The Egyptian Journal of Hospital Medicine (October 2024) Vol. 97, Page 3634-3639

Whole Body Vibration Therapeutic Application in Physical Therapy: Review Article

Hossam A Al-Mohandes*; Amira M. Abd-Elmonem; Nahla M Ibrahim
Department of Physical Therapy for Pediatrics, Faculty of Physical Therapy, Cairo University, Giza, Egypt
***Corresponding author**: Hossam A Al-Mohandes, Email: hosamelmohandes@gmail.com,mobile:+201281494169

ABSTRACT
Mechanical oscillations, or vibrations, are closely related to the idea of waves. Whole body vibration (WBV) has become a popular kind of exercise that can help with general health improvement. This training technique uses a vibrating platform to expose a person's entire body to low frequency, low amplitude mechanical stimuli. In accordance with the tonic vibration reflex, the vibration activates the muscle spindles, generating nerve impulses that cause the muscles to contract. In humans, whole body vibration has been shown to improve power, muscle strength, and bone mineral density. WBV has drawn a lot of interest lately due to its demonstrated capacity to enhance bone mineral density (BMD), muscle function, flexibility, balance, and mobility. This review's objective was to provide various WBV strategies that are frequently employed in the rehabilitation of children with impairments.
Keywords: Mechanical oscillations; Physical therapy; Rehabilitation; Vibration; Whole body vibration.

INTRODUCTION

Recently, professional sports teams, fitness centers, and beauty parlors have been implementing whole-body vibration as an adjunct or replacement for traditional training methods. In an exercise program using WBV, the force produced by a vibration platform physically translates into workload [(1)]. WBV training involves oscillatory movements that are conveyed up through the entire body from a platform via the participant's feet [(2)].

As a safe and efficient substitute for conventional exercise techniques, vibration training has been proposed [(3)] to enhance physical function, muscle strength, balance, and fall prevention while also improving quality of life (QoL) [(4,5)].

Prior research examining the impact of intervention exercise regimens in conjunction with WBV has demonstrated improvements in muscular power and strength [(6)], flexibility [(7, 8)], muscle cross-sectional area [(9,10)], bone mineral density [(11)], and reductions in visceral fat [(12)].

Vibrating platforms have been more widely available and utilized in sports and rehabilitation facilities in recent years. (WBV), which involves exercising on a vibrating platform or standing in various static poses, is being marketed commercially as an appealing and effective substitute for resistance training [(13)].

We illustrate the therapeutic benefits of WBV training in the physical therapy rehabilitation of children with impairments in this review.

Principles of WBV Available Machines

A vibration device's potential for use in therapy and training is greatly influenced by its oscillation characteristics. The most crucial elements are oscillation movement (like a sinusoidal waveform), amplitude, and frequency. The platform's movement principle—the plate the user usually stands on—is the most noticeable distinction among the gadgets that are currently available [(13)]. Most vibration training tools fall into one of the following categories: 1) Vertical motion: The platform as a whole only moves in two directions: 2) Side-to-side (pivotal) movement because of the platform's central axis, which functions as a see-saw; one foot advances forward and the other descends. 3) Horizontal circular motion (Table 1). The platform travels in a horizontal plane in a circle. All of the systems that are now in use combine rotation in the resultant plane with motions in only one or two dimensions [(1)].

Table 1: Oscillation parameters of the most common vibration training and therapy devices [(1)].

Parameter	Vertical home use	Vertical high class	Vertical low magnitude	Side-alternating home use	Side-alternating mid class	Side-alternating high class	Horizontal circular
Amplitude (mm)	1–2	1–2	<0.1	0–8[a]	0–4[a]	0–7[a]	1–2
Frequency (Hz)	15–45	25–50	20–40	5–15	5–30	1–40	5–15
Acceleration (g)[b]	1–16	2.5–20	0.2–0.5	0–7	0–14	0–45	1–8
Application time (min)[c]	<3	<3	10–30	<3	<3	<3	<10

Received 30/04/2024
Accepted 30/06/2024

Adverse effects of WBV

The International Organization for Standardization (ISO) has established guidelines that describe measurement techniques, provide warning tales, and provide exposure limits with regard to the hand arm vibration (HAV) and WBV hazard levels. According to frequency and displacement declarations supplied by the manufacturer, numerous platforms possess the potential to result in musculoskeletal, neurological, and vascular damage. To ensure safe use, vibration exposure levels that cause health issues must be avoided [(14)].

