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Effects of local vibration therapy on various performance parameters: a narrative literature review

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Introduction: *The therapeutic effects of local muscle vibration (LMV) remain controversial due to a lack of specific protocols. This review was conducted to better understand the effects of various LMV application protocols.*

Methods*: A comprehensive literature search was performed based on title and abstract and a set of predetermined inclusion criteria. Study quality was then evaluated via the PEDro scale.*

Results: *23 articles were returned initially, and 21 studies were evaluated. The average PEDro score was 5.97/10. Reported outcome measures included muscle activation, strength, power, and range of motion / flexibility. The frequency and amplitude of LMV ranged from 5 - 300 Hz and 0.12 -12 mm respectively, and duration from 6 seconds - 30 minutes.*

Introduction : *Les effets thérapeutiques des vibrations musculaires locales (VML) demeurent controversés en raison de l'absence de protocoles précis. Cette revue de synthèse visait à mieux comprendre les effets de divers protocoles d'utilisation des VML.*

Méthodologie *: On a effectué une recherche exhaustive de littérature* à l'aide des mots du titre et du résumé ainsi qu'un ensemble de critères d'inclusion *pré*déterminés. La qualité de l'étude a ensuite été évaluée à l'aide de l'échelle *PEDro*.

Résultats : *23 articles ont été envoyés au point de départ et 21 études ont été évaluées. La cote moyenne sur l'échelle PEDro était de 5,97 sur 10. Les r*ésultats *signalés étaient l'activation musculaire, la force, la puissance, l'amplitude du mouvement et la souplesse. La fréquence et l'amplitude des VML étaient de 5* à *300 Hz et de 0,12 à 12 mm respectivement, et la durée variait de 6 secondes à 30 minutes.*

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Conclusion: *Most studies found that LMV elicits beneficial changes in the mentioned outcome measures. However, the methodological procedures used are quite heterogeneous. Further research is needed to understand the optimal application of LMV.*

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KEY WORDS: chiropractic, vibration, local muscle vibration, performance

Conclusion : *La plupart des études ont montré que les VML étaient bénéfiques sur les résultats mentionnés. Cependant les méthodologies utilisées étaient très hétérogènes. Il faudrait mener d'autres études pour savoir dans quels cas les VML procurent des bienfaits optimaux.*

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MOTS CLÉS : chiropratique, vibration, vibration musculaire locale, performance

Introduction

The use of vibratory stimuli has demonstrated practical applications in the areas of therapeutic rehabilitation and exercise performance. Much of the current evidence in support of vibration therapy has examined the effects of indirect vibration on muscle function through the application of whole-body vibration (WBV). Some limitations concerning WBV are the difficulty of applying the vibration stimulation to targeted muscles for a wide range of exercises and the attenuation of the vibratory signal by the time it reaches the intended muscle during its transmission through soft tissue, which may hinder the sought after therapeutic effects.[1] Furthermore, both the agonist and antagonist muscles are stimulated by indirectly applied vibration, which may decrease the net force output around a joint as a consequence of reciprocal inhibition.[1] Recently, local muscle vibration (LMV) has been demonstrating therapeutic and functional influences on muscle that addresses these concerns, providing an economically viable and portable alternative to WBV.[2,4,9,14,16-17,19-22]

The neurophysiological mechanism through which vibratory stimulation operates has been attributed to the tonic vibratory reflex (TVR). This mechanism is stimulated by a sequence of rapid muscle stretching that occurs when applying vibration, triggering muscle spindles and thereby causing an involuntary production of strength.[2] Other mechanisms of improved muscle function following vibration include elevated muscle temperature, enhanced corticospinal excitability and intracortical processes.[2] However, it has been suggested that the neurophysiological mechanisms may differ between LMV and WBV since the latter stimulates multiple receptors throughout the body or extremity resulting in adaptations to the motor unit firing frequency and synchronization, muscle tuning, intramuscular coordination and central motor command, while the former exerts its effects on receptors proximal to the simulator.[2] Such observations have proposed the hypothesis that a muscle's electrical and mechanical response could vary with the frequency of vibration and the damping characteristics of the soft tissue to the vibratory stimulus.

