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Special Communication

Whole Body Vibration Therapy for Children with Disabilities: A Survey of Potential Risks and Benefits

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Cerebral palsy;
Spasticity;
Exercise;
Mobility

Abstract The purpose of this report is to remind providers of the potential risks of Whole Body Vibration Therapy (WBVT) for children with disabilities. We reviewed the current state of knowledge and learned that WBVT may have potential risk of injury for some children. To the best of our knowledge this review is the first to clarify WBVT risks. We believe WBVT may have therapeutic value but we recommend caution and offer suggestions for future research.

Background

It is well established that mechanical vibration can have beneficial as well as harmful effects in humans.[1-25] The principal component of vibration is its intensity.[20] Vibrational intensity is complex and will be discussed later. Briefly summarized, intensity is measured in units of gravitational force (g). High intensity vibration is greater than 1 g. Low intensity is less than 1g. Most beneficial effects of Whole Body Vibration (WBV) result from low intensity vibrations. Most deleterious effects result from chronic exposures to high intensity vibrations.[7,19,20]

Decades of study of vibration in the workplace have established that mechanical signals can be extremely harmful to many human tissues and organ systems.[1,7,8,12,19-24,26] It is well accepted that Whole Body Vibration (WBV) can result in intervertebral disk displacement, spinal vertebrae degeneration, and osteoarthritis. Vibration transmitted through the spinal column to the head may induce hearing loss, visual impairment, retinal tearing, vestibular damage,

List of abbreviations: GMFCS, Gross Motor Functional Classification Scale; ISO, International Standards Organization; RV, rotating vibration; TLV, Threshold Limit Values; WBV, Whole Body Vibration; WBTV, Whole Body Vibration Therapy; VV, vertical vibration.

Disclosures: None.

Ethics: The studies reviewed in this report used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and included the PEDro scale for estimating the quality of the meta-analysis and the Cochrane Collaboration's "Risk of Bias" tool to assess bias. No patient identifiers were included in this report. IRB approval was not required. WBV machines referred to in this report are not licensed by the FDA as therapeutic devices. They are used as exercise machines under the FDA "510" designation.

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and even brain hemorrhaging at very high vibration magnitudes.[1,6-8,10,12,19,20,24,26] Because of the severity of risk to human organs and tissues the International Standards Organization (ISO) has recommended limits for human exposure to vibration known as Threshold Limit Values (TLV; ISO-TLV 2631).[7,19,20]

Humans receive low intensity vibrations daily and are not injured by them. The musculoskeletal system is well designed to absorb and dampen vibrations, for example in walking. Low intensity vibrations are not only well tolerated, they are often beneficial.[1-15]

Despite strong advisories to limit human exposure to vibration, the possible beneficial effects of vibration began to be investigated around the start of the Space Age. In the 1960s WBV machines were investigated to prevent bone loss in astronauts during space flight.[27] Using extremely low magnitude g forces (0.3 g) WBV treatment (or "training") was found to be anabolic to bone and muscle.[10,24,27] Numerous studies confirmed that mechanical vibrations stimulate reflexive muscular contractions with beneficial effects such as improved strength and motor control, increased bone mineral density, improved gait speed, decreased spasticity, and increased muscle mass in the short term.[1-18,22,24,25,27]

In the 1970s enthusiasm for WBV training increased both in the exercise and fitness community and in the medical world.[1-10] WBV machines were designed to enhance athletic training and to function as an exercise surrogate for those who cannot exercise.[10,24] WBV was promoted for strength building and to treat conditions ranging from osteoporosis to neurologic impairments like Parkinson's disease and cerebral palsy.[8,10,12] Initial reports appeared promising.[1-17] Vibration's risks seemed to be forgotten or ignored. Growing interest in the benefits of WBV stimulated the development of increasingly powerful WBV machines purported to produce a variety of health benefits including enhanced athletic performance. Manufacturer's brochures and even the scientific WBV literature overflowed with positive results.[1-17]

