Medical Rehabilitation / Rehabilitacja Medyczna (Med Rehabil) 2018, 22 (3): 11-19 DOI: 10.5604/01.3001.0012.6898 eISSN 1896–3250

Effect of vibrational therapy on muscle tissue

Wpływ terapii wibracyjnej na tkankę mięśniową człowieka

Paweł Pogwizd [1 (A, B, D,E,F)], Alicja Pasterczyk-Szczurek [1 (E,F)], Monika Bigosińska [2 (E,F)]

[1] Research and Development Department of Vitberg, Nowy Sącz, Poland
[2] Department of Physical Education, Institute of Physical Education, State University of Applied Science, Nowy Sącz, Poland

Key words
muscles, force, vibration, WBV

Abstract
Introduction: In an adult human, on average, muscles constitute about 40% of their body mass. They are the basic structural and functional elements of the musculoskeletal system based mainly on shrinkage of their fibres. This state, among others, ensures and induces motor reactions defined in a given situation, affects balance and muscle balance, the efficiency of neuromuscular connections, and also decides the efficiency of the motor system.
Aim of study: The aim of the work was to review literature regarding the impact of treatments using vibrational stimulus on human muscle tissue. Particular attention was paid to the observed improvement of its motor properties after the completion of vibrational therapy application. An attempt was also made to present the widest possible use of vibrational procedures in various disease states related to the functionality of muscle tissue, which is why in the present overview, the included research was differentiated in terms of target groups and investigated muscles.
Material and methods: The analysis included domestic and foreign literature, in which the positive effect of vibrational treatments on the motor properties of adults was discussed. Studies were selected, the authors of which described the most important parameters of the vibrational stimulus used, such as: frequency, amplitude and duration of exposure. Research work from the last 15 years has been analysed (not including the historical part). However, as many as 70% of the referred studies have been published in the last 5 years. Data from the following databases was analysed: Medline, Embase, Cochrane CENTRAL trials register, ScienceDirect, PubMed, IEEE Xplore, Wiley Online Library. Key words used: muscles, force, vibration, WBV.
Summary-Conclusions: Numerous reports indicate the positive effect of vibrational therapy on human muscle tissue. These treatments, among others, prevent muscle atrophy, and in this way, improve or reproduce the lost motor skills of the investigated people. Treatments with the use of vibrations can be performed by the patients themselves without special supervision, the devices that trigger them are easy to use and do not require significant physical effort, which is an undoubted advantage for the elderly and ill patients as well as athletes during the restitution period. It seems wise that any future research regarding the possibility of use of using vibrations in various disease states, including covering the broadly understood pathology of the musculoskeletal system, should focus on the development of optimal parameters and conditions for the use of vibration treatments, associating them with selected disease entities, developing indications and contraindications for their use, as well as determine hypotheses of the effectiveness of undertaken activities and their scientific verification.

Słowa kluczowe
mięśnie, siła, wibracja, WBV

Streszczenie
Wstęp: U dorosłego człowieka mięśnie stanowią średnio około 40% jego masy ciała. Są podstawowym elementem strukturalnym i funkcjonalnym układu mięśniowo-szkieletowego opartego w głównej mierze na kurczliwości ich włókien. Taki stan rzeczy między innymi zapewnia i wywołuje określone w danej sytuacji reakcje motoryczne, wpływa na zachowanie równowagi i balans mięśniowy, sprawność połączeń nerwowo-mięśniowych, a także decyduje o wydolności układu ruchu.
Cel pracy: Celem pracy było dokonanie przeglądu piśmiennictwa, dotyczącego oddziaływania zabiegów z wykorzystaniem bodźca wibracyjnego na tkankę mięśniową człowieka. Szczególną uwagę zwrócono na zaobserwowaną poprawę jego właściwości motorycznych po zakończeniu terapii wibracyjnej. Podjęto także próbę przedstawienia możliwie, jak najszerszego zasto-

The individual division of this paper was as follows: a – research work project; B – data collection; C – statistical analysis; D – data interpretation; E – manuscript compilation; F – publication search

Article received: 4 May. 2018; Accepted: 15 Oct. 2018

Please cite as: Pogwizd P., Pasterczyk-Szczurek A., Bigosińska M. Effect of vibrational therapy on muscle tissue. Med Rehabil 2018; 22(3): 11-19. DOI: 10.5604/01.3001.0012.6898 (Ahead of print)

