

Whole body vibration and cerebral palsy: a systematic review

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Purpose: The goal of this review is to evaluate the effects of whole body vibration on outcomes in patients with cerebral palsy. The findings in this review may help clinicians make evidence informed decisions on the use of whole body vibration for cerebral palsy.

Methods: A systematic search was conducted on April 29, 2014. The following search terms were used to search of several databases: (whole body vibration OR whole-body vibration OR whole body-vibration OR WBV) AND (cerebral palsy). Articles that met the inclusion criteria were assessed using the Scottish intercollegiate guidelines network (SIGN) rating system to assess the methodology and bias of the articles for randomized control trials.

Results: The search produced 25 articles, of which 12 duplicates were identified and removed. Another seven articles were not considered since they did not fit the inclusion criteria, leaving a total of five studies for

Objectif : L'objectif de cette étude est d'évaluer les effets de la vibration du corps entier sur les résultats chez les patients atteints de paralysie cérébrale. Les conclusions de cette étude peuvent aider les cliniciens à prendre des décisions éclairées par des données probantes sur le recours à des vibrations du corps entier pour la paralysie cérébrale.

Méthodologie : Une recherche systématique a été effectuée le 29 avril 2014. Les termes de recherche suivants ont été utilisés pour la recherche de plusieurs bases de données : (whole body vibration OR whole-body vibration OR whole body-vibration OR WBV) AND (cerebral palsy) [(vibration du corps entier) ET (paralysie cérébrale)]. Les articles qui répondaient aux critères d'inclusion ont été évalués à l'aide du système de notation SIGN (Scottish intercollegiate guidelines network) pour évaluer la méthodologie et la partialité des articles pour des essais cliniques randomisés.

Résultats : La recherche a permis de recenser 25 articles, dont 12 qui étaient doubles ont été éliminés. Sept autres articles n'ont pas été retenus, car ils ne répondaient pas aux critères d'inclusion, laissant au

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review. Four of the articles analyzed the effects of WBV in children while the other study focused on adults with cerebral palsy. There was one low quality article, four acceptable quality articles and one high quality article when assessed using the SIGN criteria.

Conclusions: *It appears that whole body vibration has the potential to provide symptomatic relief for patients with cerebral palsy. Whole body vibration may improve spasticity, muscle strength and coordination. There is a lack of research to conclusively determine whether it does alter bone mineral density.*

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KEY WORDS: cerebral palsy, whole body vibration, chiropractic

Introduction

Dynamic mechanical loading of the skeleton is an arduous task and troublesome to induce in children who suffer from severe cerebral palsy (CP). Most of this difficulty results from the fact that these children are unable to achieve and maintain an upright position. The lack of dynamic weight bearing in this population predisposes them to reduced bone mineral density (BMD) and pre-mature osteoporosis.¹⁻³ These children are also more prone to muscle weakness, which contributes to pain, deformity and functional loss.^{4,5}

Cerebral palsy is a disease that has a prevalence of two cases per 1,000 live born neonates.⁶ The first signs tend to appear around 19 months however mild cases can present as late as five years old.⁷ The symptoms can include motor problems, cognitive impairment or seizures.⁷ CP can be grouped based on the motor effects it has on the individual, these can include pyramidal/spastic CP or extrapyramidal/non-spastic CP.^{7,8} Pyramidal or spastic CP is the most common type and is associated with tight or contracted muscles.^{6,8} These motor changes are caused by damage to the brain tissue, which can result from various possible mechanisms.⁷

total cinq articles pour l'étude. Quatre des articles analysaient les effets de la vibration du corps entier chez les enfants tandis que l'autre étude portait sur des adultes atteints de paralysie cérébrale. L'évaluation de la qualité des articles selon les critères SIGN a révélé un article de qualité médiocre, quatre articles de qualité acceptable et un article de bonne qualité.