Unfortunately the evidence for beneficial effects of WBV was and remains quite weak.[10,21,23,24] Despite the lack of evidence for its safety and efficacy, WBV treatment for children with disabilities continues to gain attention for treating cerebral palsy and osteoporosis. In both these conditions WBVT may have some therapeutic value but the evidence is weak, potential risks are significant, and more research is needed.[10,24,25]

Survey of current clinical studies of WBVT for children with disabilities

Systematic reviews and meta-analyses of WBVT

We attempted a systematic review of recent meta-analyses of WBVT for children but found this impossible. We used standard search engines (PubMedC, Cochrane Library, Orthopedicsweblinks, UptoDate) with key words "whole body vibration", "cerebral palsy", "spasticity", "exercise", and "mobility" to locate relevant research. All the studies we found were deficient in critical data (table 1). Investigators did not report the specific intensity of vibrations used but listed only their WBV machine's frequency (Hz) and/or displacement (D). There was no consistency among treatment protocols. Studies could not be aggregated. Adverse events were not often reported and there were no long term results (greater than 6 months). Examples of studies that demonstrate WBV research deficiencies are shown in table 1.

In the studies listed intensities of vibrations delivered were not reported so we computed intensities as shown in the column labelled "g" using data from the studies. Table 1 reveals that g forces in many WBV studies were in the high intensity range (>1g). Many of the estimated g forces (intensities) of these studies appear to be greater than accepted ISO-TLV 2631 safe limits and could potentially be harmful to children.[7,19,20]

Many WBV studies also lacked other important information. For example GMFCS (Gross Motor Functional Classification Scale) classifications were not always documented in children with cerebral palsy. Studies were generally small and not controlled, and confounding factors such as antispasticity medications were not listed. Many different outcome measures were used to evaluate the benefits of WBV therapy. It was not clear whether beneficial effects were temporary or permanent or even additive with more treatments.

No study has established the safety and efficacy of WBV, and precise indications for WBV have not been agreed upon.[13,17,18,24,25] Long term effects remain unknown.[7,13,17-21,24,25] We were unable to confirm that WBV researchers systematically searched for adverse events. Several authors have advised caution in interpreting their result because of

Table 1 Examples of WBVT Protocols

Source	Study	Frequency (Hz)	Displacement (mm)	Duration (min)	g
Saquetto et al[17]	Ibrahim (2014)[28]	12-18	2-6	9	7.8
"	El Shamy (2014)[29]	12-18	?	9	-
"	Le & Chon (2013)[30]	5-25	?	12	-
Ritzman et al[13]	Ahberg (2006)[31]	25-40	4	6	25.7
"	Cheng (2015)[32]	20	2	5	3.2
"	Eklund (1969)[33]	100-200	1.5	1-2	241.2 (?)
Li et al[18]	El-Bagalaty (2021)[34]	5-25	0-3.9	20	9.8
"	Duran (2020)[35]	8-20	1-2	15	3.2
"	Gusso (2016)[36]	15-20	1	9	1.6
Cai et al[25]	Yin (2019)[37]	12	4	6-15	2.3
"	TeKin (2021)[38]	15	4	15	3.6
"	Hegazy (2021)[39]	10-25	2	10	5.0

the heterogeneity of cases, small numbers, and wide variation of treatment protocols.[10,17,18,24,24] WBV investigators have consistently recommended more research into WBV.[10,13,17,18,24,25] Specific contraindications to WBV therapy are listed in the appendix of this report.[10]

Survey of Vibration Physics and Biological Effects

Vibration Exercise

Vibration exercise (also known as "treatment" or "training") is a forced oscillation in which energy is transferred from an actuator (vibration device) to a resonator (human subject). The energy can be delivered locally, for example using a hand held vibrator. Vibration energy can also be delivered to an entire person standing on the vibration platform.[8,10,13,17,18] Vibration forces are the training stimuli but they are also potentially harmful.[7,8,10,12,19,20]

