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Effects of Vibration Training on Stride Length and Gait Speed in Cerebral Palsy Patients: A Systematic Review

Mr Aiden E. Cook[1*], Dr Jeremy A. Moody[1], Rhiannon A. Owens[2], Dr Joseph I. Esformes[1]

[1]*School of Sport and Health Sciences, Cardiff Metropolitan University, Cyncoed Campus, Cyncoed Road, Cardiff, Wales, UK, CF23 6XD*

[2]*SDR Rehabilitation UK Ltd., Celtic Manor Resort, Newport, Wales, UK, NP18 1HQ*

Corresponding Author: Mr Aiden E. Cook,** *School of Sport and Health Sciences, Cardiff Metropolitan University, Cyncoed Campus, Cyncoed Road, Cardiff, Wales, UK.* ***E-mail: *st20102009@cardiffmet.ac.uk*

Abstract: *The current systematic review examined the acute effects of whole-body vibration (WBV) for minimising the effects of CP on gait speed and stride length. Most studies and medical interventions use physiotherapy or low load strength training. Studies that have used vibration as an intervention for CP were collated, and a total of nine journal articles met the inclusion criteria. There were several differences found in vibration intervention protocols. On average, studies adopted sessions that were nine minutes in length, using 12-18 Hz and an amplitude of two to six millimetres. Using these acute training variables can improve adaptations for gait speed and stride length by 21.11% and 15.43%, respectively. Further, analysis has shown that although acute changes can occur, these may also be impacted by chronic adaptions. Vibration training can positively impact CP primarily through neurological adaptations, but further research is required to examine the effectiveness of different methods of vibration training on CP.*

Keywords: *Cerebral palsy, Gait speed, Intervention, Stride length, Whole body vibration*

Abbreviations*(In order of appearance in text):* *Cerebral Palsy (CP), Kilograms (kg), Magnetic Resonance Imaging (MRI), Selective Dorsal Rhizotomy (SDR), Hertz (Hz), Standard Deviation (SD), Sample Size (n), Meters Per Second (m/s), Meters (m), Whole Body Vibration (WBV), Minutes (min), Millimetres (mm)*

1. Introduction

Cerebral palsy (CP) occurs due to trauma to the brain before the completion of cerebral development [1-2], which affects the individual's neurological system and creates a unique set of challenges. Predominantly most cases of CP are developed during the prenatal period. However, the condition can also occur during the perinatal or postnatal period of development [3]. Most common causes of CP involve weighing <2.5 kg at birth, asphyxia, born less than 32 weeks after gestation, brain haemorrhage, bacterial meningitis, child abuse, falls, or vehicle collisions [1-2, 5-6].

Medical professionals are often referred for diagnosing individuals with CP due to abnormal muscle tone or slower motor development. In clinical settings, CP can be tested using several methods, and the testing strategy can be decided based on family history and the pattern of symptoms. The most common diagnostic tools are magnetic resonance imaging (MRI) and ultrasound, but tests measuring hearing and vision ability, visual surveillance of seizures and cognitive dysfunction can also be adopted to assess physical and sensory symptoms [6].

Approximately 80% of people with CP will most commonly demonstrate symptoms of walking on their toes (scissor gait), muscle weakness, muscular hypertonicity, tremors, and increased deep tendon reflexes [1, 7].

Some individuals show symptoms that are less apparent, such as balance and coordination impairment, loss of sight and hearing, and abnormal perceptions of pain or touch. However, these, lesser common indicators, are only evident in fewer than 10% of people clinically diagnosed with CP [8]. Several treatments have been used to lessen the severity of CP, including medication, surgical intervention, physical therapy, and external aids. Treatments can alleviate the symptoms, but no intervention method can eliminate the signs and symptoms of CP.

Selective Dorsal Rhizotomy (SDR), the primary surgical procedure used for CP patients, aims to improve lower limb movement and functionality, ultimately reducing the effects of

CP [9-10]. The surgical procedure divides the motor and sensory nerves in the spinal cord into three-to-five separate pathways [11]. The predominant outcome is an increased function of the gross motor pathways, which improves the conductivity, excitability and extensibility of skeletal muscles in the lower limbs [12-13].

More than one medical treatment is often used concurrently. For example, Fowler *et al*. [14] found that completing a ten-week strength training programme in conjunction with medication is more effective than conducting either of these treatment protocols independently. The most common form of treatment for individuals with CP is physical therapy, which stimulates neuromuscular development by combining movements that affect the stretch reflex (e.g. jumping activities) and resistance exercise for tissue overload.