Conclusions : *Il semble que le traitement par vibrations du corps entier a le potentiel de fournir un soulagement symptomatique chez les patients atteints de paralysie cérébrale. La vibration du corps entier peut améliorer la spasticité, la force musculaire et la coordination. Les recherches ne sont pas suffisantes pour permettre de déterminer de façon concluante si elle modifie la densité minérale osseuse.*

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MOTS CLÉS : paralysie cérébrale, vibration du corps entier, chiropratique

Recently, whole body vibration (WBV) has become more popular in a rehabilitation setting. There are three components to vibration: frequency, amplitude and direction. Frequency is the number of complete cycles per second measured in Hertz (Hz). Amplitude is the amount of displacement measured in mm. WBV plates vibrate in one of two directions; either a vertical displacement or a side-to-side alternating vertical sinusoidal vibration. The vertical vibration creates a uniform amplitude throughout the vibration plate, whereas the sinusoidal vibration creates increased amplitude the further from the pivoting fulcrum at the centre of the vibration plate. Typical vibration sessions consists of the user standing on the platform statically, or while performing dynamic movements for a fixed duration of time.⁹ Intensity is controlled through the frequency and amplitude components.⁹

Although vibration therapy has gained such popularity, exact action of the therapy is yet to be determined.¹⁰ Many authors hypothesize that muscle spindles and alpha motor neurons are stimulated by the vibrations, which initiates a muscle contraction.¹¹ Short-term effects of vibration therapy include increased oxygen consumption, muscle temperature, skin blood flow, muscle power, and circulat-

ing levels of insulin.¹²⁻¹⁴ It has been suggested that activation of the musculoskeletal (MSK) system via WBV appears to be a promising approach to increase BMD and to improve gross motor function in patients with CP.^{15,16} Locally administered vibration has been used to decrease spasticity in children with CP.^{17,18}

In a recent study, WBV has been utilized to assist in strength training in the legs.¹⁹ Several studies have shown the influence of muscle strength on improved walking ability in children with CP.^{20,21} Activation of the musculoskeletal system seems to be a promising approach to increase BMD, muscle volume, strength, walking ability and improve gross motor function in these children.^{4,15} Similar results have been reported following strength training or exercise training interventions.^{22,23}

The purpose of this review is to evaluate the effects of whole body vibration on outcomes in patients with cerebral palsy. The findings in this review may help clinicians make evidence informed decisions on the use of whole body vibration for cerebral palsy.²⁴

Methods

Studies were identified by searching the following electronic databases: CINAHL (Cumulative Index to Nursing and Allied Health Literature), AMED (The Allied and Complementary Medicine Database), MEDLINE, SPORTDiscus, and Rehabilitation and Sports Medicine Source. The results were limited to studies published in 2002 to April 2014.

A systematic search was conducted on April 29, 2014. The following search terms were used: (whole body vibration OR whole-body vibration OR whole body-vibration OR WBV) AND (cerebral palsy). The articles were then selected based on the following inclusion criteria: 1) Randomized controlled trial; 2) Human participants with CP; 3) Intervention specifically described as whole body vibration; 4) Written in English; 5) Published in a peer-review journal; 6) Outcome measures include increasing muscle strength, motor function, balance, postural control, ambulation, mobility and bone mineral density.

Two reviewers independently reviewed the results to identify any articles that fit the inclusion criteria. If disagreement between the two reviewers occurred, a third independent reviewer would have the final decision to determine if the article met the inclusion criteria. The selected articles were then assessed with the Scottish