- ***Vibration exposure to the hands***

Hand-arm vibration syndrome (HAVS), a vasospastic, neurological, and musculoskeletal disease, can be brought on by prolonged exposure to vibration from powered devices in the hand. Peripheral nerve edema, axon demyelination, diminished vascularity, endothelial cell breakdown and overgrowth with vessel lumen occlusion, and degeneration of skin innervation are examples of tissue deterioration. Comorbidity with carpal tunnel syndrome is frequent [(15)].

Vasospastic attacks are triggered by low temperatures in cold regions and workplaces. Vasospasms are rare in warm areas, but they can be induced with manual cold-immersion testing [(16)].

- ***Vibration exposure through the feet***

Vibration exposure through the foot can cause full body vibration symptoms, such as low back pain and musculoskeletal vertebral spine degeneration linked to seat vibration, as well as HAVS-like pathology in the toes. When daily exposure duration and magnitude rise, the time it takes for HAVS to manifest reduces [(14)].

- ***Lumbar spine***

The lumbar spine, along with its supporting ligaments, muscles, and nerves, is subjected to excessive mechanical stress after years of high-intensity whole-body vibration [(14)].

Contraindications to WBV

Contraindications to WBV are listed as following [(14)]:

•Acute arterial blockage or thrombosis;

• Joint replacements (should the joint replacement be a link in the exercise sequence)

•Two cases of musculoskeletal system acute inflammatory processes include swollen joints and osteoarthritis.

• When a tendon is a component of an exercised chain, it might develop active tendinopathy.

• Recent fractures (where the bone is in the chain that is exercised); acute disk herniation and herniation of the abdomen.

• Rheumatoid arthritis.

• Gall bladder and renal stones.

• Recent surgeries and wounds that haven't fully healed.

• Epileptic seizures (to prevent additional injuries)**.**

Precautions for clinical use of WBV

The application of vibration therapy is not directly contraindicated. On the other hand, the following conditions call for prudence [(17)].

• Stress responses or fractures

• Neuropathy

• Metal pins or plates; epilepsy; recent surgery or joint replacement; fibromyalgia; open wounds or skin rashes; hypertension or clotting risk; pacemakers.

Cutaneous and Muscle Mechanoreceptors Sensitivity to WBV devices

The tissues of the skin are quite sensitive to vibrations from machines. For frequencies in the range of 30 to 40 Hz, we typically distinguish between experiences of superficial vibrations. Furthermore, with frequencies over 40 Hz, deeper sensations are distinguished. Meissner's superficial receptors and Pacini's deep receptors are the two types of skin receptors that are activated to produce these two kinds of emotions. Both fast and slow cutaneous receptors eventually exhibit a decline in their responsiveness to their natural stimuli (maintained pressure and skin stroking, respectively) over a prolonged vibration exposure (a few minutes). Additionally, they can exhibit persistently aberrant resting behaviors, which could explain the tingling feelings that typically follow vibration exposure [(14)].

Sensitivity of Muscle and Tendon Receptors to Mechanical Vibrations

The central nervous system controls the ability of muscle spindles, which are sensory receptors, to transduce variations in muscle length. Two distinct subtypes of motor neurons are used to achieve this: Both intrafusal and extrafusal fibers—the latter of which are the muscle fibers—are innervated by beta skeletal fusimotor neurons. Only intrafusal muscle fibers are innervated by gamma fusimotor neurons. Because they are susceptible to repeated, low-amplitude stresses of the supplied muscle, when a subject is at rest, mechanical vibrations given to the tendon or the muscular belly cause the main and secondary ends of the muscle spindles to fire [(13)]**.**

The Golgi tendon organs, or mechanoreceptors, are also present in muscle tendons. They are found where the tendon tissue and muscle fibers converge, and they are made up of branching nerve endings encased in a connective capsule. Group Ib afferents, sensitive fibers with a large diameter whose cellular body is located in the spinal ganglia, innervate them. These are mechanical receptors that respond to muscular contractions. Only frequencies between a few Hertz and a few tens of Hertz can cause damage to most tendon organs; in fact, some may be totally insensitive to vibration [(14)].