Vibration training is a well-accepted training and therapy method used for improving health and performance. Whole-body vibration (WBV) exposes the user to multiple ground reaction forces that create instability around a joint, which the body must react to [15]. Whole-body vibration plates involve standing on an oscillating platform. As shown in figure 1, WBV vibration plates work by oscillating on the y-axis and x-axis, with the magnitude of the vibration labelled as amplitude and the displacement measured in millimetres. An additional unit of quantifying the intensity of the vibration is hertz (Hz), which is the number of vibrations occurring per second. Using various combinations of both amplitude and Hz adjusts the intensity of the vibration. Additionally, the time spent on the platform can also impact the exercise intensity.

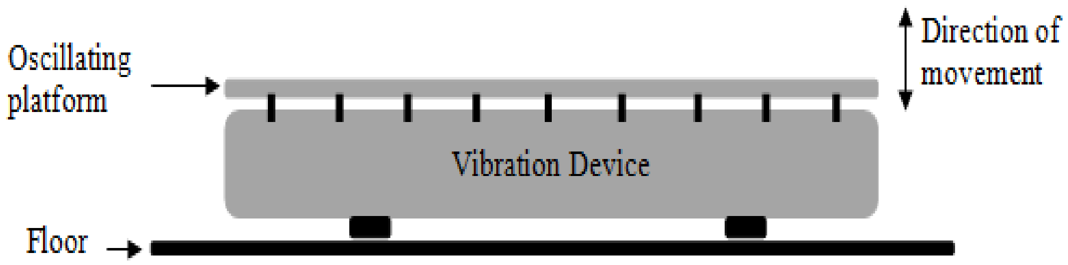

Figure1. *Illustration of a vibration platform used for whole body vibration*

Vibration can elicit several acute and chronic adaptations that may promote muscular and neural conditioning. The repeated vertical ground reaction forces evoke repeated eccentric and concentric contractions that increase the metabolic rate within the tissue [16]. Furthermore, vibration training is effective for chronic improvements in body composition [17], muscular strength [17-18] and bone density [19]. Conversely, the acute and chronic effects of WBV training and its effects on flexibility, muscle strength and power are less clear. Most studies assessing acute adaptations aim to measure muscle temperature, blood flow to the working muscles and excitation of the stretch receptors within the muscle [20].

The goal of this systematic review was to identify vibration training variables for improving gait speed and stride length in CP patients. The aim of this study is to examine the impact of vibration frequency and amplitude on stride length and gait speed.

2. Methods

2.1. Selection Criteria

Studies that used vibration as an intervention method with CP participants were included in the initial search. Additionally, studies needed to have a minimum of ten participants to be included to ensure the populations were ecologically valid and fairly represented the target population (refer to figure 2). Using a plethora of journals for sourcing the relevant literature helped with ensuring the studies met all the criteria and confirmed the research was current, therefore meaning it was less likely to be impacted by any historical validity issues. Screening of the studies for the inclusion criteria was completed by a single researcher, to minimise inter-rater reliability and to make the process of eliminating studies more efficient. However, this may have impacted intra-rater reliability.

