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Whole-Body Vibration to Enhance Skeletal Muscle Performance and Flexibility in Healthy Adults: A Narrative Review

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SUMMARY

Background. Flexibility and muscular performance assist in maintaining posture, encourage effective movement, prevent improper body alignment, maintain proper muscle length and balance, and also lower the chance of injury. The neuromuscular training technique known as whole-body vibration (WBV) has recently gained favor in health and fitness facilities. WBV has long been utilized as a non-invasive, physical therapy aid in rehabilitation, to improve muscle performance (strength, power, and endurance), encourage bone formation, and decrease the risk of injury.
Objective. The possibility of WBV exercise as a helpful and secure strategy for enhancing muscular performance and flexibility was therefore examined in the current review.
Methods. The current narrative review used a search strategy and conducted a literature search in January 2023, retrieving data from the following databases: Web of Science, PubMed, Scopus, and Google Scholar.
Results. Recommendations on how to increase muscle performance and flexibility, lower the chance of injury, and generally improve the overall quality of life are provided by the majority of the selected literature.
Conclusions. The usage of this paradigm in practice increases muscle performance and flexibility in both healthy adult athletic and non-athletic subjects is proposed.

KEY WORDS

Muscle performance; flexibility; whole body vibration training; risk of injury; healthy adult subject.

INTRODUCTION

The human body is subjected to whole-body vibration (WBV) through a variety of daily activities, such as operating industrial machinery, flying in airplanes, and driving cars. Ergonomists have previously pointed out the negative impacts of WBV on the human body (1, 2). However, in the last few decades, vibratory massagers have become more widely employed in massage therapy and in training sessions to improve muscle performance (3-6). In addition to or instead of conventional training and therapy, WBV exposure is a neuromuscular training technique that can be used in addition to or instead of conventional training and therapy. It has lately gained popularity in the healthcare sector, local gyms, and fitness and rehabilitation facilities (7-11). This is because WBV intervention has been shown to increase muscle power and strength in both athletic and non-athletic individuals (11-14), improves flexibility (15, 16), and provide additional medical benefits such as for COVID-19 patients (17, 18). A vibrating platform exposes a person's body to low frequency, low amplitude mechanical stimulation during WBV. According to the tonic vibration reflex (TVR), the vibration stimulates the muscle spindles and transmits nerve signals to begin muscular contractions (19).

Either a vibrating hand-grip device (Hand Arm Vibration) or a vibrating platform on which the subject is required to sit or stand (Whole-Body Vibration) can be used to undertake vibration training. The two primary categories of vibrating platforms are platforms that vibrate in a vertical direction (vertical platform) and platforms that vibrate by rotating in a horizontal direction (oscillating platform) (20, 21). There are primarily two ways to apply vibration to the targeted muscles: directly or indirectly. Vibration can be applied directly to the participant's tendon or the belly of the muscle when using the direct technique of application through vibrating units such as a vibrating pully or dumbbell (22). While in the indirect technique of application, vibration is applied to the subject's muscles from a vibrating source that is located far from the muscles being targeted (23, 24). Researchers' interest in WBV therapy as a means of managing patients with musculoskeletal conditions has recently been renewed, but the usefulness of short-term WBV training in improving lower-limb muscle strength, power, bone mineral density, and functional capacity, as well as in preventing falling in the healthy adult subjects is limited in the literature (25, 26). For improving balance and strength and preventing falls, WBV training has been shown to be more effective than balance training alone when combined with a supplementary exercise program (27, 28). Moreover, with the aid of sEMG recordings, multiple investigations have shown that applying (WBV) intervention acutely enhances muscle activity during exposure (29-31). Even though previous research has shown that WBV has positive effects on improving muscle performance and flexibility in the general population, the current review sought to determine whether WBV exercise has the potential to be a helpful and safe intervention for enhancing muscle performance (strength, power, and endurance) and flexibility in healthy adult subjects (athletes and non-athletes) in order to reduce the risk of injury and improve the overall quality of life.