A frequency of 30 to 50 Hz, the same frequency of the discharge rate of motor units during maximal effort, has been identified as appropriate for promoting therapeutic adaptations such as improved isometric muscle strength.[2,3,8] These improvements are observed when LMV is applied in the absence of simultaneous voluntary muscle contraction.[2,3,8] Although the precise mechanism of adaptation is not fully understood, increased EMG activity following LMV suggests greater motor unit activation and firing frequency.[2,3] Based on prior studies, some have attributed the increase in EMG to increased excitation of the alpha motor neurons through the muscle spindle system during vibration exposure, changes in corticospinal excitability, and intracortical processes.[2] There is also evidence to suggest that local vibration applied during resistance training is an effective means of increasing maximum isometric force compared to traditional training alone.[4-6] Aside from improvements in active muscle performance, it has been suggested that LMV can improve range of motion and reduce perceived stiffness relative to the traditional treatment of ice, compression, and elevation following soft tissue injuries.[7]

Although mechanical muscle vibration has received considerable attention as a potentially useful method of muscle stimulation for therapeutic and sports training purposes, the results remain controversial. Specific vibrational training protocols are lacking, resulting in uncertainties regarding the most effective vibration intensities, frequencies, and application protocols. This literature review was conducted in order to gain further insight into what is known about the effects of local vibration therapy on various performance parameters.

Methods

Search Strategy

A comprehensive literature search was performed of electronic databases PUBMED, CINAHL, Cochrane, and via the Discovery Service for the Canadian Memorial Chiropractic College (CMCC). A combination of key words such as: vibration, mechanical vibration, direct vibration, local vibration, vibration exercise, neuromuscular output, power, strength, strength training, muscle strength, explosive strength, vibratory stimulation, vibratory stimulus, muscle activation, range of motion, and maximum voluntary contraction were used to find relevant studies. The search was initially limited to articles published in English up until February 2018. All relevant articles were initially selected by title and abstract by two independent reviewers, and irrelevant articles were excluded.

Inclusion and Exclusion Criteria

For articles to be included, they must have investigated the effect of LMV on various performance parameters (i.e. muscle activation, strength, power, joint stability, range of motion / flexibility) in human subjects of any age or gender. LMV was defined as "the application of local mechanical vibration to a tendon or muscle"[9] either directly or indirectly via an automated mechanical device. Studies utilizing only whole-body vibration techniques for therapy were not included, and the studies must have been available in full-text. No limitations were imposed on the type of study included in this review.

Criteria for Evaluation Used and Method of Analysis

The quality of each selected study was evaluated by two independent reviewers (AE, DG) using the PEDro Scale (see Appendix 1). The PEDro Scale seeks to identify which studies were likely to be "internally valid (criteria 2-9) and could have sufficient statistical information to make their results interpretable (criteria 10-11)".[10] The PEDro scale awards points ranging from 0-10, with a higher score indicating a higher quality of study. Additionally, the SIGN grading system was used to evaluate the quality of any included systematic reviews. The SIGN checklist identifies aspects of a study's design that have been shown to have a significant effect on its risk of bias.[11]

Results

Identified Studies

The initial search based on title and abstract returned 23 articles. Limiters were then applied based on the agreed upon inclusion and exclusion criteria, after which two studies were removed[12,13] leaving 21 studies remaining. A full list of the included studies, their characteristics, key results / conclusions, and quality graded via the PEDro scale and SIGN criteria can be seen in Table 1.

Characteristics of Subjects

A total of 831 participants were found in the search with sample sizes varying from nine to 44 and mean ages of both men and women ranging from 20.4 ± 1.4 to 77.6 ± 10.4 years.[2,14] The majority of the studies included recreationally active participants, and 5 studies examined the effects of LMV in various groups of elite athletes.[5,15-18]

Vibration Protocols

There was great variation in the methods used to provide local vibration therapy. The frequency and amplitude of the vibration stimulus ranged from five to 300 Hz and 0.12 to 12 mm respectively.[16,19] The duration of applied vibration stimulus was recorded as low as six seconds up to 30 minutes.[9] In most studies, the control group received a sham protocol, or no intervention.

Outcome Measures / Performance Parameters Assessed

There were a number of performance parameters assessed among the included studies. The most common outcome measures assessed were muscle activation / stimulation, which was evaluated in 11 studies[1-2,6,15-17,20-24], muscle strength evaluated in 10 studies[2-4,8-9,14,16,21-22,25], muscle power evaluated in 10 studies[1-2,5,15-17,19,21,23-24], and joint flexibility / range of motion evaluated in four studies[4,7,18,20].

