Review Article

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Physiotherapy Section

Whole Body Vibration for Athletes: An Evidence Informed Review

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ABSTRACT

Whole Body Vibration (WBV) is a well-known modality which is increasingly being used by athletes to improve their conditioning levels. Muscle strength and power are major health related fitness components that contribute to marked success in athletic events. Recently, this exercise modality has been utilised by number of researches to investigate its role and efficacy in muscular conditioning. Muscle strength and power have been found to significantly increase when WBV is added to the conventional exercise program but the mechanism by which this strength and power increases has not been well documented. The present review aimed to highlight the impact of WBV on muscle strength, power, muscle activity, and the mechanism by which these gains occur in athletic populations.

Keywords: Counter movement jump, Muscle activation, Strength, Vibration therapy

INTRODUCTION

Strength is one of the various physiological and conditioning components contributing to a successful athletic and sports performance, and it is also a significant health-related fitness parameter [1]. External forces are encountered during daily activities that have the potential to induce vibrations inside the bodily tissues. The body has a mechanism to dissipate and regulate these external forces' transmission via its structures, viz., joint kinematics, synovial fluid, bone, soft tissues, and cartilage and muscle activity [2] . The detrimental effects of these vibrations are countered by the fine-tuning of the muscular activity, and it helps in reducing the amount of vibration passing through these structures [2].

These vibrations are primarily transmitted when the heel strikes the ground during running activity or when it is hit in racquet sports. The vibration stimulus spreads towards the axial skeleton and also ascends cranially. With the input of continuous vibrations, the soft tissues in the human body oscillate at the same frequency synchronous with the input frequency. Stiffness and mass are determinants of the natural frequency of the system. Muscle stiffness is proportional to the cross-bridge formation in the muscle. The amount of muscle activity required to counter the effects is directly proportional to the applied external vibration stimulus. To dampen and eliminate the tissues' oscillations, the muscle needs to be maximally activated [3].

WBV involves a method of training that uses mechanical vibrations that transmit through the body of the individual who is standing statically or dynamically on the vibrating platform [Table/Fig-1]. WBV device uses three systems: 1) vertical vibration, which includes a vertical translation of the whole plate up and down; 2) reciprocating displacements moving the right and left side of the fulcrum enhancing the lateral accelerations; 3) horizontal anteroposterior oscillations. The amplitude, magnitude, frequency, duration, and body position are the biomechanical parameters used in the WBV training [4-8]. The effects of WBV can be altered by manipulating the amplitude (mm, peak- to- peak vertical displacement), frequency (rate of repetition, number of impulses/second), duration (seconds or minutes, time spent on equipment) [3]. Direct application of vibration therapy involves using portable vibration devices that can be directly applied to the area of the body where effects are desired. The direct application is more suited to reduce pain levels. The indirect application of vibration therapy occurs when vibrations are transferred to the whole body by standing/sitting on the vibration platform [9]. A strong analogy of the WBV device can be drawn with an inverted pendulum. The inverted pendulum is where the bob (human body) is directly above the pivot (standing platform). This inverted position's stability is strongly dependent on the feedforward control system, which prevents the pendulum from falling and keeps it balanced. The platform's micro displacement in the form of oscillations is innately counterbalanced by the heightened muscle activity in the body [10].

WBV is one of the devices used for accelerated strength and other conditioning gains. This work aimed to describe the impacts of WBV training on muscle strength, power gains, muscle activity (EMG), and second to discuss the possible mechanisms underlying WBV effects.

PROPOSED MECHANISMS FOR THE EFFECTS OF WBV

With WBV gaining popularity amongst coaches and athletes, it is increasingly used along with resistance training to improve muscle strength. The laws of motion given by Sir Isaac Newton govern the WBV function: specifically, the law that states that force is equal to the product of mass and acceleration. WBV increases the acceleration component by oscillating and giving waves in a rhythmic sinusoidal pattern.