MATERIALS AND METHODS

Search strategy

The protocol used for the literature search for the current narrative review was as follows:

- Potential effects of the WBV exercises on skeletal muscle performance (strength, power, and endurance) in healthy adult athletes and non-athletes.
- Potential effects of the WBV exercises on skeletal muscle flexibility in healthy adult athletes and non-athletes.

Literature search

The sources indicated in **table I** were used to compile the information required to produce this narrative literature.

Potential effects of the WBV exercises on skeletal muscle performance (strength, power, and endurance) in healthy adult athletes and non-athletes

Strength, power, and endurance are the three main components of muscle performance, which is the ability of muscles to accomplish work. The ability of a muscle or muscle group to exert force to overcome the greatest amount of resistance in a single effort is known as muscular strength. Work performed per unit of time is referred to as power. The capacity of a muscle or muscle group to exert force repeatedly to overcome resistance is known as muscular endurance (32). The foundation of vibration training is the capacity to increase muscle strength. Previous research demonstrated that the WBV technique is constantly evolving and improved up on. It can be used to improve the amount of force that a muscle group can exert to overcome resistance in healthy adults (33). As shown in **table II**, a study conducted by Osawa *et al*. (34), showed that body weight vibration exercise did not significantly improve

Table I. The sources consulted to create this narrative literature.

Sources
□ Google Scholar search 1968-2023. Keywords: Muscle Performance, Flexibility, Whole body vibration Training, Healthy adult subjects, Athletes, Non-athletes
□ PubMed search 1970-2023. Keywords: Muscle Performance, Flexibility, Whole body vibration Training, Narrative review, Healthy adult subjects
□ Web of Science search 2019-2023. Keywords: Muscle Performance, Flexibility, Whole body vibration Training, Healthy adult subjects
□ Scopus search 2019-2023. Keywords: Muscle Performance, Flexibility, Whole body vibration Training, Healthy adult subjects
□ Hand searches of the obtained literature's references
□ Examining books and research articles on vibration effect on muscle performance and flexibility in personal and academic libraries
□ Discussions with professionals in the fields of physical therapy and rehabilitation

muscular performance in healthy untrained young individuals after 12 weeks of exercise. This may return to the shorter time of exposure, which might have provided insufficient load and stimulation to have an impact on the lower extremity muscles' strength and endurance. On the other hand, Osawa and Oguma (35) found that adding WBV to a slow-velocity resistive training program during the first stage of regular resistive training in untrained healthy adults resulted in a significant additional increase in maximal isometric and concentric knee extension and lumbar extension strength. In addition, a study conducted on recreationally active young adults showed that 8 weeks of combined WBV and resistance training did not result in a greater improvement in muscular performance than a similar exercise regimen without vibration. Also, there was no effect on isokinetic strength or muscle power. The authors reported that the displacements produced by the vibrating platform were 2.5 and 5 mm, and frequencies at 35-40 Hz were only used during the latter two weeks of the intervention. Lack of assessment-exercise specificity may make it more difficult to spot significant changes, particularly when training time is short and with only a few subjects in each group (36).

Furthermore, a study on young, healthy, active men shows that a WBV intervention involving six sets of 60 seconds each resulted in better muscular performance as detected by squat jump, countermovement jump, and power output (37). A review article by Alam *et al*. in 2018 found that WBV improve muscle strength, power, and flexibility (38). Range of amplitude and frequency, type of vibration and application method, training intensity, exercise regimen, and participant characteristics are the primary variables linked to an improvement in muscle performance. Besides, a study was conducted on recreationally active students to detect the effects of varying foot-based vibration intensities on the number of repetitions completed, the mean speed, and the perceived effort during a set of elbow-extension exercises. The results of this study indicate that upper body resistance training can be enhanced by applying vibrating stimulation to the feet (39). Additionally, a study on young competitive artistic gymnasts found that a single bout of WBV training using various execution methods for three exercises with a total duration of 2 minutes improved lower limb flexibility and explosive strength and maintained the initial level of performance for at least 15 minutes after the WBV intervention program (40). A study on sub-elite male volleyball and beach volleyball players found that adding 6-week WBV training to regular practice increases leg strength and improves jump performance more than traditional strength training (41). In addition, a study that included high-level rhythmic female gymnasts found that single bout whole body vibration was superior to an equivalent exercise program performed without vibration

Table II. Intervention parameters in the included studies that enhance muscle performance.