The Actuator - the WBV Machine

Many types of WBV exercise machines are available. They deliver vibrations via plate on which the subject stands. The plate is driven by electric motors to move in different ways: vertically, laterally, rotating, rocking, and combinations. Most studies report on a) "synchronous" (VV – vertical vibration) devices (platform moves vertically only – both feet simultaneously in the same direction) or b) "side alternating (RV – rotating vibration - platform rocks on a central fulcrum like a teeter totter).[7,10,19,20,24] Figure 1 illustrates "synchronous" VV and "side alternating" RV whole body vibration machines. "Side alternating" RV devices may be safer because they transmit half as much vibration to the core and cranium.[7] Their rocking motion induces rotation at the pelvis and allows hip joints and muscles to more effectively dampen vibration transmission up the spine.[7] Some "synchronous" VV devices may also be safe because they can only deliver WBVs of very low intensities (much less than 1g).[19,20,40]

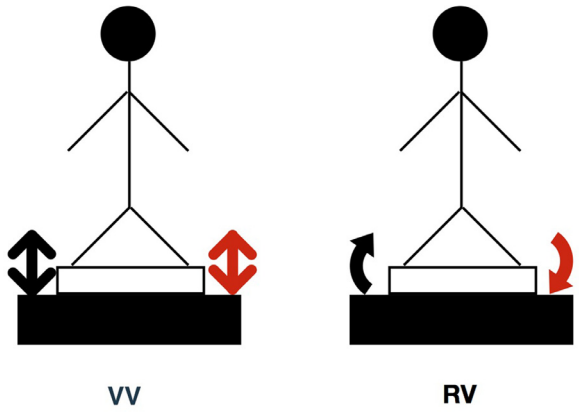

Fig 1 Stick figures are shown standing on two different types of Whole Body Vibration machines: VV depicts vertical vibration machine – platform moves only vertically ("synchronous" WBV machine); RV depicts Rotational Vibration machine – platform rocks on a central fulcrum like a teeter totter ("side alternating" WBV machine)

Newer "combination" devices are also available. These may include torsion and or motion in 3 dimensions. The forces delivered by the "combination" devices are not well understood. "Combination" WBV devices were developed in an attempt to give increased stimulation to an exercising person to obtain faster strength building. To our knowledge no WBV machines have been fully approved by the FDA as therapeutic devices. They are being used under the FDA's "510"usage permit rule as exercise machines. Not all WBV machines perform equally well.[7,8,10,17,19,20]

Vibration - the mechanical signal

Mechanical vibration is defined as an oscillation with amplitude (displacement "D" in mm), frequency (in events per second (Hz), magnitude (acceleration "g", gravitational units) and direction (eg vertical, transverse, torsional etc).[7,10,19,20]

Analyzing mechanical vibration is challenging. A good example of this is found in Abercromby et al,[7] a NASA study which was the first to use accelerometer data to quantitatively evaluate WBVT. Though simplified for non-engineers, the article is dense. Using very precise measurements and sophisticated calculations the authors concluded that "the estimated Vibration Dose Value (eVDV) associated with typical WBV training regimens (30Hz, 4mm disp, 10 min per day) exceed the recommended daily vibration exposure as defined by ISO 2631-1.".[7]

The most important quality describing vibration is intensity.[7,19,20] Intensity is a complex product of frequency (Hz) and displacement (D) measured in gravitational force units (g).[7,19,20]

$$g = \left(D[2\pi Hz]^2\right)/9.81$$

Reporting only the displacement and/or frequency of a WBV machine without its intensity makes it impossible to compare the machine to ISO-TLV standards.[19,20] Intensity of vibrations delivered along with exposure duration are the critical factors needed for applying ISO -TLV standards in the development of safe WBV treatment protocols. Several authors have investigated the actual intensity of vibrations delivered by commercially available WBV devices.[7,19,20] Many of the WBV machines studied were surprisingly powerful.