The WBV effects are because of five plausible physiological mechanisms [11]:

a) Tonic Vibration Reflex (TVR)

The vibration-induced discharge of type Ia afferents fibers provides an excitatory stimulus to the alpha motor neurons that elicits a reflex contraction. The polysynaptic pathway mediated excitatory stimulus converges onto the monosynaptic excitatory inputs. The frequencies in the spectrum of 20-200 Hz can generate TVR responses. Another important factor responsible for the TVR is the amplitude of the vibrating plate. Studies have shown that the cut off point for evoked reflex was 0.6 mm; however, higher TVR has also been reported with greater amplitudes [12-14].

The vibrations evoke muscle contractions while the individual is performing the static or dynamic exercise. The mechanical vibration causes a repeated alteration in the myotendinous unit's muscle length, which results in activation of the sensory receptors that modulate the muscle through reflex muscular activity. This reflex muscular activity (to dampen the vibration waves) works through the stretch reflex hoop and spindles. These contractions explain the increased muscular activity seen in EMG of the muscle [2,15].

Furthermore, strength increase can be attributed to the increased force-generating capability of muscles following hypertrophy and increased number of cross-bridge formation in myofilaments following WBV training [16,17].

b) Storage of Elastic Potential Energy

The sinusoidal vibrations are added as potential energy into the musculotendinous unit itself by the unique stimulus of WBV. This energy is converted to kinetic energy and is a rationale for increasing Countermovement Jump height (CMJ) [2]. The potential energy absorbed from the WBV device is primarily stored in the series (tendons) and parallel (sarcolemma, endomysium, perimysium, capsule) elastic components of the muscle apparatus according to the Hill model [18]. The stretching and back and forth movement results in action-reaction (Newton's third law) in agonist and antagonist muscles, which ideally are used to optimize control of the neuromuscular system. Subsequently, upon movement, the stored potential energy is added to the active muscle contraction. This conversion into movement and hence function represents the kinetic energy component. This kinetic energy can be further subdivided into linear and rotational kinetic energy. These are necessary for the generation of angular momentum required for a joint movement like in CMJ [6].

c) Proprioceptive Feedback Loop

The proprioceptive feedback loop is the basis of greater force production as the loop mechanism becomes more precise and accurate. WBV training helps in neuromuscular adaptation (via proprioceptive facilitation) to increase muscle strength [19]. The primary (Ia) and the secondary (II) afferents innervate the muscle spindles, with Ia afferents being the most excitable amongst the two. Previous research has shown that small amplitudes vibrations (i.e., 0.2-0.5 mm) have a preponderance to stimulate Ia afferents, while the higher amplitudes (1mm-5mm) recruit II afferents [20]. The Ia afferents have frequency specific predilection for frequencies up to 150Hz while the II afferents become active in the 20-60Hz range. Ia afferents' response is not rigid and instead is dependent on the state of the muscle, i.e., stretched, relaxed, or contracted [16]. The gamma motor neurons in stretched muscle position and voluntary isometric contraction have been found to cause higher Ia afferent stimulation. The vibrations mentioned above impact the joint capsule and receptors, due to which there is an increased discharge of gamma neurons that improve the proprioceptive abilities [20].

Increased neuromuscular activation: The sensitivity of the spindle's afferent neurons is increased by standing on the vibration device. This increased sensitivity ultimately leads to alpha motor neuron activation [21]. This activation promotes the increase in the recruitment of motor units and increased firing frequency, leading to a forceful muscle contraction. There is also an increase in the acceleration loading that translates to increased activation of muscles.

d) Vasodilatory Effect

The oscillations produced by the WBV device through the axon reflex and endothelial stress cause reflex vasodilation. The small vessel dilatation increased the mean velocity of the blood in the muscles after exposure to WBV. This is enough for the cascading events to start and result in reduced blood viscosity due to improved blood flow. The training regime of WBV further causes adaptations, whereby there is an increase in the amount of vasodilation specific chemical, i.e., Nitric Oxide (NO) and NO synthase [22]. The widening of the capillaries in the large muscles such as the quadriceps and Gastrocnemius GCM promotes the delivery, transfer and exchange of nutrients and oxygen to the body cells and this optimal delivery of nutrients and also the early removal of lactate helps in better conditioning of the muscle in athletes [23].