Author	Participants (number, age)	Category	Study design	Frequency (Hz)	Amplitude (mm)	Vibration type/device	Position of exercise	Intervention Protocol	Footwear	Effect of vibration
Osawa *et al*., 2011(34)	19 untrained healthy males and females (11 females, 8 males, 21-39 years old)	Untrained healthy men and women	A randomized controlled trial design	30, 35, 40	2	Whole platform-oscillating device (Power Plate® Next Generation, Power Plate International, Northbrook, IL, USA)	4 lower extremities and 4 trunk exercises	12-week WBV, 2-3 sets, twice weekly for 30 sec/set, with rest periods of 60 sec (total time of vibration 6.5 minutes)	No shoes, with socks	No significant effect
Osawa and Oguma, 2011 (35)	33 untrained healthy males and females (6 males (M) and 27 females (F), 22-49 years old)	Untrained healthy males and females	A randomized controlled trial design	35	2	Power Plate® Next Generation, Power Plate International, Northbrook, IL, USA	8 lower extremities, hip, and trunk exercise positioning	The training procedure involved two lower extremities (squats) and six trunk exercises containing 4 sec for concentric and 2 sec without relaxing period followed by 4 sec for eccentric in the cadence. The roll-back and hip walking exercises, 64 and 48 sec without any isometric exercise phase, respectively.	No shoes, with socks	Significant effect

Author	Participants (number, age)	Category	Study design	Frequency (Hz)	Amplitude (mm)	Vibration type/device	Position of exercise	Intervention Protocol	Footwear	Effect of vibration
Artero *et al.*, 2012 (36)	A group of 29 young adults (25 men, 4 women; age 21.8 ± 1.5)	Recreationally active young adults	Cross-over study	20, 25, 30, 35, 40	2.5, 5	A synchronous vibration (also called vertical) vibrating platform (Fitvibe Excel; N.V. GymnaUniphy, Bilzen, Belgium)	Standing position with half-squat exercises	8 weeks at a frequency of two times per week, with at least 1 day of rest period between sessions. Each training period lasted 35-40 min	Gymnastic shoes	No significant effect
Da Silva-Grigoletto *et al.*, 2011 (37)	Total number 57, age: 19.4 ± 1.6 years	Young, healthy physically active men	Randomized Trial	30	4	Vibrating platform producing sinusoidal oscillations (Nemes, Ergotest, Rome, Italy)	Isometric squat position	In phase 1, 3 sets of various durations (30, 60, and 90 seconds), whereas in phase 2, subjects experienced 3 interventions where the duration remained fixed at 60 seconds, and the number of sets achieved (3, 6 or 9) was modified. The recovery time among sets was set at 2 minutes	Sport shoes	Significant effect
Marín *et al.*, 2010 (39)	Total number 20 (14 men and 6 women), age 18.9 ± 0.8 years	Recreationally active students	Not mentioned	50 30	2.41 1.15	Uniform vertical oscillations Power Plate® Next Generation (Power Plate North America, Northbrook, IL, USA)	Squat position (30° knee flexion)	5 weeks with 1 testing session each week (a) High magnitude (HM) of vibration stimuli, the elbow-extension set was completed with overlaid vibration at 50 Hz and peak-to-peak vibration amplitude 2.41 mm; (b) low magnitude (LM) of vibration stimuli, the elbow-extension set was achieved with overlaid vibration at 30 Hz and peak-to-peak vibration amplitude 1.15 mm (LM)	Athletic shoes	Significant effect
Dallas *et al.*, (2014) (40)	Total number 32 (15 males and 19 Females), age 9.22 ±1.34 years	Young competitive artistic gymnasts	Randomized study	30	2	Vertical sinusoidal mechanical WBV (Power Plate North America, Northbrook, Illinois)	Standing position	A single session of WBV training using various execution forms of three exercises of total time 2 min. Training load on the vibration platform was as follows: two sets of 30 s for the 1st exercise and one set of 30 s for the 2nd and 3rd exercises with a rest of 30 s, to provide a suitable time for relaxation	Gymnastics shoes	Significant effect