How to Design Exercise Sessions with Whole-Body Vibration Platforms

Selecting the Appropriate Frequency

According to **Stark *et al.* [(18)],** The frequency of vibration has a significant impact on how vibration waves are transmitted throughout our bodies. They declared what was to come:

- The vibration wave penetrates farther into our bodies at lower frequencies. On the other hand, posture and

muscular pretension also have an impact on vibration transmission. Stricter posture and increased muscle pre-tension are practically required if the intention is to transmit 30 Hz vibration into the thigh. The fact that more stretch-shortening cycles occur per unit of time means that local blood flow and energy turnover increase with vibration frequency, which is another crucial factor to take into account. Higher frequencies should therefore be the main focus if achieving muscular activation and energy turnover is the desired outcome.

-Furthermore, empirical evidence indicates that vibration may also be employed to adjust muscle tone. Muscle tone is often raised with vibration frequencies between 20 and 35 Hz, whereas it tends to decrease with frequencies between 8 and 15 Hz.

Selecting the Appropriate Amplitude

Higher vibration amplitudes will, of course, cause the tissue to absorb more energy. The vibration energy is progressively absorbed by the tissue, decreasing in value as it travels farther. Because of this, the amplitude at the contact point, which is often the foot for WBV plates, needs to be sufficiently large to offset damping effects en route to the intended location. However, over amplitude can result in excessive energy transmission, perhaps causing tissue injury **(13,19)**.

Selecting the Appropriate Posture

Orientation changes on a WBV platform have a significant impact on the way vibrations are absorbed by our bodies. For instance, standing with rigid legs increases vibration in the trunk, minimizes energy loss in the leg muscles and may even reach the brain. A slumped posture will reduce vibration transmission and focus vibration energy on the shank muscles when the heels of the vibration platform are raised **(18)**.

Clinical applications of WBV

- Clinical use of WBV in relation to bone mineral density

The two primary forms of bone are cancellous bone, which is trabecular and sponge-like and found at the extremities of long bones, vertebrae, ribs, and the iliac crest, and cortical bone, which is dense and compact and located in the shafts of long bones and is principally responsible for sustaining weight. The quality features of bone, such as the architecture and geometry, the pace of bone turnover, the characteristics of the collagen matrix, and the buildup of microdamage; all have an impact on the bone tissue's strength, or its ability to resist breaking (20).

WBV causes mechanical oscillations to travel throughout the body, stimulating bone cells directly and increasing the force with which muscles contract, leading to higher stresses in the skeleton through mechanotransduction in bone tissue.

The literature indicates that the characteristics of the vibration stimulus determine the effectiveness of WBV interventions. High-magnitude protocols (≥1 g) have been demonstrated to considerably raise the BMD. Low-magnitude treatments (<1 g) have been shown to increase BMD at the hip but not at the lumbar spine, in contrast to the trochanters and lumbar spine. Furthermore, raising BMD was more successful with side-alternating vibration platforms and a semi-flexed knee stance than with synchronous platforms or standing with the knees extended on the platform (21).

- WBV application in a clinical setting for back pain.

Chronic low back pain (CLBP) without a specified cause is very common and contributes significantly to disability. In addition to pain, patients usually report diminished lumbo-sacral flexibility, which appears to be related to impaired flexion-relaxation and impairs gait and static balance (22). Young, healthy volunteers' back extensor muscles have been shown to have increased electromyographic activity during WBV during 30-Hz vibration. Increased vibration amplitude increases trunk muscle activation, whereas increased knee flexion decreases it. Furthermore, a modeling technique indicates that the back extensor muscles' significant force production is linked to this WBV-induced EMG activity. Furthermore, vibration has been shown to reduce pain perception (23,24).

- WBV's clinical use in pediatric rehabilitation

Chronically ill children and adolescents frequently have limited movement and are unable to engage in enough physical activity on a regular basis. Consequently, in addition to their original disease, secondary skeletal problems such as contractures, muscular weakness, muscle atrophy, etc., also arise.

Treatment options include surgical, pharmacological, and conservative (such as orthotics and aids and physiotherapy). The severity of motor and mental dysfunction in children and adolescents with motor disorders significantly limits the applicability of these training modalities, which often require voluntary motor skills and a strong cognitive understanding to follow instructions and complete the exercises. In contrast, WBV is a simple, quick, and reflex-based intervention (25,26).