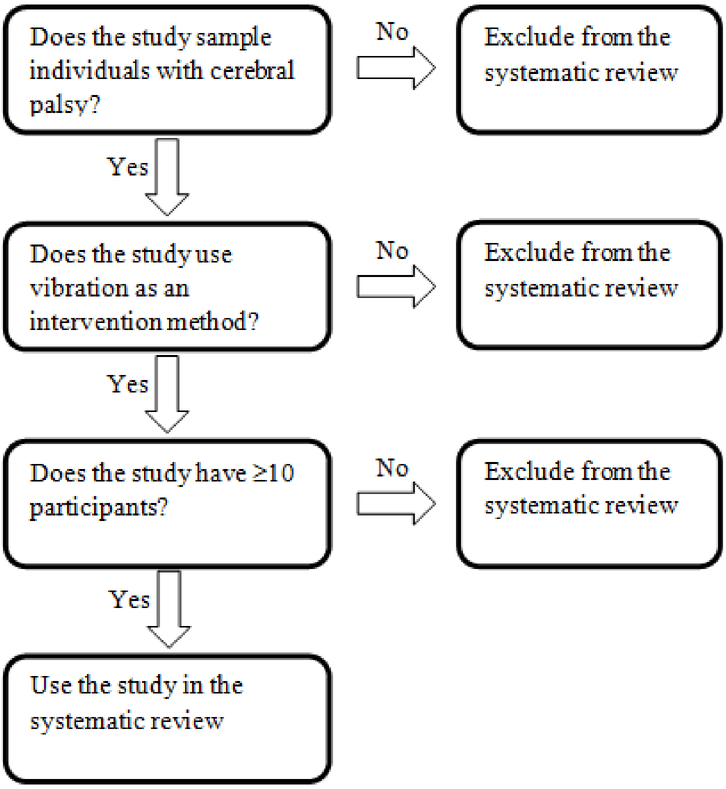

Figure 2. *Flow diagram representing how the studies were screened for inclusion*

Nine studies met the inclusion criteria out of an initial 21 (Tables 1a and 1b). The mean (±SD) values for the number of participants per study was 37 (±21). The most extended intervention was 12-months, with participants completing the protocols seven days per week, whereas the shortest was one month for five days per week. The vibration protocols ranged in duration from 1-20 min and used frequencies between 5-40 Hz and an amplitude ranging for1-9 mm.

Table 1a. *List of included studies, sample sizes, intervention protocols and findings*

Study	Sample (n)	Intervention method	Findings (mean (±SD))
1 – Ruck, Chabot and Raunch [21]	20	6-month intervention, 5 days per week Group 1 (n=10) – normal physiotherapy program Group 2 (n=10) – side-alternating WBV for 540 seconds (9 mins) at 12-18 Hz – 2-6 mm amps, and normal physiotherapy program	Gait speed (m/s) 0.50 (0.09) Stride length (m) 0.53 (0.13)
2 – Lee and Chon [22]	30	2-month intervention, 3 days per week Group 1 (n=15) – conventional physical therapy training Group 2 (n=15) – stand to squat WBV technique for 540 seconds (9 mins) at 5-25 Hz – 1-9 mm amps, and conventional physical therapy training	Gait speed (m/s) 0.48 (0.06) Stride length (m) 0.48 (0.18)
3 – Wren *et al.* [23]	31	12-month intervention, 7 days per week All participants completed both parts of the study 6 months –WBV for 600 seconds (10 mins) at 30 Hz – 6 mm amps 6 months – Assisted standing for 600 seconds (10 mins)	Gait speed (m/s) 0.46 (0.10) Stride length (m) 0.39 (0.11)

4 – El-Shamy [24]	30	3-month intervention, 5 days per week Group 1 (n=15) – traditional physical therapy Group 2 (n=15) – standing WBV for 540 seconds (9 mins) at 12-18 Hz – 2-6mm amps, and traditional physical therapy	Gait speed (m/s) 0.42 (0.09) Stride length (m) 0.54 (0.20)
5 – Katusic, Alimovic and Mejaski-Bosnjak [25]	89	3-month intervention, 2 days per week Group 1 (n=45) – physiotherapy treatment Group 2 (n=44) – sound wave vibration for 1200 seconds (20 mins) at 40 Hz – no given amplitude, and physiotherapy treatment	Gait speed (m/s) 0.28 (0.07) Stride length (m) 0.48 (0.14)

Table 1b. *List of included studies, sample sizes, intervention protocols and findings*

Study	Sample (n)	Intervention method	Findings (mean (±SD))
6 – Ibrahim, Eid and Moawd [26]	30	3-month intervention, 3 days per week Group 1 (n=15) – control group with no intervention Group 2 (n=15) – side-alternating WBV for 540 seconds (9 mins) at 12-18 Hz – 2-6 mm amps	Gait speed (m/s) 0.23 (0.03) Stride length (m) 0.51 (0.16)
7 – Gusso *et al*. [27]	40	5-month intervention, 4 days per week WBV for 540 seconds (9 mins) at 20 Hz – 6 mm amps	Gait speed (m/s) 0.40 (0.05) Stride length (m) 0.34 (0.11)
8 – Krause *et al*. [28]	44	9-month intervention, 2 days per week WBV for 60 seconds (1 min) at 16-25 Hz – 1.5-3 mm amps	Gait speed (m/s) 0.37 (0.06) Stride length (m) 0.41 (0.09)
9 – Dudoniene, Lendraitiene and Pozeriene [29]	20	1-month intervention, 5 days per week WBV for 600 seconds (10 mins) at 15 Hz – 2-6 mm amps	Gait speed (m/s) 0.41 (0.08) Stride length (m) 0.43 (0.12)

Abbreviations: *WBV – whole body vibration; Mins – minutes; Hz – hertz, vibrations per second; Amps – amplitude, magnitude of the vibration; m/s – meters per second; m – meters; SD – standard deviation; n – sample size*

2.2. Data Analysis

After completing the screening, data were extracted and inputted into a Microsoft Excel spreadsheet (Microsoft Excel, Microsoft Corporation, Redmond, WA) for further analysis. Variables were listed and extracted from each relevant study and were standardised into the same unit of measurement to allow for easier comparison between the data. Additionally, all results were entered as they were initially reported.