Internet version (original): www.rehmed.pl

sowania zabiegów wibracyjnych w różnych stanach chorobowych związanych z funkcjonalnością tkanki mięśniowej, dlatego uwzględniono w prezentowanym przeglądzie badania zróżnicowane pod względem grup docelowych oraz badanych mięśni.
Materiał i metody: Analizie poddano piśmiennictwo krajowe i zagraniczne, w którym zostało omówione pozytywne działanie zabiegów wibracyjnych na zdolności motoryczne dorosłego człowieka. Wybrano badania, których autorzy podawali najważniejsze parametry zastosowanego bodźca wibracyjnego takie jak: częstotliwość, amplituda i czas ekspozycji. Analizowano prace z przestrzeni ostatnich 15 lat (nie wliczając części historycznej). Jednak, aż 70% przywołanych badań była opublikowana w ciągu ostatnich 5 lat. Dokonano analizy przedmiotowych danych w następujących bazach: Medline, Embase, Cochrane CENTRAL trials register, ScienceDirect, PubMed, IEEE Xplore, Wiley Online Library. Słowa kluczowe, jakie użyto to: mięśnie, siła, wibracja, WBV.
Podsumowanie-Wnioski: Liczne doniesienia wskazują na pozytywny wpływ terapii wibracyjnej na tkankę mięśniową człowieka. Zabiegi te między innymi zapobiegają zanikowi mięśni, a na tej drodze poprawiają lub odtwarzają utracone zdolności motoryczne badanych osób. Zabiegi z wykorzystaniem wibracji mogą być wykonywane przez samych chorych bez szczególnego nadzoru specjalistycznego, urządzenia je wywołujące są proste w obsłudze i nie wymagają znacznego wysiłku fizycznego, co jest niewątpliwą zaletą dla osób starszych i schorowanych oraz sportowców w okresie restytucji. Wydaje się celowym, aby ewentualne przyszłe badania dotyczące możliwości wykorzystania wibracji w różnych stanach chorobowych, w tym obejmujących szeroko rozumianą patologię układu mięśniowo-szkieletowego, skoncentrować na opracowaniu optymalnych parametrów i warunków stosowania zabiegów wibracyjnych, skojarzenia ich z wybranymi jednostkami chorobowymi, opracowania wskazań i przeciwwskazań do ich wykorzystania, a także ustalenia hipotez efektywności podejmowanych działań oraz naukowej ich weryfikacji.

REACTION OF MUSCLE TISSUE TO VIBRATION

Whole-body vibration (WBV) leads to strengthening muscle stimulation and improvement in their functioning. Increased muscular activity is supported by the nerve mechanisms induced by WBV. Despite the lack of direct evidence, the most frequently cited mechanism supporting the WBV response is reflexive muscle contraction called tonic vibration reflex (TVR), which occurs during the direct vibrating stimulation of the muscular-tendon complex[1].

High-frequency mechanical vibrations applied to any human skeletal muscle contribute to the generation of a reflexive response to maintain muscle contraction subjected to vibrations, while simultaneously relaxing its major antagonists[2,3,4]. This reaction was referred to as TVR2. Only one kind of afferent unit is known, which, in addition to being sensitive to high frequency vibrations, can trigger this particular reflex – that is the Ia afferent of the muscle spindles (primary ends)[5,6,7]. It is suggested that increased muscle power observed after intense WBV occurs thanks to TVR. By stimulating the neuromuscular system, the neuromuscular spindles are stimulated (Ia afferents), manifesting themselves in the impulsive activation of motoneurons with an increased spatial range. In addition, tonic vibrational reflexes can acquire additional motor units through neuromuscular spindles and polysynaptic reflexes[8]. In contrast to vibrations locally applied to the tendon or muscle, the vibrational wave transmitted to the distal insertion, penetrates the closer muscular group and activates a large number of vibration-sensitive muscle receptors, engaging many additional motor units[9].

VIBRATION FREQUENCY AND EFFICIENCY

An important factor to be considered is vibration frequency. Different people can adapt to different frequencies of vibrations because their neuromuscular spindles have different properties, different amounts and locations of the mechanoreceptors and proprioreceptors, different flexibility properties of the muscle-tendon complex and a different percentage share of type-2 fibres[10]. Despite this, muscle tone increases linearly with increasing vibration frequency[11,12]. As mentioned earlier, stimulus in the form of vibrations selectively stimulates the ring-spiral ends of the neuromuscular spindles, causing them to be activated synchronously with the vibratory cycle[11]. Primary centripetal fibres of neuromuscular spindles are stimulated by discharges, with frequencies up to 100 Hertz (Hz)[13]. Optimal frequencies may lead to activation synchronization of the original ends of the neuromuscular spindles with the frequency of vibrations, while a vibration frequency higher than that which is optimal, results in the reduction of the synchronization of the motor unit with mechanical vibrations[14,15]. Massage using low-frequency vibrations (15-50 Hz band) increases oxygen uptake, oxygenation of the blood and muscles, local and systemic circulation, local temperature of tissues subjected to vibrations and activation of muscle metabolism enzymes. The remaining effects include loosening myofascial tissues and systemic sedation (relaxation)[9]. In some static exercises, the vibrational wave is transmitted from further to closer links of muscle groups. In contrast to physiotherapeutic treatment, such a stimulus transmission triggers a large number of muscles and can only be used at low frequencies. At high vibration frequencies, there is greater suppression of stimulation during its propagation through body tissues[16]. This view is supported, among others, by Issurin[9]. In his opinion, only low-frequency waves penetrate through stretched or strained muscles, while high frequency vibrations are absorbed by soft tissues[9].

Vibrational massage using high-frequency vibrations (100-170 Hz) leads to increased excitability of the central nervous system (CNS) as well as an increase in blood pressure. This type of massage increases muscle tone and causes their rapid stimulation[9].