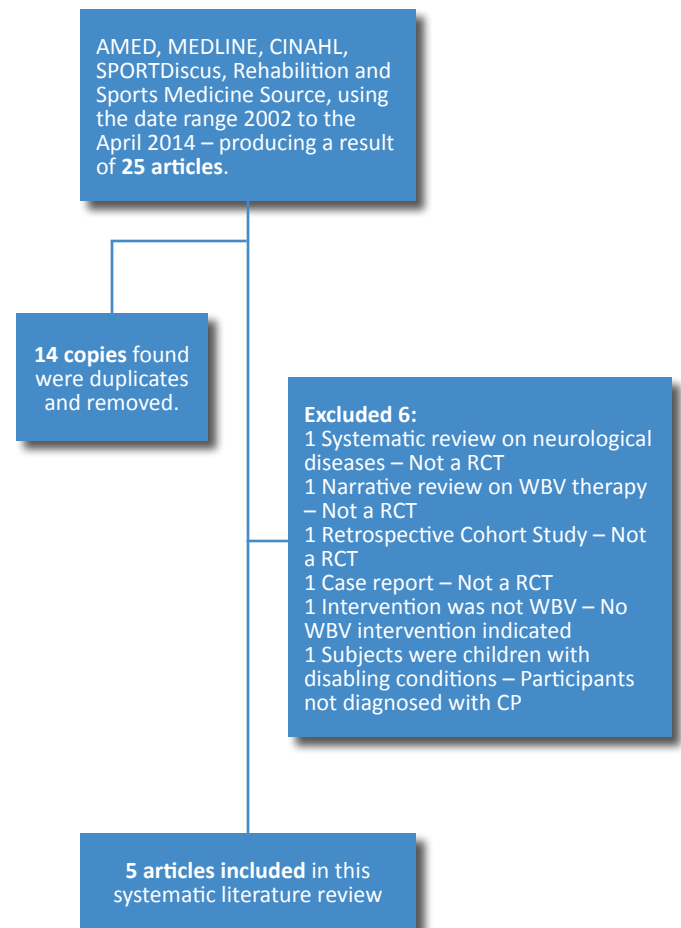


Figure 1.
Flowchart of article selection

intercollegiate guidelines network (SIGN) rating system to assess the methodology and bias of the articles for randomized control trials.²⁵ The articles were assessed by two reviewers with a third reviewer available to settle any discrepancies. Finally the data was extracted and placed into Table 1.

Results

The search came up with a total of 25 articles. There were a total of 14 duplicates that were removed (see Figure 1). Another six articles were removed as they did not fit the inclusion criteria, leaving a total of five study studies.

Table 1.
Summary of reviewed articles

Author, year of index publication	Participants	Intervention	Control	Outcome Measures	Results
Lee, 2012	30 participants with either spastic diplegia or quadriplegia CP – Mean age 10.0 – 15 male and 15 female	Conventional PT training + WBV – WBV one hour per day, three days per week – 5 to 25 Hz and the amplitude ranged from 1 to 9 mm – Protocol 10 min Warm-up (1) 3 min of 5–8 Hz (2) 3 min of 10–15 Hz (3) 3 min of 15–20 Hz (4) 3 min of 20–25 Hz (5) 3 min of 15–20 Hz (6) 3 min of 10–15 Hz. 10 min cool-down – Side-to-side alternating vertical sinusoidal vibration	Conventional PT training consisting of gentle massage, muscle stretching, and balance training for 30 minutes	1: Three-dimensional gait analyses 2: Ultrasonographic imaging of the leg muscles	– significant improvements in gait speed ($p < 0.05$) stride length ($p < 0.05$) cycle time ($p < 0.05$) – significant improvement in ankle angle ($p < 0.05$) No significance in the hip angle ($p = 0.321$) and knee angle ($p = 0.102$) – significant increase in muscle thicknesses of the tibialis anterior ($p < 0.05$) and soleus ($p < 0.05$) – No significant change gastrocnemius thickness muscle ($p = 0.645$)
Ahlborg, 2006	14 people with spastic diplegia – 8 male and 6 female – 21–41 years	– WBV group exercised 3 times weekly during 8 weeks. – Protocol: 5 minutes warm-up 6 minutes of WBV training (rest included) Ending with a short program of muscle stretching – WBV training was performed in a static standing position with hips and knees in 50° of flexion – Frequency of 25–40 Hz – Utilized NEMES-LS vibration machine, o mention of amplitude or direction utilized	– Resistance Training 3 times weekly for 8 weeks – leg press device: 3 sets of 10–15 reps with 2 minute rest	1: Muscle spasticity (modified Ashworth scale) 2: Muscle strength (isokinetic dynamometry) 3: Walking ability: 6 MWT 4: Balance: TUG 5: GMFM	– Significant reduction of spasticity in the knee extensors of the stronger leg ($p < 0.05$) – No other significant changes in spasticity – Angle speed 30°/s: no significant change – At angle speed 90°/s: Increase of concentric ($p < 0.05$) and eccentric ($p < 0.05$) work and eccentric peak torque ($p < 0.05$) in the WBV group's weaker leg – Values for 6MWT did not change significantly – Values for TUG did not change significantly after training – Spasticity: dimensions D and E increased in the WBV group ($p < 0.05$)
Ruck, 2010,	– 20 children with CP – Ages 6.2 to 12.3 years – 14 male and 6 female	Regular PT program + WBV – one WBV session a day, 5 days per week – Frequency of the vibrations can be selected by the user – Protocol 3 mins of WBV 3 mins of rest 3 mins of WBV 3 mins of rest 3 mins of WBV – 12 Hz increasing to 18 Hz as intervention progressed – Side-to-side alternating vertical sinusoidal vibration	Conventional PT: the program was individualized according to the needs of each child 1–2 times per week	1: Walking speed: 10 m walk test 2: Areal BMD of lumbar spine and femur diaphysis 3: D and E domains of the 88 item GMFM	– No significant group differences were found for the changes in GMFM – increased the average walking speed by a median of 0.18 m/s ($p < 0.05$) – No significant differences in areal BMD at the lumbar spine – distal femur, areal BMD in femur metaphysis tended to decrease in controls and to increase in the WBV groups – Femur diaphysis: a significant reduction of BMD in the WBV group.
El-Shamy, 2014,	– 30 children who were diagnosed with spastic diplegic CP – Ages 8–12 – 23 male and 7 female	WBV training – Traditional PT training + WBV – Protocol 3 mins of WBV 3 mins of rest 3 mins of WBV 3 mins of rest 3 mins of WBV – 12 Hz increasing to 18 Hz as intervention progressed – Side-to-side alternating vertical sinusoidal vibration	Traditional PT = neurodevelopmental techniques, muscle stretching, strengthening exercises, proprioceptive training, and balance training, for 3 mos (1 hr per day, 5 days per week	1: Knee extension peak torque to measure strength 2: stability index to measure balance.	– Significant increase in knee extensor peak torque ($p < 0.05$) – significant difference between the baseline and posttreatment: overall stability index, anteroposterior stability index, and mediolateral stability index ($p < 0.05$) – Greater improvements were seen in the stability index of the intervention group than control ($p < 0.05$)
Unger, 2013,	– 27 spastic-type CP children – Ages 6–13 years – 17 male and 10 female	– Selective trunk-targeted exercise programme using the WBV – Protocol: 45s x35Hz Warm-up 3x 30s x 35–40Hz Various sit-up exercises: crunches, cycling, hand behind head and table top 30s x 35–40Hz Hip and lumbar extension exercise 2x 30s x 35–40Hz Side lying crunches 30s x 35–40Hz Plank – No mention of the direction or amplitude parameters	– pre–post crossover study design with random assignment – 0–4 weeks one group with intervention, one group with no intervention – 4–8 weeks groups switch	1: 1 minute walk test 2: Sit-ups in 1 minute 3: 2D posturo-photography 4: ultrasound imaging	– significant increase in gait-speed ($p < 0.05$), however was not sustained when treatment was withdrawn – Sitting: +/-5degree decrease in forward sway and an increase of 2.7cm in shoulder-to-seat height – All four muscles were significantly thicker post-intervention: TrA ($p < 0.05$); OI ($p < 0.05$); OE ($p < 0.05$); RA ($p < 0.05$)