Following data extraction and filtering, the data were sorted into a table format that enabled for mean and standard deviations to be calculated efficiently. Furthermore, to allow data comparisons, the percentage difference between each result and the mean of all the results was computed.

3. Results

Participants

Stride Length

The mean (±SD) for stride length across all studies was 0.46 (±0.14) m. The least effective vibration training protocol was found in study seven, where the finding was 34.31% lower than the group mean. In contrast, the findings by El-Shamy [24] displayed the most significant improvement in stride length [0.54 (±0.20) m]. However, this change was only 1.59% greater than the outcome by Ruck, Chabot and Raunch [21]. When considering standard deviations, the two studies have a cross-over point within the findings.

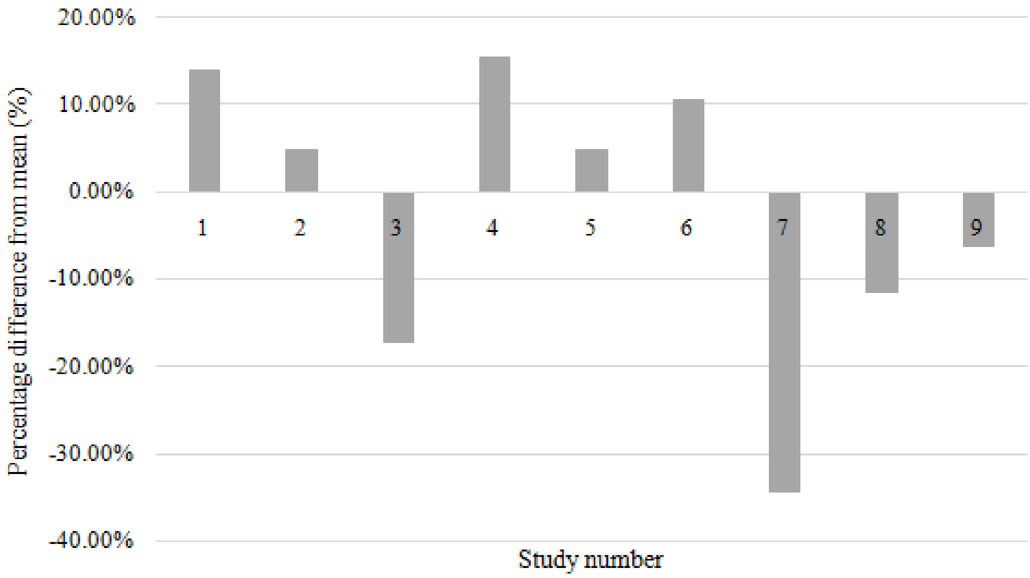

Figure3. *Bar chart displaying the percentage difference in stride length in comparison to the mean*

Gait Speed

Mean (±SD) scores for gait speed were 0.39 (0.07) $m.s^{-1}$, with six out of the studies showing a better outcome. Ruck et al. [21] exhibited the most significant percentage change [0.50 (±0.09) $m.s^{-1}$]. There is some overlap in these results when considering the deviation of the result from the mean. Therefore, some individuals within studies two [22] and three [23] may have achieved scores similar to study one [21].

Study one [21] displays the most significant improvement when combining the percentage increase in stride length and gait speed. Additionally, the use of the vibration intervention protocol in study six [26] appears the least effective when combining the scores.