Table 1.
Characteristics of included studies

Author(s) (year), study design	**Purpose**	**Method of LVT application**	**Outcome measures**	**Results and conclusions**	**PEDro score and shortcomings**
Alghadir *et al*. (2017)[9] Systematic review	To investigate the effects of local vibration on muscle strength in healthy adults. 11 studies with a total of 346 participants were included.	The frequency and amplitude of the vibration signals were 8 to 300 Hz and 0.4 to 6 mm; and timing ranged from 6s to 30 minutes	Muscle strength (Peak isometric muscle strength)	Most of the studies reported significant improvements in muscle strength after the application of local vibration. There was considerable variation in the vibration training parameters and target muscle location	Average score of included studies was reported as 5.36/10 *SIGN Grade = high quality (++)
Benedetti *et al*. (2017)[20] Randomized, controlled, single-blinded study	To (a) investigate the clinical effectiveness of high-frequency LMV on quadriceps muscle in 30 patients with knee OA between the ages of 40-65, and (b) to determine the underlying mechanism of this potential effect	Vibration was applied at 150 Hz over the rectus femoris, vastus medialis, and vastus lateralis muscle bellies of the quadriceps by means of a cup-shaped transducer with a contact surface of 5 cm for 20 min	Clinical outcome was measured using the Western Ontario and McMaster Universities Osteoarthritis Index, Visual Analogue Scale, knee range of motion, Timed Up and Go test, and Stair climbing test; Changes in muscle activation and fatigue was studied with the use of surface EMG during a sustained isometric contraction	The vibration group showed a significant change in Western Ontario and McMaster Universities Osteoarthritis Index score, Visual Analogue Scale score, Timed Up and Go test, Stair Climbing Test, and knee flexion; Surface EMG analysis suggested an increased involvement of type II muscle fibers in the group treated with vibration	9/10 Blinding of therapists administering therapy was not specified
Bosco, Cardinale, Tsarpela (1999)[15] Randomized controlled trial	To evaluate the influence of vibration on the mechanical properties of arm Flexor in a group of 12 international level boxers	5 repetitions lasting 1-min each at 30 Hz and 6 mm amplitude applied during arm flexion in isometric conditions with 1 min rest between repetitions	Mechanical Power and EMG analysis of arm flexors	Statistically significant enhancement of the average power and neuromuscular stimulation in the arm treated with vibrations	5/10 Concealment of subject allocation, similarity of groups at baseline, and blinding of subjects, therapists, and assessors was not reported
Cochrane D. (Feb 2016)[16] Randomized controlled trial	To examine the acute effect of direct vibration has on bicep curl force-generating capacity. 11 healthy team and individual sport-trained males	Vibration was applied to the biceps brachii muscles at a frequency ranging between 0–170 Hz and amplitude of 0–0.12mm on a pulsed setting for a total of 10 minutes	Peak force, mean force, rate of force development, and electromyography (EMG) were assessed during the concentric phase before and immediately after direct vibration	Following direct vibration peak force increased compared to the control arm, but this change was not significant; There were no other significant changes in mean force, rate of force development, or EMG between vibration and control arms	6/10 Concealment of subject allocation, and blinding of subjects, therapists, and assessors was not reported
Cochrane D. (June 2016)[17] Randomized controlled trial	To examine the acute effect of direct vibration on biceps brachii muscular power in 10 healthy male master field-hockey players	Vibration was applied to the biceps brachii muscles at a frequency ranging between 0–170 Hz and amplitude of 0–0.12mm on a pulsed setting for a total of 10 minutes	Mechanical peak power, mean concentric power and normalized electromyography (EMG) was assessed during the concentric phase of the biceps curl	Following vibration both peak power and mean concentric power increased compared to control; There was no significant difference in normalized EMG between vibration and control	6/10 Concealment of subject allocation, and blinding of subjects, therapists, and assessors was not reported
Couto *et al*. (2013)[25] Randomized, controlled, crossover study	To verify the acute effects of the application of local vibration on upper limbs during resistance training on the number of maximum repetitions, metabolic and hormonal responses in 32 male volunteers	vibration was locally applied at 20-Hz and 12-mm amplitude via a latissimus pull-down cable machine	Maximum number of repetitions; Blood lactate, testosterone, cortisol, creatinine kinase, creatinine, urea	No significant differences were observed in number of maximum repetitions between the control and vibration groups; Vibratory resistance training induced greater increases in testosterone and lactate concentrations; No significant changes were found in creatine kinase, creatinine or urea concentration. These data indicate that local vibration increases the metabolic and anabolic response to the resistance training, without changing the training volume	5/10 Concealment of subject allocation, and blinding of subjects, therapists, and assessors was not reported;