THE EFFECT OF VIBRATION ON MUSCLE POWER

Muscle power, the ability of muscles to work in a natural environment, significantly decreases with age. In women, the rate of decline increases after menopause, leading to a decrease in physical fitness[17]. Aging is associated with a decrease in bone mineral density (BMD) - called osteoporosis, and a decrease in lean body mass and muscle strength called sarcopenia[18,19]. Both osteoporosis and sarcopenia are serious socio-economic and personal problems because they contribute to an increased risk of falls, increased fractures and decreased physical fitness[20,21,22]. Femoral neck fractures are associated with high rates of mortality and morbidity among post-menopausal women[23]. Therefore, prevention of bone and muscle mass loss remains an important issue. Despite the overwhelming evidence that physical exercise positively affects muscular strength at any age, adjusting exercise programmes to the needs of seniors is insufficient, and often, may even be risky. Moreover, only a small percentage of older people undertake regular exercise[24]. Too intense or poorly conducted training can be dangerous for a significant amount of older people, potentially leading to traumatic injuries of the musculoskeletal system, even including fractures[25].

An alternative training method may be vibration therapy, which was evidenced in 2013 by Zaidell et al.[1] These authors have published research results showing that the use of vibrational therapy on the soles of healthy feet increases plantar flexion force (PFF). It was increased after using WBV and frequency-dependent vibration. They also observed a more significant increase in PFF at a 50 Hz vibration frequency than at 25 Hz, suggesting that stronger TVR reflex occurred at higher frequency vibrations. Using surface electromyography (EMG) and measuring initial force, this study provides direct evidence that whole-body low-frequency vibrations can induce a classic TVR response in the lower limb muscles. Therefore, the authors recommend WBV as a practical method for muscle exercise. Treatments using WBV can be used to maintain good health, in post-traumatic rehabilitation, as well as for immobilized and long-term bed stays[1].

Thomas Lapole and Chantal Pérot[26] also attempted to investigate the effects of vibration therapy on the strength of the plantar flexor muscles. 29 healthy students took part in the experiment. They were subjected to vibration therapy at 50 Hz every day for 1 hour (h). After 14 days of daily vibration treatments, plantar muscle strength increased with voluntary isometric contractions. According to the authors of this report, the noted strength gains can only be explained through improved muscle activation. This is confirmed by the increase in EMG of the triceps muscle of the calf, which was significantly correlated with strength gains and neuromuscular performance with voluntary contractions. The (cocontraction) index did not change after exposure to vibration, indicating that there were no changes in the activation patterns between agonists and antagonists. Thus, only improvement in activation of the triceps of the calf can explain the greater generation of strength. The authors of the cited study believe that the impact of vibration training mainly regards neuronal adaptations, with increased muscle activation[26].

However, El-Shamy[27], in an article from 2017, undertook assessment of the impact of whole-body vibration on the strength of the quadriceps muscle. The experiment was conducted among a group of 30 children with haemophilia in the age range of 9 to 13 years. The parameters of vibratory stimulus in the present study were as follows: the frequency was 30 to 40 Hz, 2 to 4 mm between-peak vertical displacement and the duration of the exercise ranged from 12 to 15 minutes. The vibrations were generated by Power Plate Next Generation Vibration. After 12 weeks of therapy, it was observed that the programme of WBV training combined with standard physiotherapy caused greater improvement in the strength of the quadriceps muscle of the thigh compared to the use of only standard physiotherapy. The strength of this muscle was determined using the Biodex System-4 dynamometer (Biodex Medical System, Shirley, NY). The author of the study claims that improvement in muscle strength after WBV was associated with reflex muscle activity and not loading exercises. This means that the main ends of the muscle spindles are stimulated by vibrations, which in turn, stimulate motoneurons, causing activation of motor units, leading to muscle contraction known as tonic vibrational reflex (TVR). El-Shamy also hypothesizes that a protocol with greater intensity, duration and amplitude of vibrations could allow to achieve better results among this population[27].

Research regarding the impact of vibrational therapy on the strength of the quadriceps muscle was also undertaken in 2016 by Pamukoff et al[28]. In their experiment, the effects of single, whole-body (WBV) and local (LMV – Local Muscle Vibration) vibration sessions were examined, which affected functioning of the quadriceps muscle in patients following anterior cruciate ligament reconstruction (ACLR). In the research, they applied vibrations at 30 Hz, for a total duration of 6 minutes. The results obtained by these authors show that vibratory impulses improve the strength of the quadriceps muscle, voluntary activation and cortical-motor excitability in people following ACLR. Therefore, stimulation with vibrations may be an appropriate procedure to increase the function of the quadriceps muscle of the thigh and could be effective in restoring strength of this muscle in people with traumatic injuries to the knee joint[28].

In 2015, research on the impact of vibration on the strength of the quadriceps was also undertaken by Ekaterina Tankisheva et al.[29]. Their aim was to analyse the influence of 6-month, local vibrational training on muscle strength, muscle mass and physical performance in post-menopausal women (66-88 years of age). The frequency of vibrations during the procedure was between 30 Hz and 45 Hz. Vibration was applied to the area in the middle of the thigh and in the vicinity of the hip joint in a lying position once a day for a maximum of 30 minutes, 5 times a week. The participants from the control group continued to perform their usual activities and were not included in any additional training programme. The measured variables were isometric and dynamic strength of the quadriceps muscles. The authors of this study observed a significant difference between groups after a 6-month period in favour of the group subjected to vibrational exposure in relation to the isometric force of straightening the knee. According to them, this difference may be caused by the adaptation of the nervous system, taking into account the increase in the synchronization of the motor unit, the arrest of antagonistic muscles or the re-contraction of synergistic muscles[29].

