test. The anthropometric measurements, which were required to conduct Davis protocol, were taken before the recording. Sixteen spherical markers were carefully placed as required by the protocol. Two additional hemispherical markers were used for the static test. In the next step, the static test measurement was recorded for the three gait tests in the following phase.

The measurements connected with the gait analysis were taken four times – before and after the first vibration, after 2 weeks, which was after six vibration treatment procedures, and after 4 weeks, which was after 12 treatment procedures. Each of the analyses was carried out on a Tuesday afternoon, the day after the treatment procedure on the vibration platform.

### Measurement procedures

The test in the laboratory was performed four times according to the following schedule:
- Measurement I – before the first vibration treatment
- Measurement II – after the first vibration treatment
- Measurement II – after 6th vibration treatment
- Measurement IV – after 12th vibration treatment

The gait parameters subjected to analysis were the time spent supported on each of the extremities and the range of motion of the knee and coxal articulation. The obtained results were subjected to statistical analysis. A descriptive analysis of the obtained results was used due to the small number of participants.

## Results

The analysis of parameters connected with the time of load of a given lower extremity indicates a considerable asymmetry between the left and right extremity. The load of the left extremity lasted almost 10% longer. This parameter equalized considerably after the first treatment procedure. The subsequent procedures on the vibration platform affected the percentage value of the load of both extremities; this influence has not however been as significant as after the first treatment procedure. The detailed results are presented in Table 2.

**Table 2:** Percentage and time parameters relating to the lower extremities load during gait in the subsequent measurements.

| Subsequent measurements | Left extremity | | Right extremity | |
|---|---|---|---|---|
| | Mean value, % | Mean time, s | Mean value, % | Mean time, s |
| Measurement I | 66.7 | 1.67 | 75.17 | 1.86 |
| Measurement II | 70.25 | 1.76 | 73.75 | 1.78 |
| Measurement III | 70.57 | 1.45 | 73.6 | 1.48 |
| Measurement IV | 70.53 | 1.56 | 73.4 | 1.61 |

Next, the kinematic parameters connected with flexion of the knee and hip articulations were subjected to analysis.

The mobility of the articulations of both hips did not change considerably, although a significant increase in the flexion mobility of both hips was observed in the third measurement. However, the subsequent test on the vibration platform brought these values to the initial level. The results are included in Table 3.

The results of the range of motion tests in the articulations of both knees were considerably diverse between the left and right sides. A noticeable increase in the range of motion in the articulations of both knees was observed after the first treatment procedure on the vibration platform. It was also observed that the subsequent vibration procedures gradually minimized the difference between the range of motion of articulations on the left and right sides. The results are presented in detail in Table 4.

## Discussion

Gait disorders in people with ICP are the outcome of the functional symptoms resulting from central nervous system damage and the compensatory mechanisms formed in a long-lasting process of motor rehabilitation. The available rehabilitation methods concern mainly the childhood period when it is still possible to control the compensations. The number of ICP-specific therapeutic solutions decreases with age and so does the organism susceptibility to their corrective effect. It may be assumed that, apart from the continuation of treatment procedures from childhood, which are mainly based on neurodevelopmental methods, adapted activities such as hippotherapy or activities in water are sometimes included. The limitations resulting from age, caregivers' age and, very often, fatigue and weariness resulting from long-term rehabilitation procedures create a need for simple solutions that would be readily available and not take a long time to perform. For that reason, vibration as a procedure, performed by means of a machine, may be used at home and, if planned well, may improve or at least maintain functional capabilities. Haghbart first wrote about the possibility of a therapeutic effect in hemiplegics as a result of whole body vibration training [4, 5].

The issue of the influence of vibrations on adults with ICP was also raised by Ahlborg et al. [6]. They compared the effect of an 8-week course of resistance training therapy on decreasing muscle spasticity and improving motor functions and quadriceps femoris strength. Fourteen volunteers with spastic diplegia (aged 21–41) were randomized to specific groups. Seven patients performed 10–15 repetitions of resistance exercises for the lower extremities, and the remaining patients underwent 6-min-long vibration training with a frequency of 25–40 Hz three times a week. During the vibration, a slight bend of the knee and coxal articulation was adopted. Both groups presented with increased muscle strength without a negative effect on spasticity. Additionally, the quadriceps femoris increased, muscle tone reduced and motor performance improved in participants who were subjected to vibration therapy [6].