Those who can stand train on a standing apparatus, while children and teenagers who are unable to stand train on a tilting table with a vibration plate at the foot of the table. Smaller amplitudes with rising frequencies (based on the child's tolerance up to 27 Hz) are usually chosen for WBV in pediatric rehabilitation. These range from 1 mm amplitude or 2 mm peak-to-peak displacement, respectively, to a maximum of 2 mm amplitude or 4 mm peak-to-peak displacement, respectively. Vibration frequency for side-alternating WBV is often adjusted based on the following goals: 5–12 Hz for proprioceptive training and balance (subconscious, but not involuntary); 12–20 Hz for improving muscular function (growing muscle mass, but strong involuntary contraction; increased reflex-based involuntary contraction) **(27)**.

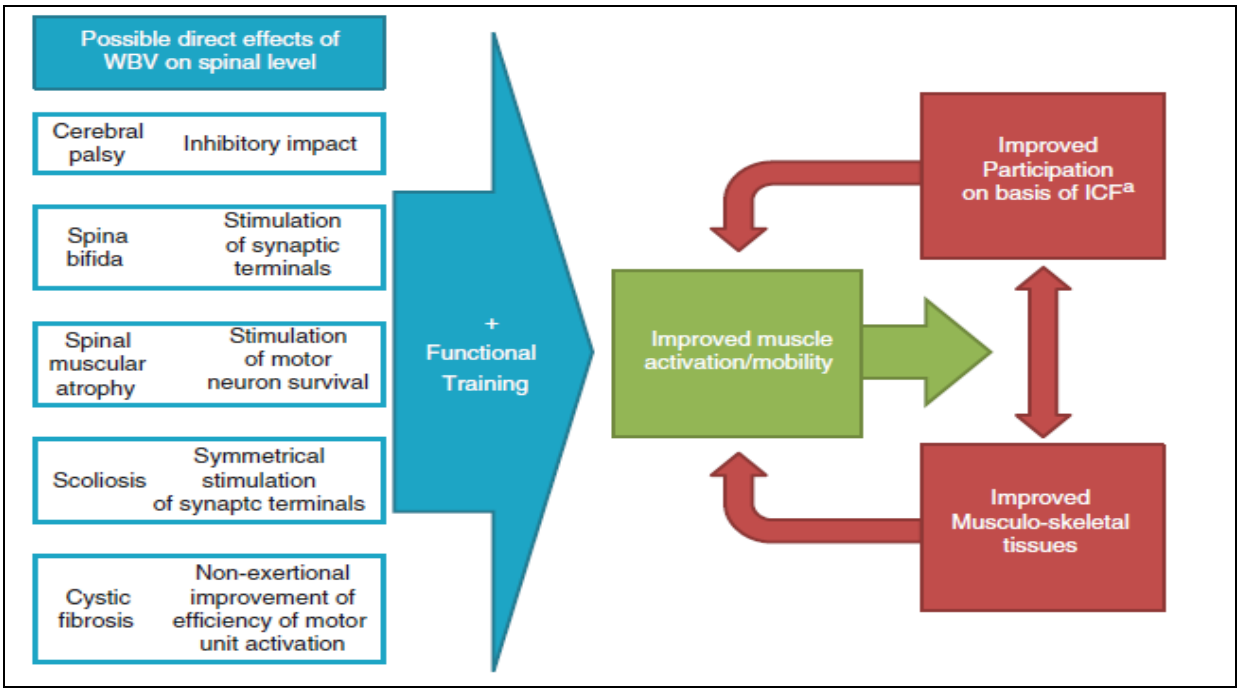

Figure 1. Conceptual model of the effects of WBV in pediatric rehabilitation; International Classification of Functioning, Disability and Health (ICF) [28]

• The role of WBV in cerebral palsy rehabilitation

Previous studies have shown that WBV may be used in both clinical and home settings to provide these kids with an alternate, safe, and effective form of treatment. The intervention improved ambulatory performance, increased active joint range, and restored muscle tone in children with WBV CP [29-32].

- ***Spinal Muscular Atrophy***

The degeneration of spinal cord motor neurons, which causes denervation, muscle weakness, and a progressive loss of motor function, is the defining feature of spinal muscular atrophy, an autosomal recessive neurodegenerative condition. One of the most common autosomal recessive diseases is spinal muscular atrophy, which occurs with a frequency of about 1:10 000. Types II, or intermediate form, and III, or juvenile form with Kugelberg-Welander syndrome, are the less severe forms of spinal muscular atrophy [31]. Early in life, a child may accomplish motor milestones like sitting and walking, but as the disease progresses, these abilities may be lost [33].