Investigators have pointed out that several WBV machines far exceed ISO-TLV standards and some are capable of delivering vibrations with intensities of greater than 15g, making them potentially dangerous for healthy adults, not to mention frail children with disabilities.[7,19,20] Some machines may not be well described by manufacturers or may not deliver desired vibrations consistently. As shown in table 1 the lack of complete information about the intensity of delivered vibrations has been a major deficiency of the WBV literature.[10,13,17-21,24,25]

The Resonator-human subject on the WBV machine

The beneficial effects of WBV are thought to result from involuntary muscle contractions.[1-18,22,24,25,27] The vibration's mechanical signal causes a reflex muscular contraction

known as the "tonic vibration reflex". The resulting muscular work results in the beneficial effects of WBV.[6,7,10,24] Supraspinal control may be involved; however the exact mechanisms remain unclear.[8,10] There are inconsistent and conflicting reports concerning the effects of vibration on the stretch reflex, muscle spindles, Golgi tendon organs, cellular and enzymatic responses, and reflex modulation by the central nervous system.[6,8,10,13,16-18,24-27,29,41-43]

Although the exact mechanisms of WBV actions remain unclear, the results of low intensity WBV therapy have generally been encouraging.[13,17,18,24,25,27] WBV therapy has been reported to improve gait speed, strength and motor control, and increase bone mineral density and muscle mass in the short term in children with disabilities from various conditions (Cerebral Palsy, Osteogenesis Imperfecta, Trisomy 21, cancer).[1,3,6,8,11,13,15,16,18,24,25,40] Most WBV studies have focused on positive results. Adverse events have rarely been mentioned.[6,13,21-24,26]

In our review we were unable to confirm that researchers systematically searched for adverse events. We could not find a listing of criteria for monitoring patients for adverse events such as falls, fractures or more subtle injuries. Retinal tears resulting from using WBV exercise machines have been documented in adults.[26] We worry about pediatric brain and/ or eye injuries because we know of several children who have received WBV therapy by sitting on the WBV platform. Sitting is recommended by some manufacturers and has been reported by Ritzman et al.[13] We found no accelerometer data to verify the safety of WBV treatment in positions other than standing. WBV investigators have repeatedly stressed the importance of damping vibration transmission to the core and head by standing with knees flexed.[7,10,19,20]

Resonance

Resonance is a danger from vibration. Harmonic accumulation of energy within the resonator (human) can lead to vibration amplitudes greater in the resonator (human) than in the actuator (WBV machine) . This can potentially damage the resonator (human tissue or organ damage as discussed previously) for example retinal tearing or cochlear injury.[8,10,19,20,24,26] Resonance can occur within the trunk at frequency of approximately 5Hz and in the lower extremities at frequencies below 20 Hz.[8,19,20] Vibration frequencies above 50 Hz may cause muscle damage to the lower extremities.[8,10] Vibrations transmitted up the spinal column have caused intracerebral hemorrhaging.[7,23] Resonance forces can be prevented by postural changes. Standing in a crouch posture allows muscles and joints to exert a damping effect and decrease vibration transmission to the core and cranium.[7,10,19,20] Some children with disabilities may not be able to assume or maintain recommended positioning because of cognitive and/or physical limitations.

Guidelines for WBV

Guidelines for vibration exposure in humans were developed after numerous reports of injuries attributed to vibration were analyzed.[7,8,10,12,19,20,23,24,26] Long term effects of WBV on the brain are unknown but concerns have been raised about sub concussive brain injury possibly leading to neurodegenerative conditions like Alzheimer's disease.[10,19,20] The International Organization for Standards guidelines for vibration exposure limits known as Threshold Limit Values (ISO-TLV) were developed for healthy individuals in workplace environments. These guidelines may not be completely applicable to children, but they are a good starting point.[1,7,8,10,19,20,24] ISO 2631 is regarded as the safe WBV exposure limit.[7,19,20]

The ISO 2631 guideline allows formulation of safe therapeutic WBV protocols. Unfortunately the guideline is complex and has not been followed in many WBV studies. The ISO 2631-1 guideline requires knowing the intensity of vibrations delivered in order to calculate a safe exposure time. Most WBV studies did not report the intensity of vibrations in their protocols so following the ISO 2631 guideline could not be assured. As table 1 illustrates, we calculated that many of the published protocols appear to show high intensity vibrations that are greater than ISO 2631 recommendations.[7,19,20]