Author(s) (year), study design	Purpose	Method of LVT application	Outcome measures	Results and conclusions	PEDro score and shortcomings
Custer *et al*. (2017)[19] Single-blind crossover study	To examine the effects of a local-vibration intervention after a bout of exercise on balance, power, and self-reported pain in 19 healthy, moderately active subjects	Subjects received four 2-minute vibration interventions at 2-mm peak amplitude and frequency between 5 - 35 Hz	Static balance, dynamic balance, power via vertical jump test, self-reported pain	The local vibration intervention did not affect balance, power, or self-reported pain; There were no differences between outcome measures between the active and sham vibration conditions	7/10 Concealment of subject allocation, and blinding of subjects and therapists was not reported
Goebel, Kleinoder, Yue, Gosh, Mester. (2015)[4] Randomized controlled trial	Biomechanical advantage of combining localized vibrations to hamstring muscles involved in a traditional resistance training routine was examined in 36 healthy male and female subjects with at least 2 years' experience in resistance training	Local vibration was applied directly to hamstring muscles during exercise with a constant amplitude of 4 mm and a variable frequency between 18 - 38 Hz	Maximum isometric force of the hamstrings and maximum range of motion and muscle tension at maximum knee angle	The vibrational training group showed statistically significant improvements in maximum isometric force after the first week of training compared to 3 weeks for the traditional training regimen; The vibrational training group retained gain in performance for a longer time after the testing regimen than traditional training; The range of motion was improved, and muscle tension increase was less for the vibrational training group compared to the traditional training group	6/10 Concealment of subject allocation, and blinding of subjects, therapists, and assessors was not reported
Iodice, Bellomo, Gialluca, Fano, Saggini (2010)[3] Randomized controlled trial	To evaluate the acute and long-term effects of local high-intensity vibration on muscle performance and blood hormone concentrations in 18 healthy young men	Vibration was delivered for 30 min at 300 Hz, 2mm amplitude over 3 sessions a week for a total of 4 weeks; Vibration was applied over the base of the vastus intermedius, rectus femoris, vastus lateralis, vastus medialis, gluteus maximus, biceps femoris, gastrocnemius, and tibialis anterior	Counter-movement jumping (CMJ), maximal isometric voluntary contraction (MVC) test, and hormonal levels were measured before the procedure, immediately thereafter, and 1 h later	The HLV protocol significantly increased the serum level of growth hormone (GH, P \ 0.05) and creatine phosphokinase (CPK, P \ 0.05), and decreased the level of cortisol; There was a significant improvement in MVC; Overall, there were significant improvements in muscle performance after several weeks of vibration treatment, and some hormonal responses and minor performance improvements were detectable after a single session	6/10 Concealment of subject allocation, and blinding of subjects, therapists, and assessors was not reported
Issurin and Tenenbaum (1999)[5] Randomized controlled clinical trial	To establish the acute and residual effects of vibratory stimulation in explosive strength exercises in 14 elite and 14 amateur athletes during bilateral biceps curl exercises	Vibration amplitude was transmitted indirectly via cables to the upper limb with an amplitude of 3 mm and frequency of 44 Hz	The acute and chronic /residual maximal and mean power of bilateral biceps curl exercises was measured	Exercise mode with vibratory stimulation resulted in a significant immediate effect for mean power and for maximal power	6/10 Concealment of subject allocation, and blinding of subjects, therapists, and assessors was not reported
Kurt (2015)[18] Randomized controlled trial	To compare the effects of whole body vs. local vibration on lower body flexibility levels, and to assess whether vibration treatments were superior to static or dynamic stretching methods for lower body flexibility in 24 healthy well trained male combat athletes	Whole body or local vibration at a frequency of 30 Hz and a 4mm amplitude. Vibration was applied for 1 minute	Subjects performed the stand-and-reach test at the 15th second and the 2nd, 4th, 6th, 8th, and 15th minute following the intervention	Local vibration application showed statistically significant increased flexibility compared to other protocols. Subjects with high flexibility seem to benefit more from local vibration compared with other methods	6/10 Concealment of subject allocation, and blinding of subjects, therapists, and assessors was not reported