Legend of Terms:

CP	– Cerebral Palsy	6MWT	– Six-Minute Walk Test	TrA	– Transverse Abdominus
WBV	– Whole Body Vibration	DEXA	– dual-energy x-ray absorption	OI	– Internal Oblique
PT	– Physiotherapy	BMD	– Bone Mineral Density	OE	– External Oblique
GMFM	– Gross Motor Function Measure	Min	– Minute	RA	– Rectus Abdominus
TUG	– Timed Up and Go test	Hz	– Hertz	mm	– Millimeter

Four of the articles analyzed the effects of WBV in children^{19,26-28} while the other study focused on adults with CP.²⁹ These studies had interventions ranging from the immediate acute effects of WBV up to six months after intervention. The type of CP was heterogeneous across the studies and included children and adults with spastic diplegic, hemiplegic, and quadriplegia forms of CP. There were four acceptable quality and one high quality article when assessed using the SIGN criteria.

Lee and Chon used a WBV protocol that was unique from the other studies.¹⁹ WBV was performed three times a week for eight weeks. The protocol involved six three-minute vibration sessions while squatting with frequencies varying in Hz (5-25) and received three-minute breaks. The experimental group had an increase in gait speed, stride length, cycle time and ankle angle as well as hypertrophy of the tibialis anterior and the soleus compared to the control group. The control group consisted of general physiotherapy, stretching and balance training. This was rated as a high quality randomized control trial (RCT).

Ahlborg et al., utilized WBV three times a week for eight weeks compared to a resistance training control group.²⁹ The experimental protocol consisted of six minutes of WBV including rest; the frequency was 25–40Hz. The protocol included a five minute warm-up and ended with static stretching. Spasticity, walking, balance and gross motor function were measured pre and post intervention. It was found that there was no significant difference between the groups in any of the measured variables. However, for time to complete each intervention, the WBV training intervention required less time than the resistance training to complete the protocol. This article was rated as an acceptable RCT.