An example of a safe WBV protocol comes from the VIBE Study of Mogil et al.[40] Their treatment protocol consisted of 2 10-minute WBV treatments per day using the Juvent Micro Impact Platform[a] delivering low magnitude high frequency vibrations at 32 to 37 Hz, and displacement = 0.05mm resulting in a g force = 0.3g to 0.4 g. Sixty-five children used that regimen for 1 year and improved their bone mineral density with no adverse events.[40]

Recommendations for future research

Only WBV machines delivering low intensity vibration should be used. Some side alternating (RV) devices may safer because they transmit less vibration to the core and cranium than vertical only (VV) platforms.[7,10,19,20] Treatment protocols should include exact machine settings of frequency, displacement, intensity, direction, and duration of exposure and frequency of treatment sessions so studies can be compared. Clear indications for and expected outcomes from WBV need to be defined. GMFCS classification for all subjects with cerebral palsy should be included with other standard demographic data. Studies need to be controlled, randomized, and be powered enough to show statistical significance. Confounding factors such as spasticity, contractures, seizure disorders, medications, or surgical interventions should be listed. Duration of effects of WBV and long-term findings (beyond 2 years) need to be documented. Percentage of children who improve should be listed using standard measures such as walking speed, get up and go test, or change in GMFCS classification. Accelerometer data documenting vibratory forces should be included — including in positions other than the ideal "crouch" stance (eg sitting on the platform with accelerometer on the head). Special attention should be paid to negative results. Reasons for stopping or altering treatments should be explained. Many potential candidates for WBV may be nonverbal so investigators must be especially vigilant for occult injuries and subtle findings. Perhaps a child is crying because of discomfort, not simply out of fear. Specific criteria for identifying adverse effects need to be developed (eg crying, falls, refusal, changes in vital signs, GI signs like vomiting or diarrhea, incontinence, respiratory alterations like wheezing,

tachypnea, change in mental state or worsening of neurologic impairments such as ataxia or seizures, delayed effects such as sleep patterns, etc).

A good study of WBV treatment for children with disabilities could be modeled on the NIH supported study by Andrea Wysocki et al.[24] This report exhaustively analyzed WBVT for osteoporosis using not only the standard scientific literature but also the "gray literature" (such as manufacturers' brochures) and information from "key informants" such as academics, known experts, sales representatives, and consumers.

Conclusions

Until more research has confirmed the safety and efficacy of WBV treatments, we advise caution in prescribing WBV treatment for children with disabilities, especially those who are nonverbal and/or have cognitive impairment and/or GMFCS classification of 4 or 5. We believe that WBV should not be used without the supervision of a specially qualified physical therapist. The financial considerations of WBV therapy are beyond the scope of this report. WBVT may have therapeutic value for treating children with disabilities, but the evidence is weak.[10,13,17,18,21] WBVT may have potential risks for children and long-term effects are unknown.[8,13,19,20,24] More research is needed to establish indications for WBVT and to verify its safety and efficacy.[13,17,18,21,24,25,27,40]

Suppliers

a. Juvent Micro Impact Platform; Regenerative Technologies Corporation.

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Appendix 1 Contraindications for Whole Body Vibration Treatment[10]

Pregnancy, acute thrombosis, serious cardiovascular disease, pacemaker, recent wounds from trauma or surgery, hip or knee implants, acute hernia, discopathy, spondylosis, sever diabetes, epilepsy, recent infection, severe migraine, tumors, recently placed intrauterine devices, metal pins or plates, renal stones, organ failure