Author	Participants (number, age)	Category	Study design	Frequency (Hz)	Amplitude (mm)	Vibration type/device	Position of exercise	Intervention Protocol	Footwear	Effect of vibration
Pérez-Turpin *et al.*, 2014 (41)	Total number 23 (12 male volleyball and 11 beach volleyball players)	Sub-elite male volleyball and beach volleyball	Randomized study	30-40	1.7-2.5	Vibration platform (Power Plate®, Power Plate International Ltd., London, UK)	Standing, squat, one-leg squat	The WBV training technique involved performing 4 sets × 30-second spurts of each exercise with WBV with a 2 minutes recovery after each repeat, 3 days a week, for 3 weeks. For the following 3 weeks, the duration of repetition was increased to 60 seconds	Not mentioned	Significant effect
Despina *et al.*, 2014 (42)	Total number 11, age 17.54 ± 0.52 years	Elite female rhythmic gymnasts	Cross-sectional study	30	2	Side-to-side alternating vertical sinusoidal mechanical vibration Galileo 900 platform (Galileo Fitness, Novotec, Germany)	Standing	The participants were exposed to WBV training using different implementation forms of five exercises each one lasting for 15 s for a total time of 75 s	Gymnastics shoes	Significant effect
Rønnestad *et al.*, 2012 (43)	Total number 12, age 24 ± 5 years	National-level, drug-free, male powerlifters	Randomized study	50	3	Vibration platform synchronously produced the vibration stimulus (Pneu-Vibe Pro, Pneumex, Inc. Sandpoint, ID, USA)	Standing in an erect position with the external load on their shoulders then squat	An acute bout of vibration was exchanged immediately after the participants were standing in an erect position with the external load on their shoulders (65 kg-100 kg)	Hard heel weightlifting shoes	Significant effect
Annino *et al.*, 2017 (44)	Total number 20, age 24.8±2.5 years	Young college male students	Randomized study	35	5	Vertical sinusoidal WBV (Nemes LC; Boscosystem, Rieti, Italy)	Stood on the vibration platform in half squat position	The vibration protocol consisted of 2 sets of five 60-second repetitions separated by 60seconds of passive recovery with resting periods between sets of 5minutes (10minutes of WBV, 25minutes all session)	Not mentioned	Significant effect

in terms of the short-term effect on performance in flexibility, strength, and a number of balance tests (42). Moreover, in a study applied to national-level, drug-free, male powerlifters, the findings of this study imply that in well-trained people, such as powerlifters, the administration of WBV50Hz acutely boosts peak power production during squat jump. This increase in power was followed by a rise in the quadriceps muscles' EMG activity (43). According to a study conducted on young male college students, 10 minutes of WBV had an impact on their flexibility and explosive strength performance by inhibiting antagonist muscles more than agonist muscles, which are involved in the stretch reflex (44).

Potential effects of the WBV exercises on skeletal muscle flexibility in healthy adult athletes and non-athletes

Aging-related changes in tendons and ligaments, as well as sedentary lifestyles, limit joint mobility and reduce flexibility. At least one expert recommends the regular practice of flexibility activities like yoga and stretching. To increase the range of motion of a joint, vibration, transcutaneous electrical nerve stimulation, and heated packs are frequently used as exogenous stimulation to skeletal muscles or tendons around the joint (45). The essential mechanism of vibration in enhancing muscle flexibility is presynaptic inhibition of group Ia afferent fibers or a "busy line" phenomenon that is formed when vibration stimulation and stretching influence the same Ia pathways. Additionally, combining a strong stretch stimulus with vibration may activate the Golgi tendon organ through Ib pathways, inhibiting the vibrated muscle's autogenic response (46 ,47).