e) Metabolic effects of vibration

WBV has been reported to cause responses in concurrence with aerobic exercises. The literature suggests that when WBV is performed to exhaustion, then there is reduced oxygen uptake. The impaired neuromuscular performance due to the onset of peripheral fatigue reduces CMJ height performance. This even became evident with blood lactate level measurement. However, athletes, after recovery from fatigue, regained the CMJ height within 20 seconds. The cardiovascular system can be considered to be mildly loaded by WBV intervention [24]. This form of training might be useful to prevent athletic deconditioning, especially for those who are recovering from musculoskeletal injury and are advised to abstain from sports activity [25,26].

WBV AND POWER GAINS

Power is a beneficial component for many sports, and it is defined as the sudden explosive force generation in a unit of time. Power has been found to increase acutely in amateur and elite athletes. If this increase is practically significant, then it can improve the performance of athletes during play. A study conducted to assess the immediate effects of WBV on muscle performance reported that average power was increased immediately after the treatment in the arm exposed to vibration compared to the control arm [27]. Power gains had been observed following the use of WBV[28,29].

Another research studied the acute effect of vibration on elite and amateur athletes following administration of treatment with vibrating cables (oscillations at 44Hz frequency and 3mm amplitude) during bilateral biceps curls on a pulley machine. An improvement of 10.4% and 7.95% was observed in the elite and amateur athletes, respectively, in maximum power measured during biceps curls exercises [29]. Power gains can also be measured by using a CMJ. Significant improvement was observed for explosive strength and temporal variables after six weeks of WBV. Furthermore, WBV helped healthy individuals to maintain the vertical jump performance (jump height) [30,31]. A study recruited resistance-trained male subjects and demonstrated an increase in explosive power and maximal strength following a vibration platform's use during resistance training [32,33]. Furthermore, a study of female athletes exhibited the effectiveness of low-intensity resistance training as compared to 12 weeks of WBV training using a 2.28 and 5.09 gm of magnitude and 35-40 Hz frequency when CMJ was analysed [33,34].

A comparison of WBV warm-up effects for improving fencer's performance on the power gains was examined in a study. Sixteen male fencers were recruited, and they were submitted to WBV (30 Hz and 2mm amplitude), and recordings at baseline, immediately after intervention and at 1- and 2-minutes time interval postintervention were obtained. The outcome measures for the study were 10m sprint run and CMJ. The study concluded that improvement continued in higher proportion after the cessation of the intervention. Peak power output improved at 1 minute and 2-minute time points by 4.94% and 11.52% and rate of force development by 13.40% and 18.38%, respectively [35]. This study's promising result can be very useful for coaches and trainers who intend to use the WBV device both as a warm-up tool and muscle power enhancer in the limited time available before the event. However, a recent research found no significant improvement in power and strength outcomes in the lower limbs following a five weeks WBV protocol in well-trained sprinters [36].

A limited number of studies are present that have examined the WBV effects for a longer duration (24 weeks). In one of the studies, forty-eight untrained females were recruited and divided into three groups. The WBV group performed unloaded static and dynamic exercises on a vibration platform (35-40 Hz, 2.5-5.0 mm), and it was compared to the fitness training and control group. The ballistic knee extensor strength was equally improved in both groups, i.e., WBV and fitness training group [37]. The CMJ height improvement was observed on similar lines when WBV training was performed (2mm amplitude) for 32 weeks in young non-active individuals [38]. The above-mentioned research suggests that most studies [37,38] reported increased muscle power both for the upper and lower quadrant (CMJ) when athletes underwent a stipulated WBV regime. The muscles' power increased when WBV was used at a frequency of 35-40 Hz, and the regime had to be of sufficient duration. Long duration intervention studies [34,39] have shown promising results for improving power. However, there are few conflicting studies that have concluded nonsignificant difference on muscle power when WBV was combined with resistance exercises (6-10 repetition maximum (RM) or 75%-90% 1RM of training intensities) [32,40].