Ruck et al. studied the effects of WBV on walking speed and BMD in a younger CP population (5-12.9).²⁶ The experimental group underwent their regular physiotherapy treatments plus five vibration sessions per week for six months, whereas the control group only underwent the regular physical therapy. The WBV sessions consisted of three minute periods with three minutes of rest in between. The frequency depended upon the child's tolerability to the vibration. There was a significant difference in the 10m walk times with the experimental group decreasing their time by a median of 18m/s, while the control group showed no change. The differences in BMD after

the intervention period, however, were unexpected. The distal femur metaphysis tended to increase in the WBV group, whereas there was a reduction in BMD in the femoral diaphysis.²⁶ This article was rated as an acceptable RCT.

El-Shamy looked at the effect of WBV on both muscle strength and balance.²⁸ The experimental protocol consisted of WBV with conventional physiotherapy compared to a control group who only received conventional physiotherapy. The WBV intervention consisted of a nine minute intermittent WBV with the frequency controlled by the user. The author evaluated knee extension peak torque to measure strength and a stability index to measure balance. After the intervention, there was a significant increase in the knee extensor torque ($p < 0.05$) as well as improved anteroposterior stability and mediolateral stability index ($p < 0.05$). The stability improvements were found in both the control and intervention groups, however the control group had a significantly larger increase ($p < 0.05$). This article was rated as an acceptable RCT.

Finally, Unger et al. looked at the effectiveness of a trunk strengthening program using WBV.²⁷ This experimental intervention consisted of the patients performing different selective trunk-targeted exercises while using WBV. The protocol consisted of a 45 second(s) warm-up at 35Hz, followed by three 30 second exercises (crunches, cycling, hand behind head and table top) at 35–40Hz, then 30 seconds of hip and lumbar extension exercise at 35–40Hz, then finished with two 30 second side lying crunches and a 30 second plank. Gait and core improvements were tested using the 1-Minute Walk Test, 2D-posturography, ultrasound imaging and sit-ups in one minute. The authors found that there was a significant increase in distance walked ($p < 0.05$), more upright posture, an increase in sit-ups executed ($p < 0.05$) and an increase in resting thicknesses of all the four abdominal muscles was recorded: transversus abdominis ($p < 0.05$) obliquus internus ($p < 0.05$), obliquus externus ($p < 0.05$) and the rectus abdominis ($p < 0.05$). It was also noted that the strength and posture gains were maintained at four weeks post-intervention. This article was rated as an acceptable RCT.

Strength and Motor Function

Four studies found that WBV resulted in a statistically significant increase in muscle strength and force (Ruck, Unger, El-shamy, Ahlborg).²⁶⁻²⁹ The comparison study of

physiotherapy versus WBV found increased thickness of tibialis anterior (31%) and soleus muscles (40%).¹⁹ The comparison study of exercise versus WBV found no significant differences in isokinetic quadriceps muscle strength between groups.²⁹ However, El-Shamy found that there was a significant increase in the knee extensor torque.²⁸ Additionally, Unger et al. found that there was an increase in the abdominal musculature thickness with a core targeting WBV intervention.²⁷ This was accompanied by the number of sit-ups a participant could perform in one minute.²⁷ Ahlborg, and Ruck all used the Gross Motor Function Measure (GMFM) to assess motor function and found improvements in the sitting and crawling sections.^{26,29}

Spasticity

One study (Ahlborg) found that there was a significant decrease in knee extensor spasticity using the modified Ashworth scale in the WBV group. Additionally, there was a decrease side effects of muscle stiffness and soreness noted in the WBV compared to the exercise group.²⁹

Bone Density

One study (Ruck) found a paradoxical change in BMD within participants' femurs.²⁶ This change consisted of an increase within the distal femur metaphysis in the intervention group compared to the control group. However it was also noted that there was significant decrease in BMD in the femoral diaphysis. Finally it was noted that there was no changes to the BMD of the lumbar spine. The authors suggested that one possible explanation for this finding is the difficulty in performing densitometry for the distal femur with CP patients. This is due to positioning and movement artifacts.