Only a small number of experiments have addressed the use of mechanical vibration to increase flexibility (40, 42, 44) These studies have shown that vibration can improve flexibility, but more research is needed to confirm these findings as shown in **table III** and mentioned before in improving muscle performance. Similarly, as included in **table III**, another study detected a significant improvement in flexibility by applying three vibration procedures (VP4, VP6, and VP8) with peak-to-peak vibration amplitudes of 4 mm, 6 mm, and 8 mm and one control protocol (CP) for a total of 6 minutes. In addition, the frequency study included a control protocol (CP) for 6 minutes with a peak-to-peak vibration amplitude of 6 mm as well as three vibration protocols (VP15 Hz, VP20 Hz, and VP30 Hz) at 15 Hz, 20 Hz, and 30 Hz in the same study (48).

Also, the most recent study that investigated the effect of mechanical vibration on flexibility is the literature review conducted by Đorđević *et al.* (49) determined that artistic gymnasts' flexibility has improved as a result of using a WBV platform in both males and females. Additional-

Table III. Intervention parameters in the included studies that enhance muscle flexibility.

Author	Participants (number, age)	Category	Study design	Frequency (Hz)	Amplitude (mm)	Vibration type/device	Position of exercise	Intervention Protocol	Footwear	Effect of vibration
Dallas *et al.*, (2014) (40)	Total number 32 (15 males and 19 Females), age 9.22 ± 1.34 years	Young competitive artisticgymnasts	Randomized study	30	2	Vertical sinusoidal mechanical WBV (Power Plate North America, Northbrook, Illinois)	Standing position	A single session of WBV training using various execution forms of three exercises of total time 2 min. Training load on the vibration platform was as follows: two sets of 30 s for the 1st exercise and one set of 30 s for the 2nd and 3rd exercises with a rest of 30 s, to provide a suitable time for relaxation	Gymnastics shoes	Significant effect

Author	Participants (number, age)	Category	Study design	Frequency (Hz)	Amplitude (mm)	Vibration type/device	Position of exercise	Intervention Protocol	Footwear	Effect of vibration
Despina *et al.*, 2014 (42)	Total number 11, age 17.54 ± 0.52 years	Elite female rhythmic gymnasts	Cross-sectional study	30	2	Side-to-side alternating vertical sinusoidal mechanical vibration Galileo 900 platform (Galileo Fitness, Novotec, Germany)	Standing	The participants were exposed to WBV training using various execution forms of five exercises each one lasting for 15 s for a total time of 75 s	Gymnastics shoes	Significant effect
Annino *et al.*, 2017 (44)	Total number 20, age 24.8±2.5 years	Young college female students	Randomized study	35	5	Vertical sinusoidal WBV (Nemes LC; Boscosystem, Rieti, Italy)	Stood on the vibration platform in half squat position	The vibration procedure consisted of 2 sets of five 60-second repetitions parted by 60seconds of passive recovery with resting periods between sets of 5 minutes (10minutes of WBV, 25 minutes for all session)	Not mentioned	Significan effect
Gerodimos *et al.*, 2010 (48)	Total number 43 (25 in 1st study and 18 in 2nd study), (age: 20.5 ± 1.7 years in 1st study and (age: 20.2 ± 2.0 years in 2nd study)	Healthy and physically active female subjects	Randomized balanced design	25 15, 20, 30	4, 6, 8 6	Side-to-side alternating vertical sinusoidal vibrating platform (Galileo Fitness, Novotec, Germany)	Maintained an upright position with their knees flexed at 170- and their feet in full contact with the platform	The participants in the amplitude study experienced three vibration protocols (VP4, VP6, and VP8) with amplitudes of 4 mm, 6 mm, and 8 mm and one control procedure (CP) for a total of six minutes. The frequency study included a control protocol (CP) for 6 minutes, 6 mm as well as three vibration protocols (VP15 Hz, VP20 Hz, and VP30 Hz) at 15 Hz, 20 Hz, and 30 Hz	Non-slippery socks	Significant effect
Lim and Park, 2019 (51)	Total number 20 (14 Male and 6 Female), aged 20.21 ± 1.01 for the vibration group and 21.72 ± 2.16 with the non-vibration group	College students participated in this study	Randomized control trial	30	Not mentioned	Foam roller with vibration	Sitting on the floor	The application of a foam roller with vibration to the hamstring for 1 min 5 times for a total of 10 min	Not mentioned	Significant effect