Most obese people maintain a sedentary lifestyle and are reluctant to take part in regular exercise programmes. Therefore, Chiara Milanese et al.[30] investigated the impact of whole-body vibration (WBV) on body composition and muscular strength in obese women. Participants of the study were assigned to a 10-week WBV training, twice a week. During each 14-minute vibration training session, 5 minutes of rest were used. Parameters of the vibratory stimulus were as follows: amplitude from 2 to 5 mm, frequency from 40 to 60 Hz. For this purpose, the following device was used – BioplateRF, BIOS, Milano, Italy. The maximum strength rating (max. of 1 repetition) included flexion and extension tests of the lower limbs. After completing the test protocol, limb endurance tests were increased in the WBV group. These results indicate that WBV exercises can improve muscular strength in obese women and can also be a useful means in supporting obese individuals in undertaking decisions and actions promoting a healthy lifestyle[30].

In society, one-third of adults and half of the elderly in nursing homes suffer from chronic or temporary urinary incontinence (UI)[31]. This is a nagging condition that seriously affects the physical, social, psychological and sexual well-being of patients[32]. In 2015, Farzinmeher et al.[33] published the results of a study in which they assessed the effectiveness of whole-body vibration in improving pelvic floor muscle strength in women suffering from stress urinary incontinence (SIU). 43 women suffering from this disease were invited to take part in the experiment. The research was carried out for 4 weeks with the use of a vibration platform (Power plate, USA). A vibration frequency of 30 to 50 Hz was applied. The duration of a single treatment session was from 4 to 16 minutes. The maximum voluntary contraction (PFM – pelvic floor muscle) was assessed by the authors on the basis of an approved, standardized, modified Oxford scale via palpation, performed by a physical therapist who was qualified to evaluate pelvic floor muscles. The results of the study showed that after treatments, there was improvement in the tension and strength of the PFM, which may be associated with increasing strength and re-contractions of the synergistic muscles of the pelvic floor, hip, abdomen and others during WBV. The results of these studies showed that the therapeutic effect of these treatments persisted after 3 months[33].

VIBRATION AS A WAY TO PREVENT MUSCLE DYSTROPHY

Immobilization is a well-accepted analogy to the loss of body condition caused by the lack of activity that is usually seen in bedridden patients. Similar effects were observed in astronauts as a result of long-term zero gravity exposure[34,35,36]. Prolonged immobilization of the human body results in functional disorders and loss of the condition of the musculoskeletal system, which can be reduced by means of appropriate muscular exercises. WBV is used as a way to prevent muscle atrophy and bone loss during weightlessness in space and as a training option for athletes and patients with various co-morbidities. The spinal cord reflex function means that WBV may be appropriate for unconscious patients, because muscle contraction occurs at the level of the spinal cord and not in the brain[37].

In 2004, Dieter Blottner et al. conducted research to assess whether short sessions of vibrational training (2-3 times a day) prevent the degradation of muscle fibres and phenotypic traits, and help maintain the strength of the skeletal muscle group of the thigh and calf while lying in bed. In these studies, vibrational therapy was applied to the muscles of the lower limb by means of a vibrating platform with a modification, enabling the treatments to be carried out in a lying position. During 55 days of voluntary bed immobilization, the frequency of vibrations varied from 19 Hz (at the beginning of the study) to 25.9 Hz (at the end). During the experiment, the authors measured the maximum voluntary isometric plantar flexion force (MIPF) based on the platform (Novotec, Pforzheim, Germany) and a special, resistance device. The measurements were taken before the period of bed rest and after the tests. After the experiment, the authors concluded that both the calf muscle structure and the production of strength can be maintained for 8 weeks of absolute staying in bed thanks to the use of vibrational exercises. The authors of the study believe that the vibrational exercise of the sole of the foot with the Galileo Space device (19-26 Hz) is based on muscle reflexes that produce many cycles of contraction-muscle relaxation (i.e. 26 Hz equals approximately 1,600 cycles per minute). Muscle reflexes can produce mechanical tension and neuromuscular activation, sufficient to maintain the structure and function of the musculoskeletal system[38]. The authors of this study also believe that short protocols for vibrating foot soles seem simpler than other types of exercises and can be used in future prevention programmes to compensate for lower limb atrophy caused by lack of physical activity during prolonged, clinical be stays, in rehabilitation or during spaceflights[39].

In 2017, Wollersheim et al.[37] published an article regarding the impact of vibrational therapy on the reduction of muscular fatigue in immobilized, mechanically ventilated patients at the Intensive Care Unit (ICU). Muscle dystrophy and weakness due to intensive care hospitalization are common complications in these patients. Therefore, the authors of this report were guided by the idea of bridging the gap between the onset of severe illness and active muscle training, using external devices during immobilization and sedation phases to trigger muscle contractions. In the above-mentioned study, vibrational exercises on the feet of patients from these units were used. Vibration stimuli of 24 Hz and 26 Hz were used. WBV sessions lasted 9 minutes. These authors noted that fixed vibration sessions increase both carbon dioxide removal and oxygen depletion in those treated under these conditions as a result of muscle stimulation. Depending on the frequency of the vibratory stimulus, WBVs cause over 1,000 muscle contractions per minute, thus leading to increased strength and muscle mass. In conclusion, further research supports the principle that WBV stimulates the muscles and improves their metabolism[37].