Author(s) (year), study design	Purpose	Method of LVT application	Outcome measures	Results and conclusions	PEDro score and shortcomings
Luo *et al*. (2008)[24] Randomized cross-over study	To determine whether vibration applied directly to a muscle-tendon could enhance neuromuscular output during and 1.5 and 10 min after a bout of ballistic knee extensions in 14 young male volunteers	Vibration at an amplitude of 1.2 mm and frequency of 65 Hz was applied with a portable vibrator strapped over the distal tendon of the quadriceps (time of vibration application not provided)	Knee joint angular velocity, moment, power, and rectus femoris and vastus lateralis electromyography were measured during the knee extension	Vibration did not induce significant changes in peak angular velocity, time to peak angular velocity, peak moment, time to peak moment, peak power, time to peak power, or average EMG of the rectus femoris and vastus lateralis; It was concluded that direct vibration, at the selected amplitude and frequency, does not enhance these neuromuscular variables in ballistic knee extensions during or immediately after training	7/10 Concealment of subject allocation, and blinding of therapists and assessors was not reported
Luo *et al*. (2009)[23] Randomized cross-over study	To examine the influence of resistance load on the acute and acute residual effects of vibration training on the bicep tendon in 11 male subjects during a maximal- effort dynamic resistance exercise	Vibration was applied at an amplitude of 1.2 mm and frequency of 65 Hz over the biceps brachii tendon (time of vibration application not provided)	Concentric elbow joint angular velocity, moment, power, and bicep root mean square electromyogrphy (EMGrms) were measured during training and in the pre- and post-training tests	During training (acute effect) and at 5 minutes after training (acute residual effect), vibration did not induce a significant change in EMGrms, mean and peak angular velocities, moment, power, time to peak power, and initial power at 100 milliseconds after the start of the concentric phase for either resistance loads	7/10 Concealment of subject allocation, and blinding therapists and assessors was not reported
Mischi *et al*. (2009)[6] Cross-over study	To evaluate the effects of activation and coactivation of biceps and triceps muscles during isometric exercises performed with and without superimposing vibration stimulation in 12 healthy volunteers.	A sinusoidal vibration was modulated at 28 Hz. The amplitude of the input sinusoidal waveform was set to 1.2V. An electromagnetic actuator produces a mechanical torque which is modulated in time by a sinusoidal function and then a mechanical transmission is used to transmit the generated force to the muscle	Root Mean Square of the recorded surface EMG signal	In general, a larger EMG_{RMS} activity of the biceps and triceps brachii muscles was observed when vibration was applied	4/10 Similarity of subjects at baseline, random allocation of subjects along with concealment of allocation was not stated; Additionally, blinding of subjects, therapists, and assessors was not reported
Moran, McNamara, Luo (2007)[1] Randomized cross-over study	To examine the acute effects of direct vibration on neuromuscular performance in maximal-effort dynamic exercises in 14 young healthy adult males. To examine the acute residual effect of direct vibration training, both with and without a resistance exercise. Finally, to examine whether acute and acute residual effects of vibration training, if any, were placebo effects	Vibration was produced by a portable muscle-tendon vibrator that was strapped onto the skin over the biceps tendon. Vibration amplitude and frequency were set at 1.2mm and 65 Hz	Angular velocity, moment, power, and biceps root mean squared value of EMG and mean power frequency of EMG were determined for the concentric phase of muscle activation	Direct vibration of 65 Hz and an amplitude of 1.2mm applied to the biceps brachii muscle tendon does not enhance neuromuscular performance in maximal-effort contractions during or immediately after training	7/10 Concealment of subject allocation, and blinding of therapists and assessors was not reported; Additionally, it is unclear if outcome measures were obtained from at least 85% of subjects initially allocated.
Pamukoff, Ryan, Blackburn (2014)[2] Single group, cross-over study	Compared the acute effects of 30 Hz vs. 60 Hz LMV exposure applied to the right quadriceps muscle in 20 healthy volunteers on strength, rate of torque development, and EMG amplitude. Secondarily, to determine the duration of the observed effects following LMV exposure	A custom-built LMV device was secured over the quadriceps tendon. Subjects were placed in an isometric squat and LMV was applied as 6x1min treatment at a frequency of 30 Hz (amplitude of 1.2mm) or 60 Hz (amplitude of 0.4mm)	Isometric knee extensor peak torque (PT), rate of torque development (RTD), and electromyography (EMG) of the quadriceps	Results suggest that 30 Hz LMV treatment acutely enhances EMG activity in the quadriceps muscles for at least 5 minutes, and may increase PT in healthy individuals. LMV had no effect on RTD	6/10 Similarity of subjects at baseline, along with concealment of random allocation was not stated; Additionally, blinding of therapists and assessors was not reported