Literature analysis presents many applications for vibrations in obtaining therapeutic effects. An increase in lower extremity muscle strength and capacity, both in people who are not physically active and in athletes, is presented in the research carried out by Delecluse et al. [7] and Fagnani et al. [8]. There are also studies referring to a reduction of complaints in patients with osteoarthritis [9], brain strokes [10], Parkinson disease [11] and multiple sclerosis [12] as well as in geriatric patients [13–15] and postmenopausal women [16]. It is important that while analyzing the influence of vibration therapy on increases of these parameters, most of the researchers have focused on the articulation of the knee.

Delecluse showed an increase in quadricep femoris dynamic strength or over 9.0% (±3.2%) after a 12-week-long training course with a frequency of 35–40 Hz [7]. The mechanism for the influence of vibrations on spasticity reduction is probably underlain by an increase in muscle bioelectrical activity [17]. The disorder in the muscle

**Table 3:** Range of flexion of the hip articulations measured in the subsequent tests in the sagittal axis.

| Subsequent measurements | Flexion of the left hip articulation [°] | Flexion of the right hip articulation [°] |
|---|---:|---:|
| Measurement I | 18.1 | 15.7 |
| Measurement II | 18.9 | 13.4 |
| Measurement III | 21.3 | 20 |
| Measurement IV | 19.2 | 16 |

**Table 4:** Range of flexion of the articulations of knees measured in the subsequent tests in the sagittal axis.

| Subsequent measurements | Flexion of the left knee [°] | Flexion of the right knee [°] |
|---|---:|---:|
| Measurement I | 25.8 | 17.77 |
| Measurement II | 27.35 | 21.55 |
| Measurement III | 27.87 | 23.83 |
| Measurement IV | 27.33 | 23.47 |

activity control, caused by damage to the central nervous system, is intensified by the vibrations' influence.

Among other things, it has been hypothesized that vibrations of low frequency and low amplitude are very subtle mechanical micro-impulses received by skin receptors that affect change in nerve impulses (code) from the muscles. In this way, the neural control is reinforced [18].

The influence of vibrations on the damaged central nervous system was also analyzed by Tihanyi et al. [10]. They conducted a vibration procedure with a frequency of 20 Hz in eight patients after brain strokes, obtaining an increase in isometric and eccentric strength in extension of the articulation of the knee by 36.6% and 22.2%, respectively.

Seeking optimal vibration parameters refers to the frequency, amplitude and duration of the treatment procedure. Amplitude is rarely stated in the methodology of the performed procedures. It is assumed that it is at the level of 2–5 mm. In the case of frequency, many authors point out that a lower frequency, at the level of 20–30 Hz, produces better results [15, 19, 20]. It has also been suggested that the duration of the procedure should be between 1 and 2 min [19, 20].

The results obtained through this research cannot be considered to refer to the population in general due to the small number of participants. It was decided to introduce very restrictive inclusion criteria to obtain as much information as possible about the effects of the proposed procedure and to have full control over the quality of the conducted research. The results seem to support a finding that the treatment procedure does produce good effects. It may be said that a device that produces vibrations in the frequency of 20 Hz and that a patient with CP could be equipped with may be an easy-to-use and economical element of everyday therapy.

## Conclusions

1. The vibration procedure influenced an improvement in the range of flexion in knee articulation.
2. The vibration procedure did not change the range of flexion in hip articulation.
3. Equalization of the time disparities in the load of both extremities was obtained after the first treatment procedure.
4. In the case of this group of women, the vibration procedure may be complementary to the rehabilitation process.

**Acknowledgments:** Many thanks to Dariusz Kluger, Head of the Rehabilitation Center, for the help.

**Author contributions:** The authors have accepted responsibility for the entire content of this submitted manuscript and approved submission.
**Financial support:** None declared.
**Employment or leadership:** None declared.
**Honorarium:** None declared.
**Competing interests:** The funding organization(s) played no role in the study design; in the collection, analysis, and interpretation of data; in the writing of the report; or in the decision to submit the report for publication.