VIBRATION IN THE TREATMENT OF MUSCLE SPASTICITY

Spasticity is defined as impaired sensory-motor control resulting from damage to the central motor neuron (UMN – upper motor neuron), presented as uninterrupted or continuous involuntary muscle activation[40]. Under clinical conditions, spasticity is assessed as increased resistance to passive muscle stretching depending on the speed of movement[41]. The purpose of any spasticity treatment plan is to improve passive and active functions, and to prevent secondary problems such as pain, sprain or trauma. Lower limb muscle dysfunction is common among children with bilateral cerebral palsy (CP). Spasticity causes stiffness and weakness in the muscles and limits the performance of daily activities such as standing or walking. Teeraporn Tupimai et al.[42] conducted an experiment to check the effect of whole-body vibration (WBV) on spasticity, strength and balance in children as well as adolescents with CP. The study involved 12 children and adolescents with spastic CP in the age range of 6 to 18 years. A vibration device (AIKO, ETF-001CG, Thailand) producing vibrations at 20 Hz was used for the tests. Participants of the experiment were assessed using the Modified Ashworth Scale (MAS), the Five-Times Sit-To-Stand Test (FTSTS) and the Pediatric Balance Scale (PBS). FTSTS is a reliable tool for assessing the strength of the lower limb muscles and the ability to maintain balance. The results obtained during the study indicate that the 6-week combination of long-term Passive Muscle Stretching (PMS) with WBV can produce positive effects in relieving spasticity, shortening the time to perform the Five-Times Sit-to-Stand Test due to increased muscle strength and improved balance in those patients[42].

Ruck et al.[43] also conducted a randomized, controlled pilot study to determine the effects of WBV on 22 children with CP. During the 6-month duration of the study, children were assigned to continue the traditional physiotherapy programme or to use WBV as an adjunct to the programme. There were no significant differences in the groups concerning changes in motor function, but the change in walking speed was significantly higher in the WBV group[43].

The attempt to investigate the impact of vibration therapy to fight spasticity in children with cerebral palsy was also undertaken by Katusic et al.[44]. During the 12-week treatment period, all children attended physical therapy treatments in accordance with their rehabilitation programme. Physiotherapy consisted of 3, 40-minute sessions a week. The level of spasticity was assessed using the Modified Ashworth Scale (MAS). The results show that the procedure of vibrotherapy together with classical physiotherapy reduces the level of spasticity and increases the motor efficiency in children with spastic CP[44].

Gait disorders are one of the most frequent and life-changing effects of multiple sclerosis (MS – Multiple Sclerosis), often associated with spasticity. This issue was addressed by Camerota et al.[45] The aim of their study was to assess the effectiveness of local vibrations in improving gait in patients suffering from MS with acute spasticity of the lower limb, measured by Ga Analysis Gait Analysis. In their research, they used a vibratory stimulus at a frequency of 100 Hz and an amplitude of 200-500 μm. The therapy was applied to the quadriceps and lumbar muscles in the area of the spine. After therapy, they observed greater extension in the hip joint most likely associated with an increase in moment and strength in the hip joint. In addition, increasing extension in this joint allowed patients to lift the foot from the floor in the dorsiflexion mechanism. This behaviour is explained by the authors with the increase in the moment and value of peak strength for the talocrural joint. In addition, an increase in the plantar flexion angle of the foot was noted[45].

It is also assumed that weakening of plantar flexion in the foot negatively affects motor function and general posture of a person. Therefore, improvement in the balance, gait speed and mobility after the use of whole-body vibrations observed in the above studies may be directly related to the improvement of the strength of lower limb muscles. These data indicate that WBV can reduce spasticity, increase muscle strength and improve motor performance in people with CP.

VIBRATION AND SPORTS TRAINING

Efficient muscles are an important aspect in performing both sports activities and daily physical activity. Plyometric and endurance training were hitherto the main methods of increasing explosive power[46]. In scientific reports, it is indicated that vibration training is gaining popularity as a form of neuromuscular training, mainly due to its time efficiency and simplicity of usage[8,46,47].

An attempt to use vibrations in competitive sports was undertaken, among others, by Cohrane and Stannard[8]. 18 healthy, female field hockey players were invited to take part in their experiment. The experimental group was subjected to vibrational exercises using the Galileo Sport platform at a frequency of 26 Hz and an amplitude of 5 mm. In the control group, the participants, in a seated position, pedalled with an intensity of 50 revolutions per minute on an ergometric bicycle with a friction brake (Monark 818 E, Sweden). After completing the tests, it was found that intense whole-body vibrations cause nerve strengthening of muscle reflexes, which was demonstrated in the improvement of the results of the arm countermovement vertical jump (ACMVJ) and agility. In addition, muscle groups subjected to less vibration show no physiological changes. According to the authors of this report, WBV stimulates both concentric and eccentric muscle contractions while cycling requires only concentric muscle activity. ACMVJ triggers the activation of the systolic-diastolic cardiac cycle, where stretching receptors are activated in the eccentric contraction phase. Considering the significant increase in ACMVJ results after WBV compared to cycling, it can be presumed that the additional WBV effect compared to cycling was due to the applied eccentric stimulation[8].