To enhance neuromuscular interactions as soon as possible in infants and adolescents with neuromuscular problems, safe, and effective manner, WBV has recently piqued the interest of clinicians and scientists. Whole-body vibration produces involuntary muscle contractions through reflex-based muscle contractions, which has the benefit of offering afferent feedback pathways [34,35]. Because WBV activates muscle spindles and stimulates α motor neurons through 1a afferent fibers, it may be helpful for those with spinal muscular atrophy. This is because WBV may have neuroprotective properties [36,37].

- ***Effect of WBV in rehabilitation of Down syndrome***

Known to be caused by a chromosomal defect called trisomy 21, Down syndrome (DS) is the most prevalent genetic form of mental impairment. Clinical symptoms, such as orthopedic, cardiovascular, musculoskeletal, and respiratory issues together with perceptual deficits, are what define children with Down syndrome. Compared to their healthy counterparts, children with DS were shown to be less able to adjust their motor action to the situation and to produce more force when needed [38,39].

WBV is currently regarded as one of the most well-liked training techniques since it uses high-frequency mechanical stimuli produced by a vibrating platform that are conveyed throughout the body to promote bone loading and sensory receptor stimulation. This is because children with Down syndrome have sensory issues and low proprioception [13].

Balance was assessed using the Biodex Stability System (BSS; Biodex, Inc., Shirley, NY, USA) in the **Villarroya *et al.*** [40] research. Using BSS, the tilting degree for each axis under dynamic conditions was determined. These three forms of stability indices are medial-lateral, total, and partial. The outcomes showed statistical significance in the intervention groups and a significant improvement in both the control and intervention groups. The authors stated that WBV training significantly improves the stability of kids and teenagers with DS.

Additionally, they noticed that the mean oscillation velocity had decreased and lateromedial inclination level.

Effect of WBV in rehabilitation of spina bifida

A congenital condition known as spinal cord malformation results from one or more vertebral arches failing to fully close during the first few weeks of pregnancy [(41)]. Based on severity, three types of malformations can be identified [(42)]. The most severe kind, called myelomeningocele (MMC), results in the spinal cord, meninges, and nerve roots sticking out of a hole in the spine, paralyzing the body beneath the malformation either totally or partially. The other two types of deformity are spina bifida occulta (SB) and meningocele (MC). Flaccid paralysis (muscle weakness and wasting), diminished or absent tendon reflex, exteroceptive and/or proprioceptive feeling, and congenital malformations are the main clinical signs in a kid with lumbosacral MMC [(43)].

WBV training with a rotary-type platform and high-frequency/low-amplitude vibratory input has received a lot of attention lately as a means of helping the MMC population reach their therapy objectives. Previous research showed that WBV-assisted training improved velocity and reduced resistivity in every artery under investigation, leading to a marked improvement in patients' lower limb circulation who had MMC. WBV-lower-extremity contractures, particularly knee contractures, were also relieved by aided training [(44)].

In children with MMC treated with WBV, one study found improvement in motor function [(37),] while another indicated a beneficial effect on bone mineral density [(45)]. For people, such as those with MMC, who are unable to elicit voluntary contractions, axial vibration causes reflexive muscular contraction [(46)].

CONCLUSION

In certain illnesses and conditions, the WBV intervention is thought to be a safe intervention that improves muscle strength, postural stability, bone mass, and spasticity. More evidence points to the benefits for muscle strength, balance, and walking speed. WBV should, however, be used extremely carefully and customized based on a thorough evaluation of each individual patient with a disability.

- **Sources of funding:** Funding organizations from the public, private, or charity sectors did not give this study a particular grant.
- **Conflicts of interest:** There are no conflicts of interest, according to the authors.