WBV AND MUSCLE STRENGTH

Muscular strength is defined as the maximum amount of force that a muscle can exert against some form of resistance. In one recent study, the immediate effects of WBV on upper quadrant musculature and testosterone secretion were assessed [41]. The intervention consisted of push-up on the WBV device (30 Hz) and force-time curves was used as an outcome measure. They reported that although the results depend upon individual factors and quantum of training, WBV has an impactful influence on the dynamic work of upper extremity muscle. Several studies have confirmed the immediate beneficial effects and short-term effects of WBV on upper extremity muscles [42,43]. In an additional study, conducted on the upper extremity, collegiate students were administered WBV plus strength training on the right side and strength training alone on the left side three times a week, spanning four weeks. The training intensity was kept at 70% of 1 RM (4 sets of 12 reps). The Biceps Brachii (BB) muscle strength training with the additive effect of WBV demonstrated higher isometric strength gains (43%) than strength training alone (22%) [44].

Strength gains were also observed in well-trained ballerinas (ballet dancers) in quadriceps femoris muscles using a 30- Hz frequency for vibrations as this stimulus induces adaptations in muscles influencing the body's spectrum of strength and power [45]. Gains observed in muscle strength also get translated as performance enhancement in endurance sports. Hence, WBV could also prove to be of great help as an alternative training strategy for long-distance athletes [17]. WBV when compounded with strength training, helped enhance maximum strength production while having no adverse effects on endurance predictors [46]. The WBV exposes the individual standing on a WBV platform to an extra force of 7.7 kg when the platform has a 6 mm peak to peak oscillatory displacement and 30 Hz vibration frequency [24,34]. This creates a counter muscle contraction to stabilise the body segments.

In a study, participants equally divided into two groups were subjected to progressive WBV superimposed on progressive high resistance training and progressive high resistance training alone for six weeks duration. The high resistance exercise included weighted squats, bends, and heel raises. The group in which WBV was superimposed onto exercises showed more significant improvement in plantar flexor muscle strength, which might be suitable for professional sports where particular focus is on calf muscle activity [47].

On the contrary, a study done on normal subjects and those with rotator cuff tendinitis found no difference between the WBV group and resistance training group in the rotator cuff muscle strength when measured in total isokinetic work by the rotator cuff. However, an increment in the rotator cuff muscle strength was seen in both the groups after ten weeks of study [19]. The possible reason for this result could be the lower frequency of the WBV device (<30 Hz) and its amplitude (<4 mm) used in the study, which might not have generated optimal stimulus for muscle reflex contraction.

The research mentioned above suggests that muscle strength improvements are seen when athletes undergo a stipulated WBV regime, and this strength increase does not even cause confounding of the endurance parameters. Optimal stimulus (frequency: 30 Hz and amplitude: 6mm) is necessary for achieving strength gains. Coaches can practically utilise this information for training athletes belonging to both strength and endurance sports.

WBV AND MUSCLE ACTIVITY (EMG)

Muscle activity denotes motor unit recruitment, which on summation would translate into strength gains. However, muscle activity can also be understood or considered a building block of a strength unit. Measurement of muscle activity and strength are different things or and are not synonymous. Limited studies have investigated the effect of WBV on upper body muscle activity. When comparing the surface EMG activity after WBV exposure, most studies have found significantly higher EMG activity. A research study investigated the acute effect of WBV on EMG activity of upper extremity muscles, viz., Serratus Anterior (SA), Upper Trapezius (UT), Triceps Brachii (TB), and BB in a static modified push-up position. In comparison with pre-vibrational status, the results showed increased EMG activity in these muscles by an average of 60%, 206%, 120%, and 106%, respectively [48].

Two researchers reported that WBV increased the EMG activity of TB and BB muscle from 0.3% to 0.7%, and 5 % to 10%, respectively. The subjects held the static biceps curl in the squat position [49,50]. Dynamic squat was also performed on WBV for 11 weeks. The results reported a significant increase in both lower and upper extremity muscle strength [49].