Author	Participants (number, age)	Category	Study design	Frequency (Hz)	Amplitude (mm)	Vibration type/device	Position of exercise	Intervention Protocol	Footwear	Effect of vibration
Azizi *et al.*, 2021 (52)	Total number- 56, aged 23.82 ± 3.17 years	Healthy young women	Randomized control trial	30	2	The platform of the Power plate	Standing with bending knees (about 20 degrees) while their legs were open as much as the shoulder width	Each participant was treated in three 30-second sets with 30 seconds of rest between each set. WBV platforms transmit vibrations in two ways. The first type is synchronous, which transmits vibration to both legs simultaneously and applies a straight linear acceleration to the trunk. The second type is side-alternating, which transmits vibrations intermittently, so when the right leg is at the lowest amplitude level, the left one is at the highest	Without shoes and socks	Significant effect

ly, combining typical static stretching with WBV may help artistic gymnasts become more flexible. However, care should be taken when interpreting these findings. Further studies are necessary since this evaluation did not identify the most effective vibrational procedure, and time should be considered to develop several vibrational experimental methods. According to another study, the best acceleration for boosting flexibility was between 5 and 10 g. Although there is a lack of published data on muscle and tendon stiffness, what is known is that accelerations below 6.4 g were the most effective, despite the fact that WBV is normally substantially less successful at building stiffness than at increasing flexibility (50). In a study conducted by Lim and Park (51), on young healthy adults, active straight leg raising and active knee extension tests significantly improved with the use of a vibrating foam roller with a frequency of 32 Hz, and hamstring flexibility also increased. Another study was conducted on healthy young women using WBV with muscle energy technique (MET) to detect their effect on flexibility and hamstring muscle stiffness, the results of this study demonstrated that a single WBV and MET session improved hamstring flexibility and reduced stiffness, although there was little difference in the effectiveness of the two techniques (52).

DISCUSSION

A review study of the available literature has been conducted based on the effects of various WBV applications on the population of healthy adult athletes and non-athletes at various frequencies, intensities, and application methods. Studies on the impact of WBV on the performance of skeletal muscles have highlighted the importance of vibration as a tool for enhancing muscle power, strength, and endurance. Only a small number of studies (2 studies out of 10 chosen studies) revealed a non-significant impact of vibration on muscle performance (34, 36). The lack of load and stimulation at the time of exposure may have prevented any non-significant effects from having an impact on the strength and endurance of the muscles in the lower extremities. Furthermore, when training time is limited and there are few participants in each group, a lack of assessment-exercise specificity may make it more challenging to detect substantial changes.

In the other 8 selected studies (35, 37, 39-44) the significant improvement in muscle performance due to the WBV returned to neural adaptation enhancement during the initial phases of training. Despite the fact that the precise processes are still unknown, the additional gain in knee extension strength seen in the resistive training with WBV group implies that WBV may be a useful workout stimulus for beginners

(35). For exercises involving explosive motions, such as jumping as a warm-up exercise, WBV training is advised. The best dose-response relationship for this approach is still unknown, though. The frequency and peak-to-peak displacement of WBV have been the subject of numerous studies that have concentrated on the short-term effects of WBV on boosting muscle responsiveness. The ideal time frame and quantity of sets for reaching this goal are still unknown. Jumping ability and power performance can be improved by performing 6 sets of 60 seconds each. Coaches may want to consider employing WBV despite the fact that its impact on performance is probably variable and negligible for the majority of athletes due to the potential benefit it may have when the WBV time is optimized (37). In addition, compared to standard strength training, the incorporation of 6-week WBV training into everyday practice by volleyball and beach volleyball players develops more leg strength (41). Furthermore, when compared to the no-WBV condition, introducing acute WBV (50 Hz) during loaded squat jumps causes well-trained participants like powerlifters to produce more peak power through the stimulation of the neuromuscular system during overloaded power exercise (43).