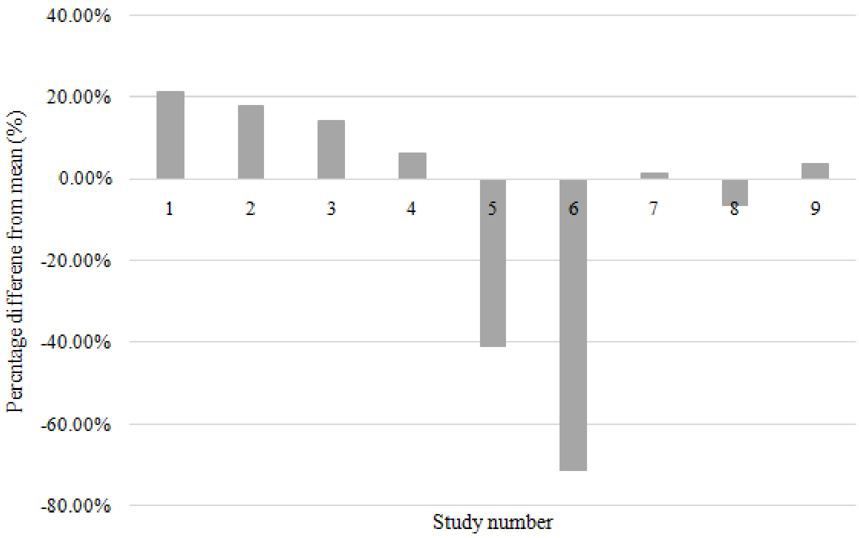

Figure4. *Bar chart displaying the percentage difference in gait speed in comparison to the mean*

4. Discussion

The studies examined in the current systematic review show that the use of WBV can acutely enhance stride length and gait speed in CP patients. However, further research is required to compare WBV to different treatments and to examine the concurrent use of vibration training with other methods. Studies one [21], two [22] and four [24] achieved better outcomes than the group average for both stride length and gate speed. Additionally, studies one and four [21, 24] used WBV at 12-18 Hz, with an amplitude of 2-6mm. Both studies applied the vibration stimulus for 540 s (9 min) and combined the vibration intervention with physiotherapy.

It is hard to determine whether these responses solely reflect acute responses to WBV. Several studies have found that WBV training can positively impact muscular strength when training programmes last up to 24 weeks [17, 19, 30]. Conversely De Ruiter *et al*. [31] confirmed results that oppose this statement, making it difficult to confirm whether the adaptations are acute or chronic. Most studies indicate that the most pronounced WBV changes occur when the participant is standing or squatting on the platform, allowing the pre-contraction of muscles via the transmission of vibrations through the feet [32-33]. Therefore, it may not be as beneficial for individuals who are unable to fully bear weight on the platform due to lower leg immobility or trauma [34]. Therefore, these individuals may consider alternative methods of vibration training, such as localised/targeted vibration, which requires less contribution from the participant because the device can be applied to the tendon or muscle while the person is either laying down or seated [35]. However, localised vibration can cause physiological side-effects such as reflexive tonic vibration that may alter the results of the experimental condition.

The excitation of the spinal cord can explain the acute effects revealed in the current systematic review.WBV training can elicit neurological adaptations by primary motor nerve enhancement and the excitation of the reflex in the spinal cord [36]. According to Lapole and Pérot [37], the involuntary contractions that occur during vibration training increase proprioceptive excitatory inputs to the feedback loop, which results in an increased neural drive. Moreover, vibration training has been found to improve the reflex action of muscle fibres in the lower limbs, especially following electrical stimulation of the sensory fibres [38]. Central nervous system adaptations, such as the amplitude of electric waves, can aid reflexive stabilisation that improves inter- and intra-muscular coordination. However, even though the effects are evident immediately after being exposed to a vibration stimulus, the responses peak after being consecutively trained for ≥14 days [38].

Vibration training can also stimulate the stretch-shortening cycle, positively impacting the activation and potentiation of the muscle. This effect is due to the constant lengthening and shortening of the muscles during vibration training. Therefore, vibration acts as a micro-ground reaction force that further desensitises the Golgi tendon organ [39]. This response helps familiarise the muscle spindle to changes in length and rate of change of the muscle [39]. Finally, vibrations cause movement within the muscle that increase blood flow and circulation, enhancing muscle temperature and hydration therefore improving the contractility, extensibility and elasticity of soft tissues.

5. Conclusions

Based on the outcomes of this systematic review, vibration training can enhance stride length and gait speed in individuals with CP. We recommend using nine minutes of either standing or side-alternating WBV at an amplitude of 2-6mm and a frequency of 12-18 Hz. Although the results of the current systematic review are promising and support the use of WBV as an intervention method to elicit beneficial acute adaptations, it is crucial to examine the use of targeted/localised vibration training for those individual with restricted lower limb mobility or unable to bear their weight. Finally, further research should be conducted comparing the two methods to confirm the neural and muscular adaptations in CP patients, with further considerations taken for assessing measurements of functional movement and muscle performance.

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