References

1. Seidel H, Heide R. Long term effects of whole body vibration treatment: a critical survey of the literature. Int Arch Occup Environ Health 1986;58:1–26.
2. Frost HM. The Mechanostat: a proposed pathogenic mechanism of osteoporosis and the bone mass effects of mechanical and nonmechanical agents. Bone Miner 1987;2:73–85.
3. Rubin C, Turner AS, Bain S, Mallinckrodt C, McLeod K. Anabolism. Low mechanical signals strengthen long bones. Nature 2001;412:603–4.
4. Rubin C, Xu G, Judex S. The anabolic activity of bone tissue, suppressed by disuse, is normalized by brief exposure to extremely low-magnitude mechanical stimuli. FASEB J 2001;15:2225–9.
5. Schoneau E, Frost HM. The Muscle-Bone unit in children and adolescents. Calcific Tiss Int 2002;70:405–7.
6. Cardinale M, Pope MH. The effects of Whole Body Vibration on humans: dangerous or advantageous? Acta Physiol Hung 2003;90:195–206.
7. Abercromby AFJ, 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;39:1794–800.
8. Rittweger J. Vibration as an exercise modality: how it may work, and what its potential might be. Eur J Appl Physiol 2010;108:877–904.
9. Gojanovic B, Feihl F, Liaudet L, Gremion G, Waeber B. Whole Body Vibration training elevates creatine kinase levels in sedentary subjects. Swiss Med Wkly 2011;141:w13222.
10. Albasini A, Krause M, Rembitzki I. Using Whole Body Vibration in physical therapy and sport. Clinical Practice and Treatment Exercises. London: Churchill Livingstone, Elsevier; 2010.
11. Games KE, Sefton JM, Wilson AE. WholeBody Vibration and blood flow and muscle oxygenation - a meta analysis. J Athl Train 2015;50:542–9.
12. Uher I, Pasterczyk A, Bigonsinska M, Svedova M. Vibration Therapy and its influence on health. Biomed J Sci and Tech Re 2018;6:5499–502.
13. Ritzman R, Stark C, Krause A. Vibration Therapy in patients with cerebral palsy: a systematic review. Neuropsychiatr Dis Treat 2018;14:1607–25.
14. Swolin-Eide D, Magnusson P. Does Whole Body Vibration Treatment make children's bones stronger? Curr Osteoporosis Rep 2020;18:471–9.
15. Sanudo B, Seixas A, Gloekl R, et al. Potential application of Whole Body Vibration exercise for improving the clinical conditions of COVID infected individuals: a narrative review from the World Association Of Vibration Exercise Experts (WAVEX). Int J Environ Res Public Health 2020;17:3650.
16. Wren TAL, Lee DC, Reiki H, Rethlefsen SA, Kay RM, Dorey FJ, VG. Effect of high frequency low magnitude vibration on bone and muscle in children with cerebral palsy. J Pediatr Orthop 2010;30:732–8.
17. Saquetto M, Carvalho V, Silva C, Conceicao C, Gomes-Neto M. The effects of whole body vibration on mobility and balance in children with cerebral palsy: a systematic review with meta-analysis. J Musculoskelet Neuronal Interact 2015;15:137–44.
18. Li S, Yu W, Li W, Wang J, Gao L, Li S. The impact of whole body vibration training on bone minerals and lean mass in children and adolescents with motor disabilities: a systematic review and meta-analysis. Children (Basel) 2022;9:266.
19. Muir J, Kiel DP, Rubin CT. Safety and severity of accelerations delivered from whole body vibration exercise devices to standing adults. J Sci Med Sport 2013;16:526–31.
20. Chan ME, Uzer G, Rubin CT. The potential benefits and inherent risks of vibration as a non-drug therapy for the prevention and treatment of osteoporosis. Curr Osteoporosis Rep 2013;11:36–44.