Author(s) (year), study design	Purpose	Method of LVT application	Outcome measures	Results and conclusions	PEDro score and shortcomings
Peer, Barkley, Knapp (2009)[7] Controlled clinical trial	To determine whether segmental biomechanical muscle stimulation (BMS) muscle therapy increases range of motion and reduces perceived stiffness in physically 10 active individuals with acute and subacute ankle sprains or hamstring strains	Three BMS placements were used for 2 minutes each at 20 Hz for the ankle. Four BMS placements were used for 2 minutes each at 20 Hz. Amplitude was not provided although the authors mentioned that the Swisswing device used in the study was capable of 1-6mm amplitudes independent of frequency and load	Ankle dorsiflexion/plantar flexion/inversion/eversion, hamstring flexibility, and subjective ratings of stiffness were measured	Significant increase in ankle dorsiflexion and eversion, and hamstring flexibility, and significantly decreased perceived ankle and hamstring stiffness following segmental BMS at 20 Hz	5/10 Random allocation of subjects along with concealment of subject allocation was not stated; Additionally, blinding of subjects, therapists, and assessors was not reported
Pietrangelo *et al*. (2009)[8] Controlled clinical trial	To determine whether a training program of passive muscle stimulation through local mechanical vibrations at high frequency applied to the lower limbs induced an increase in muscle mass and strength in 9 elderly subjects showing signs of sarcopenia	Local vibratory stimulation was applied on the skin of the distal part of the quadriceps. The duration of each application was 15 min and the frequency was 300 Hz (amplitude not provided)	Knee extensor isometric strength, thigh circumference, as well as needle biopsies of the vastus lateralis, cellular features and gene expression profiles were analyzed	Treated muscles displayed enhanced maximal isometric strength and increased content of fast MyHC-2X myosin. Single muscle fiber analysis did not show any change in cross-sectional area or specific tension. Changes in gene expression after 12 weeks of local vibration training in pathways related to energy metabolism, sarcomeric protein balance and oxidative stress response	4/10 Similarity of subjects at baseline, random allocation of subjects along with concealment of allocation was not stated; Additionally, blinding of subjects, therapists, and assessors was not reported
Souron R, Besson T, *et al*. (2017)[21] Randomized controlled trial	To evaluate the effects of a 4-week local vibration training (LVT) program on the function of the knee extensors and corticospinal properties in 17 healthy young and old subjects	Vibration device set to 100 Hz and 1 mm amplitude and was strapped directly on the right rectus femoris muscle; Subjects received 3, 1-hour sessions over 4 weeks for a total of 12 sessions	Jump performance, maximal voluntary force (MVC) and electromyographic (EMG) activity on vastus lateralis and rectus femoris muscles were assessed; Single pulse Transcranial Magnetic Stimulation (TMS) allowed evaluation of cortical voluntary activation (VATMS), motor evoked potential (MEP) area and silent period (SP) duration	LVT seems as effective in young as in old subjects to improve maximal functional capacities through neural modulations and may be used as an efficient alternative training method to improve muscular performance in both healthy young and old subjects	5/10 Random allocation of subjects along with concealment of subject allocation was not stated; Additionally, blinding of subjects, therapists, and assessors was not reported
Souron R, Farabet A, *et al*. (2017)[22] Controlled clinical trial	To evaluate the effects of an 8-week local vibration training (LVT) program on functional and corticospinal properties of dorsiflexor muscles in 44 male and female subjects	The vibration group performed 24, 1-hour sessions (3 sessions/week) at 100-Hz and 1mm amplitude applied to the right tibialis anterior	Maximal voluntary contraction (MVC) torque; Transcranial magnetic stimulation (TMS) was used to evaluate cortical voluntary activation (VATMS); Motor evoked potential (MEP); Cortical silent period (CSP) and input-output curve parameters	Despite no changes in excitability or inhibition, local vibration seems to be a promising method to improve strength through an increase of maximal voluntary activation, i.e. neural adaptations	5/10 Randomization and concealment of subject allocation, and blinding of subjects, therapists, and assessors was not reported
Tankisheva *et al*. (2015)[14] Randomized controlled trial	To investigate the effect of 6 months' local vibration training on bone mineral density (BMD), muscle strength, muscle mass, and physical performance in 35 postmenopausal women (66–88 years)	6-months of local vibration treatment with frequency between 30 - 45 Hz and acceleration between 1.71 - 3.58g; The vibration was applied for 30 minutes on the midthigh and around the hip in supine-lying position once per day, 5 days / week	The primary outcome variables were the isometric and dynamic quadriceps muscle strength and the BMD of the hip; Muscle mass of the quadriceps and physical performance was also assessed via the Modified Physical Performance Test and Shuttle Walk Test	A net benefit of 13.84% in isometric muscle strength at 60-degree knee angle in favor of the vibration group compared with controls; No changes in BMD, muscle mass, or physical performance were found in both groups; Overall, 6 months of local vibration training improved some aspects of muscle strength but had no effect on BMD, muscle mass, and physical performance in post-menopausal women	8/10 Blinding of subjects and therapists who delivered therapy was not reported