Less than 10 years later, because in 2014, Cochrane and Hayden Booker[46] published research results in which they assessed the impact of vibration on results achieved in sport. 14 athletes took part in the experiment, including high-, long- and triple-jumpers. Again, the Galileo Sport vibratory platform at a frequency of 26 Hz was used for the tests. The vibration amplitude this time was 6.4 mm. During the follow-up session, the vibrating apparatus was turned off, and the participants of the study maintained the same position as the competitors from the experimental group. The authors of the research noticed that intense, intermittent vibration training contributed to increasing the distance and speed of repetitive long jumps, which can be used as an additional warm-up method, helping increase the level of explosive power. These authors also suggest that muscular functions are stimulated by intense vibratory training, and although electromyography has not been performed in the course of this study, it is likely that neuronal factors may be responsible for the significant increase in muscle performance which is similar to long-term neural changes observed in the case of traditional resistance and strength training[46].

Recently, Ronnestad et al.[47] also undertook a study on the impact of vibrational therapy on increasing muscle strength in competitive athletes. 12 competitors, competing at a national level, not taking any drugs, participated in powerlifting trials. Each of them qualified for the national powerlifting championships in 2010 (Norway) in their respective weight categories. A vibration platform was also used (Pneu-Vibe Pro, Pneumex, Inc., Sandpoint, ID, USA). The aim of the experiment was to study the distinct impact of whole-body vibrations at 50 Hz with a peak amplitude of 3 mm on peak power in the squat jump (SJ). These tests were carried out on a Smith device (platform) (Gym 80 International, Gelsenkirchen, Germany). The results this study showed that the use of WBV clearly increases the generated peak power during the SJ in those taking part in the project. The increase in power was accompanied by an increased level of EMG activity in the quadriceps muscles. The authors of the quoted reports suggest that WBV can activate the neuromuscular spindle at 50 pulses per second and thus, increase the stimuli acting on the motoneuron set to a much greater extent than without the use of WBV. At the same time, they explain the higher EMG activity and higher peak power during the SJ. Therefore, WBV can be used to significantly increase stimuli affecting the neuromuscular system during strength training with a high load in well-trained athletes whose performances depend on peak power output (e.g. footballers)[47].

SUMMARY

The above-cited literature review contains selected studies, the authors of which have studied the impact of vibrational treatments on human muscle tissue. Although different types of muscles were subjected to vibrational exposure, and subjects were different in terms of age, sex and health status, the positive effects of vibrotherapy were observed. Research shows very broad application of the positive effects of vibrational treatments among patients immobilized in bed to professional athletes. Vibrational therapy proves to be effective in preventing muscle dystrophy, and above all, its regular use improves the motoric properties of a human. Therefore, vibration exercises can be a solution to maintaining physical fitness in people suffering from various illnesses and in those elder. It is worth using this method to support pharmacological treatment and physical therapy or as an alternative to expensive manual massage. Young people, especially those practicing sport actively, can implement vibrational training to improve performance in their sports.

In Table 1, the most important parameters of the vibrational stimulus used in the aforementioned tests are presented. We can unequivocally state that the authors largely reproduce the same research protocols, as noted in 14 of them, based on the frequency of vibrations from 30 to below 50 Hz. Additionally, vibration treatments lasting less than 20 minutes were used in 75% of the studies. Some authors openly admit that in their research, they use proven research protocols instead of proposing new or maybe even more effective solutions[1,27,43,44]. Therefore, it seems reasonable to investigate the impact of different vibration frequencies on specific muscle groups in patients suffering from various diseases and to develop the most optimal application, position and duration of exposure to vibration. The most commonly used device in the cited studies was a vibrating platform, which was used in 12 of them. The vibration platform, however, has its limitations due to its weight and dimensions. In addition, treatments on vibration platforms are carried out in a standing posi-

Table 1

Parameters of the vibratory stimulus in the aforementioned tests

Test (reference position)	Year of publication	Frequency of vibration (Hz)	Amplitude of vibration (mm)	Duration of treatment session	Equipment used in test
(1)	2013	25 and 50	1.5	70 seconds	Vibration platform (Fitvibe Medical, Gymna Uniphy, Germany)
(26)	2010	50	0.2	60 minutes	Electric point stimulator (DS7A, Digitimer Ltd., UK)
(27)	2017	30-40	2-4	15 minutes	Vibration Platform (Power Plate, USA)
(28)	2016	30	1.6	6 minutes	Vibration platform and special-order device generating local vibrations
(29)	2015	30-45	n.d	max 30 minutes	Special-order vibration device
(30)	2013	40-60	2-5	14 minutes	Vibration platform (BioplateRF, BIOS, Milano, Italy)
(33)	2015	30-50	2.5 and 5	4-16 minutes	Vibration platform (Power Plate, USA)
(39)	2006	19-25	5-10	6 minutes	Vibration platform (Galileo Space)
(37)	2017	24, 26	n.d.	9 minutes	Promedi Vibrosphere and Vibration platform (Galileo, home-ICU)
(42)	2016	20	n.d.	10 minutes	Vibration platform (AIKO, ETF-001CG)
(43)	2010	12-18	2-4	9 minutes	Vibration platform (Vibraflex Home Edition II)
(44)	2013	40	n.d.	20 minutes	Vibroacoustic bed (VISIC bedpad-VSM, Acouve Laboratory Inc., Japan)
(45)	2017	10	0.2-0.5	60 minutes	Electromechanical transducer (CRO®SYSTEM, NEMOCO srl, Italy)
(8)	2005	26	6	5 minutes	Vibration platform Galileo Sport (Novotec, Pforzheim, Germany)
(46)	2014	26	6.4	6 minutes	Vibration platform Galileo Sport (Novotec, Pforzheim, Germany)
(47)	2012	50	3	n.d.	Vibration platform (Pneu-Vibe Pro, Pneumex, Inc. Sandpoint, ID, USA)