Walking speed

Four studies found that WBV resulted in improved walking speed (Lee, Ruck, Unger, Ahlborg).^{19,26,27,29} One study used Kinematic data obtained by three-dimensional analysis to evaluate gait speed which showed that WBV improved gait speed by 0.110m/s.¹⁹ Lee and Chon found there was improvement in walking and mobility, specifically gait speed, stride length, cycle time and ankle angle.¹⁹ Unger found that with the improved core strength that there was an improvement in the 1-minute walk test.²⁷ WBV intervention demonstrated a 38% improvement in

walking speed above baseline in a 10-meter walk.²⁶ The WBV group had an increase in their average walking speed of 0.180m/s while the control group had no change.

Vibration Parameters

A summary of the frequency, amplitude and time on vibration plate utilized within the interventions showed significant heterogeneity within the protocols. The following are the ranges: frequency 5–40 Hz, 1- 9 millimeters (mm) and 30 seconds – 6 minutes. The majority of studies utilized the Galileo system for the vibration intervention, this machine involves a side-to-side alternating vertical sinusoidal vibration. To control for the differences in displacement due to the teetering action, the authors would have marked distances from the centre for foot placement. As the participants' feet moved further from the fulcrum; the amplitude of the vibration increases. With this concern, there was variable reporting of the amplitude utilized within the studies. Finally the exercises utilized on the machine included squats, core exercises, standing and lunges.

Discussion

Whole body vibration as a treatment option for CP is a relatively new subject with limited high quality research. The results of most of the included articles appear promising in terms of WBV as an intervention in CP patients, in regards to building strength, decreasing spasticity, increasing functionality in the short term (up to six months); however, positive effects on bone mineral density are questionable.

Throughout the five studies investigated there was a large amount of heterogeneity in almost all aspects: WBV protocols, vibrating platforms, setups and type of CP. CP is an umbrella term and the types of CP included in the studies were heterogeneous making it difficult to extrapolate the findings to all patients with CP.^{30,31} Future research into the effects of WBV on CP, need to better address the type of CP they are investigating. With the heterogeneity of CP, it could be possible that WBV may be effective for one group while less effective or ineffective for another group.

WBV seems to be a promising adjunct to the regular therapies that CP patients participate in. Based on the studies appraised by these authors, WBV appears to be a safe and time efficient therapy that may help to improve

walking ability and increase walking speeds, overall mobility, muscle mass and force production, and decreasing spasticity. However, there should be further investigation into the effects of WBV on BMD, due to the paradoxical decreased bone mineral density seen in the WBV group by Ruck et al.²⁶ Based on all the studies, the most commonly utilized time intervals for the vibration was three minutes maximum per interval. Further research into this subject must include determining the optimal protocol to achieve therapeutic result. Other possible areas of investigation could include determining if individualized treatment protocols are more effective than a standardized programs, including investigations into the optimal time, direction of vibration, amplitude, and frequency to gain clinically relevant changes, as well as studies looking at the long-term follow-ups to determine whether these results from WBV are retained. Future research should include additional reporting of the vibration parameters utilized within the study to allow better implementation by clinician wishing to use vibration as a treatment modality.

One area for concern with investigating WBV is the difficulty in blinding participants and investigators. The nature of the intervention of WBV makes patient blinding difficult. One of the previous blinding method utilized included using a physiotherapist who was blinded to the type of intervention the patients received to perform outcome measure testing.¹⁹ This change would limit the potential for measurement bias and further strengthen the research protocols.

Although all studies used WBV as the primary intervention, the studies did not administer identical interventions in terms of the frequency, duration, or interval times. Not only were the interventions not heterogeneous, but the types and forms of CP were not heterogeneous between the populations either. Due to the small sample size, it can be argued that the results are unable to be generalized to other CP patients and populations. Further research needs to be completed with larger sample sizes and homogenous CP populations, with consistently administered treatment frequencies, durations and intervals over a set period of time.

Conclusion

In conclusion, it appears that WBV has the potential to improve symptoms in those patients with cerebral pal-

sy. It has been shown to help improve spasticity, muscle strength and coordination. There is a lack of research to conclusively state whether it does in fact alter bone mineral density. The aim of this systematic review was to compile the recent literature on vibration therapy in patients with CP in order to guide future clinical decisions when treating these patients. The authors hope that this systematic review stimulates further research in regards to WBV and its effects on the CP population.

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