Vibrating stimulus not only affect the performance of lower limbs, but vibration delivered to the foot may enhance upper body resistance workout performance. They also show that higher vibrations generate bigger advancements than lower vibrations. Fitness and exercise practitioners can use a high magnitude of vibration in the lower body to enhance upper body muscle function. Even when certain upper body workouts are not possible with direct vibration exposure, these discoveries can increase the utilization of vibration in the upper body (39).

Additionally, WBV affects not only muscle performance but also ligament, tendon, and muscle flexibility. All of the studies included in the review revealed that WBV has a beneficial effect on muscle flexibility. Athletes with a high degree of lower limb flexibility and explosive strength may see a sharp effect from employing WBV. Additionally, WBV might be useful as a pre-training exercise in gymnastics sports where muscle strength and flexibility are key components. Young artistic gymnasts who trained for 120 seconds using WBV showed larger improvements in lower limb flexibility and explosive strength than those who trained with standard body weight (40). An acute bout of WBV can improve an athlete's flexibility; this improvement in flexibility following WBV suggests that the vibration exposure may have activated the Ia inhibitory interneurons of the antagonist muscle (42, 44, 53). Additionally, under specific circumstances, a single WBV bout may dramatically enhance flexibility, which is maintained for at least 15 minutes. The size of this benefit is independent of frequency and amplitude (48). Also, the hamstring's flexibility and stiffness might both be improved after just one session of WBV and muscular energy technique (MET) (52).

Moreover, a different type of vibration training, like using a foam vibration roller rather than a WBV platform, seems to significantly improve muscular flexibility. Below 20 Hz vibrations create excessive relaxation, above 50 Hz vibrations cause muscle discomfort, and between 20 and 50 Hz vibrations would be therapeutic (51, 54). According to a study, using a vibrating foam roller with a 30-50 Hz vibration improved the hip joint range of motion and pain (55) by boosting muscular strength and increasing the sensitivity of involuntary relaxation caused by the tonic vibration reflex, the muscles' activation appears to promote flexibility. Furthermore, The FRV increased the ankle joint's range of motion and reduced discomfort among university students (56, 57). Also, a study conducted by Mukhtar *et al*. (58) showed that construction industry employees may benefit from vibration treatment. The neuromuscular performance and flexibility, grip power, and grip endurance time may all be improved by this therapy. Additionally, Zazula *et al*.'s basic research study (59) supports the significance of vibration therapy in improving muscular flexibility and malleability.

The studies included in the review used a variety of parameters, including frequency, amplitude, duration, and method of application. Future studies should focus on identifying the optimal parameters for improving muscle performance and flexibility. Additionally, it would be beneficial to have consistency in study protocols and methodology to allow for better comparison of results across different studies.

The acute effects of WBV have been extensively investigated, but there is still a lack of research on the long-term effects. The review found that WBV can improve muscle performance and flexibility in major muscle groups in the upper and lower extremities. However, more research is needed to investigate the effects of WBV on other muscle groups during dynamic activities in athletic and non-athletic population.

CONCLUSIONS

The majority of the studies included in the review indicate that WBV training can improve muscle performance and flexibility in both athletes and nonathletes. This low-cost and safe therapeutic modality can enhance muscle performance, reduce the risk of injury, and improve the overall quality of life by using different frequencies, amplitudes, durations, and methods of application.

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DATA AVAILABILITY

N/A.

CONTRIBUTIONS

MA: writing – original draft, writing – review & editing, studies selection, data analysis, methodology, final approval.
AA: writing – review & editing, studies selection, data analysis, results evaluation, final approval.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

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