Subsequently, another study showed an increase in EMG Root Mean Square (RMS) value during isometric upper limb exercises with vibration (30-35Hz) [51]. A pilot study performed to examine muscle activity after WBV training (30Hz) with press-ups concluded that myoelectric activity of both dynamic (triceps, pectoralis major) and stabiliser shoulder muscles (SA, lower trapezius) was particularly 3.5 times higher than activity observed in a standard press up in stabiliser muscles [52].

Similarly, a novice study examined the lower extremity on a horizontally moving WBV device. The study demonstrated that the intervention's effects are highly dependent on the angle of the joint and vibration frequency. Eighteen healthy adults underwent WBV intervention at different frequencies (0 Hz, 2Hz, and 4 Hz) and varied knee flexion angles (0°, 30°, and 60°). The surface EMG measured the activity of Vastus Lateralis (VL), Biceps Femoris (BF), Tibialis Anterior (TA), and GCM muscles. The highest increase in muscle activity was observed in the VL and TA muscles when the participants stood on the vibration platform(4Hz) with the knee flexed (60°) [53]. The flexed position of the knee limited the upward transmission of the vibration.

As compared to other variables, the domain of muscle latency has a dearth of evidence, and limited studies of high quality are present. In a research study examining muscle latency timing, 20 healthy athletes were assessed to see the effects of WBV on rotator cuff muscles and the timing of recruitment of shoulder musculatures. Results depicted that after WBV application, the activation of anterior deltoid, SA, and rotator cuff was early, and also the activation of shoulder muscles was greater. The author concluded that the use of vibration and exercises could increase muscle activation and improve the readiness for movement by altering muscle recruitment [15]. The WBV modality has been shown to generate equal muscle activity responses (EMG) inactive and inactive individuals. This could be a beneficial finding as this can help coaches, trainers, and clinicians working with athletes to use the findings and summary of studies performed on non-athletes and extrapolate it for the benefit of the athletic population [47].

However, the trained athletes face the possibility of greater transmissibility values of vibration to the head region than the untrained subjects. This could be due to the presence of a pre-existing rapid neuromuscular adaptation system in athletic populations. Research has also shown that the EMG responses decline within five days of daily WBV exposure [3]. Due to the gradual blunted EMG response with repeated WBV training, the distal muscles absorb lesser vibration stimulus at the periphery, and there is an increased transmission to the cranial region.

The research done on muscle activity suggests that WBV can augment both the upper quadrant and lower quadrant muscle activity. Closed chain exercises (CKC) along with WBV, also facilitate the increase in muscle activity. Although limited studies are present on muscle latency timing alteration, preliminary findings are encouraging, which could play a pivotal role in managing many rotator cuff disorders. The WBV intervention has been found to generate a similar magnitude in both the athletic and nonathletic populations.

The present review has certain recommendations that could be useful for the clinicians:

- WBV can be used as a warm-up tool before the game and for the acute improvement of power.
- WBV can be combined with resistance training for achieving enhanced gains in muscle activity, strength, and power.
- The effects of the WBV can be limited more to the lower extremity muscles by maintaining the flexed position of the hip and knee joints while standing during WBV intervention.

Future Directions for Research

Despite much research, there is still much to explore and examine the effects of WBV on athletes. Four specific areas are of particular interest: a) the effect of manipulating WBV variables such as duration, frequency, magnitude, and amplitude; b) effect of WBV on temporal variation of muscle recruitment (muscle latency) is less known; therefore, it is suggestive for future research; c) further research on the novice horizontal vibration variety of WBV is suggested; d) further research examining the long-term effects of WBV on athletic performance is also suggested.

CONCLUSION(S)

WBV is one such device that can augment the athlete's muscle strength, power, and EMG muscle activity when added to the athletes' conventional training regime. Based on the findings of the present review, it can be concluded that WBV is a safe, noninvasive modality that can be used simultaneously with conventional training to accelerate muscle strength, power, and activity gains. Optimal vibration frequency, amplitude, and duration need to be used to gain the maximal muscle strength and activation from the vibration stimulus. Muscle power requires longer duration neuromuscular adaptation for achieving gains. The present review throws light on the beneficial effects associated with WBV and concludes that these beneficial effects associated with WBV can help coaches, trainers, and clinicians working with athletes.

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