Table 2

Alternative equipment for vibrational therapy

Device	Frequency (Hz)	Amplitude (mm)
Vitberg Rehabilitation Massage Equipment (RAM Vitberg$^+$)	10-52	0.01-0.5
Vitafon (device for local microvibration treatments)	0.1-100000	0.1-10
TheraGe (vibration plate)	5-70	-
NHC Cyclo-Therapy Cyclopad (massage mat)	35-75	-

tion, which is a significant obstacle for less physically fit people. Therefore, we believe that it is worth paying attention to the offers of manufacturers of vibration therapy equipment, whose products are more mobile and allow treatment in any position (Table 2).

References

1. Zaidell L.N., Mileva K.N., Sumners D.P., Bowtell J.L. Experimental Evidence of the Tonic Vibration Reflex during Whole-Body Vibration of the Loaded and Unloaded Leg. PLOS One 2013; 8(12): e85247.
2. Eklund G., Hagbarth K.E. Normal variability of tonic vibration reflexes in man. Exp Neurol 1966; 16(1): 80-92.
3. de Gail P., Lance J. W., Neilson P.D. Differential effects on tonic and phasic reflex mechanisms produced by vibration of muscles in man. J Neurol Neurosurg Psychiatry 1966; 29(1): 1-11.
4. Lance J.W., de Gail P., Neilson P.D. Tonic and phasic spinal cord mechanisms in man. J Neurol Neurosurg Psychiatry 1966; 29(6): 535-544.
5. Jansen J.K.S. Spasticity-functional aspects. Acta Neurol Scand 1962; 38(3): 41-51.
6. Granit R. The gamma (γ) loop in the mediation of muscle tone. Clin Pharmacol Ther 1964; 5(6): 837-847.