REFERENCES

1. **Rittweger J (2010):** Vibration as an exercise modality: how it may work, and what its potential might be. Eur J Appl Physiol., 108(5):877-904.
2. **Cardinale M, Bosco C (2003):** The use of vibration as an exercise intervention. Exerc. Sport Sci. Rev., 31(1): 3–7.
3. **Wadsworth D, Lark S (2020):** Randomised control study of oxidative stress in whole body vibration exercise. The Journal of Sport and Exercise Science, 4(1): 44-52
4. **Merriman H, Jackson K (2009):** The effects of whole-body vibration training in aging adults: a systematic review. Journal of Geriatric Physical Therapy, 32(3): 134-145.
5. **Lama F, Liao L, Kwokc T *et al.* (2016):** The effect of vertical whole-body vibration on lower limb muscle activation in elderly adults: Influence of vibration frequency, amplitude and exercise. Maturitas., 88: 59-64.
6. **Delecluse C, Roelants M, Diels R *et al.* (2005):** Effects of whole body vibration training on muscle strength and sprint performance in sprint-trained athletes. International Journal of Sports Medicine, 26(8): 662-668.
7. **Petit P, Pensini M, Tessaro J *et al.* (2010):** Optimal whole-body vibration settings for muscle strength and power enhancement in human knee extensors. Journal of Electromyography and Kinesiology, 20(6): 1186-1195.
8. **Fagnani F, Giombini A, Di Cesare A *et al.* (2006):** The effects of a whole-body vibration program on muscle performance and flexibility in female athletes. American Journal of Physical Medicine & Rehabilitation, 85(12): 956-962.
9. **Bogaerts A, Verschueren S, Delecluse C *et al.* (2007):** Effects of whole body vibration training on postural control in older individuals: a 1 year randomized controlled trial. Gait & posture, 26(2): 309-316.
10. **Osawa Y, Oguma Y, Ishii N (2013):** The effects of whole-body vibration on muscle strength and power: a meta-analysis. J Musculoskelet Neuronal Interact., 13.3: 380-390.
11. **Verschueren S, Roelants M, Delecluse C *et al.* (2004):** Effect of 6-month whole body vibration training on hip density, muscle strength, and postural control in postmenopausal women: A randomized controlled pilot study. Journal of Bone and Mineral Research, 19(3): 352-9.
12. **Vissers D, Verrijken A, Mertens I *et al.* (2010):** Effect of long-term whole body vibration training on visceral adipose tissue: a preliminary report. Obesity facts, 3(2): 93-100.
13. **Rittweger J (2020):** Manual of Vibration Exercise and Vibration Therapy. Springer Nature Switzerland AG. https://link.springer.com/book/10.1007/978-3-030-43985-9
14. **Riley D, Rittweger J (2020):** Safety and Contraindications in Manual of Vibration Exercise and Vibration Therapy. Springer Nature Switzerland AG. https://www.researchgate.net/publication/341605682_Manual_of_Vibration_Exercise_and_Vibration_Therapy
15. **Pel J, Bagheri J, van Dam L *et al.* (2009):** Platform accelerations of three different whole-body vibration devices and the transmission of vertical vibrations to the lower limbs. Med Eng Phys., 31(8):937–44.
16. **Shen S, House R (2017):** Hand-arm vibration syndrome: what family physicians should know. Can Fam Physician, 63:206–10.