## References

1. Andersson C, Mattsson E. Adults with cerebral palsy: a survey describing problems, needs, and resources, with special emphasis on locomotion. Dev Med Child Neurol 2001;43:76–82.
2. Van der Dussen L, Nieuwstraten W, Roebroeck M, Stam HJ. Functional level of young adults with cerebral palsy. Clin Rehabil 2001;15:84–91.
3. Davis RB, Ounpuu S, Tyburski D, Gage JR. A gait analysis data collection and reduction technique. Hum Mov Sci 1991;10:575–87.
4. Haghbarth KE. Normal variability of tonic vibration reflexes in man. Exp Neurol 1996;16:80–92.
5. Haghbarth KE. The effect of muscle vibration in normal man and in patients with motor disorders. New Devel Electromyogr Clin Neurophysiol 1973;3:428–43.
6. Ahlborg L, Andersson CH, Per J. Whole-body vibration training compared with resistance training: effect on spasticity, muscle strength and motor performance in adults with cerebral palsy. J Rehabil Med 2006;38:302–8.
7. Delecluse C, Roelants M, Verschueren S. Strength increase after whole-body vibration compared with resistance training. Med Sci Sports Exerc 2003;35:1033–41.
8. Fagnani F, Giombini A, Pigozzi F. The effects of a whole-body vibration program on muscle performance and flexibility in female athletes. Am J Phys Med Rehabil 2006;85:956–62.
9. Trans T, Aaboe J, Henriksen M, Christensen R, Bliddal H, Lund H. Effect of whole body vibration exercise on muscle strength and proprioception in females with knee osteoarthritis. Knee 2009;16:256–61.
10. Tihanyi TK, Horvath M, Fazekas G, Hortobagyi T, Tihanyi J. One session of whole body vibration increases voluntary muscle strength transiently in patients with stroke. Clin Rehabil 2007;21:782–93.
11. Lau RW, Teo T, Yu F, Chung MC, Pang MY. Effects of whole-body vibration on sensorimotor performance in people with Parkinson disease: a systematic review. Phys Ther 2011;91:198–209.
12. Schuhfried O, Mittermaier Ch, Jovanoviv T, Pieber K, Paternostro-Sluga T. Effects of whole-body vibration in patients with multiple sclerosis: a pilot study. Clin Rehabil 2005;19:834–42.
13. Runge M, Rehfeld G, Resnicek E. Balance training and exercise in geriatric patients. J Musculoskelet Neuronal Interact 2000;1:54–8.

14. Roelants M, Delecluse C, Verschueren SM. Whole-body-vibration training increases knee-extension strength and speed of movement in older women. J Am Geriatric Soc 2004;52:901–8.
15. Bruyere O, Wuidart M, Di Palma E. Controlled whole body vibration to decrease fall risk and improve health-related quality of life of nursing home residents. Arch Phys Med Rehabil 2005;86:303–7.
16. Verschueren S, Roelants M, Delecluse C, Swinnen S, Vanderschueren D, Boonen S. Effect of 6-month whole body vibration training on hip density, muscle strength and postural control in postmenopausal women: a randomized controlled pilot study. J Bone Miner Res 2004;19:352–9.
17. Cardinale M, Lim J. Electromyography activity of vastuslateralis muscle during whole-body vibrations of different frequencies. J Strength Cond Res 2003;17:621–24.
18. Fillipi GM, Camerota F, Saraceni VM. Mechanical vibration and motor rehabilitation. A new opportunity. Sci Riabilitaz 2007;8:55–61.
19. Torvinen S, Kannus P, Sievanen H, Järvinen-Tero AH, Pasanen M, Kontulainen S. Effect of a vibration exposure on muscular performance and body balance. Randomized cross-over study. Clin Physiol FunctImaging 2002;22:145–52.
20. Melnyk M, Kofler B, Faist M, Hodapp M, Gollhofer A. Effect of a whole-body vibration session on knee stability. J Sports Med 2008;29:839–44.