7. Matthews P.B.C. Muscle spindles and their motor control. Physiol Rev 1964; 44(2): 219-288.
8. Cochrane D.J., Stannard S.R. Acute whole body vibration training increases vertical jump and flexibility performance in elite female field hockey players. Br J Sports Med 2005; 39(11): 860-865.
9. Issurin V.B. Vibrations and their applications in sport: A review. J Sports Med Phys Fitness 2005; 45: 324-336.
10. Cardinale M., Lim J. The acute effects of two different whole body vibration frequencies on vertical jump performance. Med Sport 2003; 56(4): 287-292.
11. Bishop B. Neurophysiology of motor responses evoked by vibratory stimulation. Phys Ther 1974; 54(12): 1273-1282.
12. Kwaśna K., Chmielewska D., Piecha M., Halski T., Taradaj J., Juras G., et al. Wybrane metody zachowawczego leczenia wysiłkowego nietrzymania moczu – metody fizjoterapeutyczne. Część 2. Prz Menopauzalny 2012; 5: 372-375.
13. Roll J.P., Vedel J.P., Ribot E. Alteration of proprioceptive messages induced by tendon vibration in man: a microneurographic study. Exp Brain Res 1989; 76(1): 213-222.
14. Jackson S., Turner D.L. Prolonged muscle vibration reduces maximal voluntary knee extension performance in both the ipsilateral and the contralateral limb in man. Eur J Appl Physiol 2003; 88(4-5): 380-386.
15. Martin B.J., Park H.S. Analysis of the tonic vibration reflex: influence of vibration variables on motor unit synchronization and fatigue. Eur J Appl Physiol 1997; 75(6): 504-511.
16. Issurin V.B., Liebermann D.G., Tenenbaum G. Effect of vibratory stimulation training on maximal force and flexibility. J Sports Sci 1994; 12(6): 561-566.
17. Thomas M., Fiatarone M.A., Fielding R.A. Leg power in young women: relationship. to body composition, strength, and function. Med Sci Sports Exerc 1996; 28: 1321-1326.
18. Melton L.J. III. How many women have osteoporosis now? J Bone Miner Res 1995; 10(2): 175-177.
19. Tung S., Iqbal J. Evolution, aging, and osteoporosis. Ann N Y Acad Sci 2007; 1116(1): 499-506.
20. Doherty T.J. Invited review: Aging and sarcopenia. J Appl Physiol 2003; 95(4): 1717-1727.
21. Roubenoff R. Sarcopenia and its implications for the elderly. Eur J Clin Nutr 2000; 54: 40-47.
22. Sinaki M., Brey R.H., Hughes C.A., Larson D.R., Kaufman K.R. Balance disorder and increased risk of falls in osteoporosis and kyphosis: Significance of kyphotic posture and muscle strength. Osteoporos Int 2005; 16(8): 1004-1010.
23. Cauley J.A., Thompson D.E., Ensrud K.C., Scott J.C., Black D. Risk of mortality following clinical fractures. Osteoporos Int 2000; 11(7): 556-561.
24. Mazzeo R.S., Tanaka H. Exercise prescription for the elderly: current recommendations. Sports Med 2001; 31(11): 809-818.
25. Forwood M.R., Burr D.B. Physical activity and bone mass: Exercises in futility? Bone Miner 1993; 21(2): 89-112.
26. Lapole T., Pérot Ch. Effects of repeated Achilles tendon vibration on triceps surae force production. J Electromyogr Kinesiol 2010; 20: 648-654.
27. El-Shamy S. Effect of whole body vibration training on quadriceps strength, bone mineral density, and functional capacity in children with hemophilia: a randomized clinical trial. J Musculoskelet Neuronal Interact 2017; 17(2): 19-26.
28. Pamukoff D.N., Pietrosimone B., Lewek M.D., Ryan E.D., Weinhold P.S., Lee D.R., et al. Whole-Body and Local Muscle Vibration Immediately Improve Quadriceps Function in Individuals With Anterior Cruciate Ligament Reconstruction. Arch Phys Med Rehabil 2016; 97(7): 1121-1129.
29. Tankisheva E., Bogaerts A., Boonen S., Delecluse Ch., Jansen P., Verschueren S. Effects of a six-month local vibration training on bone density, muscle strength, muscle mass, and physical performance in postmenopausal women. J Strength Cond Res 2015; 29(9): 2613-2622.
30. Milanese Ch., Piscitelli F., Zenti M.G., Moghetti P., Sandri M., Zancanaro C. Ten-week whole-body vibration training improves body composition and muscle strength in obese women. Int J Med Sci 2013; 10(3): 307-311.
31. Viktrup L., Koke S., Burgio K.L., Ouslander J.G. Stress urinary incontinence in active elderly women. South Med J 2005; 98: 79-89.
32. Kashanian M., Ali S.S., Nazemi M., Bahasadri S. Evaluation of the effect of pelvic floor muscle training (PFMT or Kegel exercise) and assisted pelvic floor muscle training (APFMT) by a resistance device (Kegelmaster device) on the urinary incontinence in women "comparison between them: a randomized trial". Eur J Obstet Gynecol Reprod Biol 2011; 159: 218-223.
33. Farzinmehr A., Moezy A., Koohpayehzadeh J., Kashanian M. A. Comparative study of whole body vibration training and pelvic floor muscle training on women's stress urinary incontinence: three- month follow-up. J Family Reprod Health 2015; 9(4): 147-154.
34. Akima H., Kubo K., Kanehisa H., Suzuki Y., Gunji A., Fukunaga T. Leg-press resistance training during 20 days of 6 degrees head -down tilt bed rest prevents muscle deconditioning. Eur J Appl Physiol 2000; 82(1-2): 30-38.
35. Berg H.E., Tesch P.A. A gravity-independent ergometer to be used for resistance training in space. Aviat Space Environ Med 1994; 65(8): 752-756.
36. Berg H.E., Tesch P.A. Force and power characteristics of a resistance exercise device for use in space. Acta Astronaut 1998; 42(1-8): 219-230.
37. Wollersheim T., Haas K., Wolf S., Mai K., Spies C., Steinhagen-Thiessen E., et al. Whole-body vibration to prevent intensive care unit-acquired weakness: safety, feasibility, and metabolic response. Crit Care 2017; 21: 9.
38. Dieter Blottner D., Salanova M., Puttmann B., Schiffl G., Felsenberg D., Buehring B., et al. Human skeletal muscle structure and function preserved by vibration muscle exercise following 55 days of bed rest. Eur J Appl Physiol 2006; 97(3): 261-271.
39. Sale D.G. Neural adaptation to resistance training. Med Sci Sports Exerc 1988; 20(5): 135-145.
40. Pandyan A.D., Gregoric M., Barnes M.P., Wood D., Van Wijck F., Burridge J., et al. Spasticity: Clinical perceptions, neurological realities and meaningful measurement. Disabil Rehabil 2005; 27(1-2): 2-6.
41. Gorter J.W., Verschuren O., Van Riel L., Ketelaar M. The relationship between spasticity in young children (18 months of age) with cerebral palsy and their gross motor function development. BMC Musculoskelet Disord 2009; 10: 108-116.
42. Tupimai T., Peungsuwan P., Prasertnoo J., Yamauchi J. Effect of combining passive muscle stretching and whole body vibration on spasticity and physical performance of children and adolescents with cerebral palsy. J Phys Ther Sci 2016; 28(1): 7-13.
43. Ruck J., Chabot G., Rauch F. Vibration treatment in cerebral palsy: A randomized controlled pilot study. J Musculoskelet Neuronal Interact 2010; 10(1): 77-83.
44. Katusic A., Alimovic S., Mejaski-Bosnjak V. The effect of vibration therapy on spasticity and motor function in children with cerebral palsy: A randomized controlled trial. NeuroRehabilitation 2013; 32(1): 1-8.
45. Camerota F., Celletti C., Di Sipio E., De Fino C., Simbolotti C., Germanotta M. Focal muscle vibration, an effective rehabilitative approach in severe gait impairment due to multiple sclerosis. J Neurol Sci 2017; 372: 33-39.
46. Cochrane D.J., Booker H. Does acute vibration exercise enhance horizontal jump performance? J Sports Sci Med 2014; 13: 315-320.
47. Rønnestad B.R., Holden G., Samnøy L.E., Paulsen G. Acute effect of whole-body vibration on power, one-repetition maximum, and muscle activation in power lifters. J Strength Cond Res 2012; 26(2): 531-539.

Address for correspondence

Paweł Pogwizd
e-mail: pawel.pogwizd@vitberg.com