17. **Lupowitz L (2022):** Vibration therapy–A clinical commentary. International Journal of Sports Physical Therapy, 17(6): 984.
18. **Stark C, Rittweger J (2020):** How to Design Exercise Sessions with Whole-Body Vibration Platforms in Manual of Vibration Exercise and Vibration Therapy. https://www.researchgate.net/publication/341604400_How_to_Design_Exercise_Sessions_with_Whole-Body_Vibration_Platforms
19. **Souron R, Besson, T, Millet G *et al.* (2017):** Acute and chronic neuromuscular adaptations to local vibration training. Eur J Appl Physiol., 117: 1939–1964.
20. **Burr D (2014):** Bone morphology and organization. In: Burr DB, Allen MR, editors. Basic and applied bone biology. San Diego., CA., Elsevier, Inc., p. 3–25.
21. **Oliveira L, Oliveira R, Pires-Oliveira D (2016):** Effects of whole body vibration on bone mineral density in postmenopausal women: a systematic review and meta-analysis. Osteoporos Int., 27(10):2913–33
22. **Maher C, Underwood M, Buchbinder R (2017):** Non-specific low back pain. Lancet, 389(10070):736–47.
23. **Wirth B, Zurfluh S, Muller R (2011):** Acute effects of whole-body vibration on trunk muscles in young healthy adults. J Electromyogr Kinesiol., 21(3):450–7.
24. **Perchthaler D, Hauser S, Heitkamp H *et al.* (2015):** Acute effects of whole-body vibration on trunk and neck muscle activity in consideration of different vibration loads. J Sports Sci Med., 14(1):155–62.
25. **Ryan J, Cassidy E, Noorduyn S *et al.* (2017):** Exercise interventions for cerebral palsy. Cochrane Database Syst Rev., 6:CD011660.
26. **Stark C, Duran I, Schoenau E (2020):** Pediatric Rehabilitation in Manual of Vibration Exercise and Vibration Therapy. https://ouci.dntb.gov.ua/en/works/9j8QyPN4/
27. **Ritzmann R, Stark C, Krause A (2018):** Vibration therapy in patients with cerebral palsy: a systematic review. Neuropsychiatr Dis Treat., 14:1607–25.
28. **Rosenbaum P, Stewart D (2004):** The World Health Organization International Classification of Functioning, Disability, and Health: a model to guide clinical thinking, practice and research in the field of cerebral palsy. Semin Pediatr Neurol., 11(1):5–10
29. **Marwa M, Ibrahim A, Mohamed A *et al.* (2014):** Effect of whole-body vibration on muscle strength, spasticity, and motor performance in spastic diplegic cerebral palsy children. Egyptian Journal of Medical Human Genetics, 15: 173-179.
30. **Yabumoto T, Shin S, Watanabe T *et al.* (2015):** Whole-body vibration training improves the walking ability of a moderately impaired child with cerebral palsy: a case study. Journal of Physical Therapy Science, 27(9): 3023-3025.
31. **Cheng K, Yu C, Wong K *et al.* (2015):** Effects of an eight-week whole body vibration on lower extremity muscle tone and function in children with cerebral palsy. Research in developmental disabilities, 38, 256-261.
32. **Wirth B, Brichta L, Schrank B *et al.* (2006):** Spinal muscular atrophy: from gene to therapy. Semin Pediatr Neurol., 13(2):121–131.
33. **Stark C, Duran I, Cirak S *et al.* (2018):** Vibration-assisted home training program for children with spinal muscular atrophy. Child Neurol Open, 5:2329048X18780477.
34. **Ruck J, Chabot G, Rauch F (2010):** Vibration treatment in cerebral palsy: A randomized controlled pilot study. Journal of Musculoskeletal Neuronal Interactions, 10(1): 77–83.
35. **Matute-Llorente A, Gonzalez-Aguero A, Gomez-Cabello A *et al.* (2014):** Effect of whole-body vibration therapy on health-related physical fitness in children and adolescents with disabilities: A systematic review. J Adolesc Health., 54(4):385–396.
36. **Krause A, Schonau E, Gollhofer A *et al.* (2017):** Alleviation of motor impairments in patients with cerebral palsy: Acute effects of whole-body vibration on stretch reflex response, voluntary muscle activation and mobility. Front Neurol., 8:416.
37. **Stark C, Hoyer-Kuhn H, Semler O *et al.* (2015):** Neuromuscular training based on whole body vibration in children with spina bifida: A retrospective analysis of a new physiotherapy treatment program. Childs Nerv Syst., 31(2):301–309.
38. **Fidler D, Hepburn S, Mankin G *et al.* (2005)**: Praxis skills in young children with Down syndrome, other developmental disabilities, and typically developing children. Am J Occup Ther., 59:129Y38.
39. **Eid M, Aly S, Mohamed R (2018):** Effect of twister wrap orthosis on foot pressure distribution and balance in diplegic cerebral palsy. J Musculoskelet Neuronal Interact., 18(4):543-550.
40. **Villarroya M, González-Aguero A, Moros T *et al.* (2013):** Effects of whole body vibration training on balance in adolescents with and without Down syndrome. Res Dev Disabil., 34(10):3057–3065.
41. **Sandler D (2010):** Children with spina bifida: key clinical issues. Pediatr. Clin. N. Am., 57 879–892.
42. **Rossi A, Biancheri R, Cama A *et al.* (2004)**: Imaging in spine and spinal cord malformations. Eur. J. Radiol., 50 177–200.
43. **Vinck A, Nijhuis-van der Sanden M, Roeleveld N *et al.* (2010):** Motor profile and cognitive functioning in children with spina bifida. Eur. J. Paed. Neurol., 14 86–92.
44. **Szopa A, Domagalska-Szopa M, Siwiec A *et al.* (2021):** I. Effects of whole-body vibration-assisted training on lower limb blood flow in children with myelomeningocele. Front Bioeng Biotechnol., 9:601747.
45. **Emara H (2014):** Effect of whole body vibration on bone mineral density in children with myelomeningocele. Dent. Med Sci., 13:47–51.
46. **Christova M, Rafolt D, Mayr W *et al.* (2010):** Vibration stimulation during non-fatiguing tonic contraction induces outlasting neuroplastic effects. J. Electromyogr. Kinesiol., 20:627–635.