21. Leite HR, Camargos ACR, Mendonca VA, Lacerda ACR, Soares BA, Oliveira VC. Current evidence does not support whole body vibration in clinical practice in children and adolescents with disabilities: a systematic review of randomized controlled trials. Braz J Phys Ther 2019;23:196–211.
22. Ruck J, Chabot G, Rauch F. Vibration treatment in cerebral palsy: a randomized controlled pilot study. J Musculoskelet Interact 2010;10:77–83.
23. Patterson F, Miralami R, Tansey KE, Prabhu RK, Priddy LB. Deleterious effects of whole body vibration on the spine: a review of in vivo, ex vivo, and in vitro models. Animal Model Exp Med 2021;4:77–86.
24. Wysocki A, Butler M, Shamliyan T. Whole body vibration therpay for Osteoporosis. Technical Brief No. 10. Rockville, MD: Agency for Healthcare Research and Quality; 2011.
25. Cai X, Qian G, Cai S, Wang F, Da Y, Ossowski Z. The Effects of Whole Body Vibration on lower extremity function in children with cerebral palsy: a meta-analysis. PLoS One 2023;18:e0282604.
26. Maggiano J, Mei-Chan Y, Chen S, You T, Rathod R. Retinal tear after whole body vibration exercise. BMC Ophthalmology 2020;20:37.
27. NASA Science. Good Vibrations. Available at https://science.nasa.gov. Accessed November 2, 2001.
28. Ibrahim MM, Eid MA, Moawd SA. Effect of whole body vibration on muscle strength, spasticity, and motor performance in spastic diplegic cerebral palsy children. Egypt J Med Hum Genetics 2014;15:173–9.
29. El-Shamy SM. Effect of whole body vibration on muscle strength and balance in diplegic cerebral palsy: a randomized controlled trial. Am J Phys Med Rehabil 2014;93:114–21.
30. Lee BK, Chan SC. Effect of whole body vibration training on mobility in children with cerebral palsy: a randomized controlled experimenter-blinded study. Clin Rehabil 2013;27:599–607.
31. Ahlborg L, Andersson C, Julin P. 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.
32. Cheng HY, Ju YY, Chen CL, Chuang LL, Cheng CH. Effects of whole body vibration on spasticity and lower extremity function in children with cerebral palsy. Hum Mov Sci 2015;39:65–72.
33. Eklund G, Steen M. Muscle vibration therapy in children with cerebral palsy. Scand J Rehabil Med 1969;1:35–7.
34. El-Bagalaty AE, Ismaeel MM. Suit therapy versus whole body vibration on bone mineral density in children with spastic diplegia. JMNI 2021;21:79–84.
35. Duran I, Martakis K, Stark C, Schafmeyer L, Rehberg M, Schonau E. Effect of an interval rehabilitation program with home based, vibration assisted training on the development of muscle and bone in children with cerebral palsy—an observational study. J Pediatr Endocrinol Metab 2020;33:1083–92.
36. Gusso S, Munns CF, Colle P, et al. Effects of whole body vibration training on physical function, bone and muscle mass in adolescents and young adults with cerebral palsy. Sci Rep 2016;6:22518.
37. Yin HW, Li HF, Zhang X, et al. The effects of whole body vibration therapy on lower extremity motor function of children with spastic diplegia. Chin J Phys Med Rehabil 2019;41:752–6.
38. Tekin F, Kavlak E. Short and long term effects of whole body vibration on spasticity and motor performance in children with hemiparetic cerebral palsy. Percept Mot Skills 2021;128:1107–29.
39. Hegazy RG, Abdel-aziem AA, El Hadidy EI, Ali YM. Effects of whole body vibration on quadriceps and hamstring muscle strength, endurance, and power in children with hemiparetic cerebral palsy: a randomized controlled study. Bull Faculty Phys Ther 2021;26:1–10.
40. Mogil RJ, KasteSC Ferry RJ, et al. Effect of low magnitude high frequency mechanical stimulation on bone mineral density among young cancer survivors: a randomized clinical trial. JAMA Oncol 2016;2:908–14.
41. Simonsen EB. Contributions to the understanding of gait control. Dan Med J 2014;61:B4823.
42. Cakar HI, Cidem M, Kara S, Karacan I. Vibration paradox and H reflex suppression: is H reflex suppression results from distorting effect of vibration? Musculoskelet Neuronal Interact 2014;14:318–24.
43. Palmieri RM, Ingersoll CD, Hoffman MA. The Hoffman Reflex: methodological considerations and applications for use in sports medicine and athletic training. J Athl Train 2004;39:268–77.