Quality Assessment

The included studies had PEDro scores ranging from 4/10 to 9/10 with an average score of 5.97/10. The most commonly adhered to PEDro criteria were random allocation (criteria 2), similarity of groups at baseline (criteria 4), outcome measure assessments (criteria 8-9), and between group statistical comparisons with both point measures and measure of variability (criteria 10-11). The most commonly missed PEDro criteria among the studies were concealment of random allocation (criteria 3), and appropriate blinding of subjects, therapists, and assessors (criteria 5-7).

Discussion

This literature review was conducted in order to assess the existing evidence on the effect of local vibration on a variety of performance parameters. Overall, 21 studies with a total of 831 participants were evaluated. There were a number of outcome measures utilized in the literature, with the most common being muscle activation / stimulation reported in 11 studies [1-2,6,15-17,20-24], muscle strength reported in 10 studies [2-4,8-9,14,16,21-22,25], muscle power reported in 10 studies [1-2,5,15-17,19,21,23-24], and joint flexibility / range of motion being reported in four studies[4,7,18,20].

The included studies had PEDro scores ranging from 5/10 to 9/10 with an average score of 5.97/10. Overall, 12 studies were deemed to be of high methodological quality, and nine of fair quality. The average PEDro rating of 5.97/10 across all of the included studies falls within the upper limit of the 'fair' quality category.[10] The most commonly met PEDro criteria were random allocation (criteria 2), similarity of groups at baseline (criteria 4), outcome measure assessments (criteria 8-9), and between group statistical comparisons with both point measures and measure of variability (criteria 10-11). Given that criteria 2 to 9 are intended to assess the internal validity of a given study[10], only four out of these possible eight criteria were commonly met. The most commonly missed PEDro criteria were concealment of random allocation (criteria 3), and appropriate blinding of subjects, therapists, and assessors (criteria 5-7) - the remaining four criteria used to assess for internal validity.[10] Based on this observation, the limited internal validity of the current body of evidence investigating the effects of local vibration therapy in various performance parameters should be considered when interpreting study results. On the other hand, criteria 10 and 11 of the PEDro scale are intended to determine if there is sufficient statistical information to make a study's results interpretable.[10] These criteria were among those more commonly met throughout the papers evaluated in this literature synthesis. Lastly, it is worth noting that although criteria 1 is not included in the calculation the PEDro score, it was also fulfilled by a large majority of the studies evaluated here. This criterion speaks to the external validity or "generalizability" of the trial.[10]

The methods of local application varied significantly among the included studies. Methods ranged from indirect vibration transmission through a cable in some studies [5-6,15,25], to the application of specific hand-held vibration devices directly over the targeted muscle[1-4,7-8,14,16-19,20-24]. Further, some trials applied local vibration in combination with exercise, while others applied the intervention while subjects were at rest. When grouped, 11 out of the 15 studies (73%)[2-4,7-8,14,16-22] who utilized a direct LMV application technique showed positive results among their respective outcome measures, compared to four out of five studies (80%) [5,6,15] reporting positive results when an indirect LMV technique was used. Clearly, the limited number of trials employing indirect LMV methods makes it difficult to draw a true comparison of the two techniques. Based on the studies included in this review, it appears that both direct and indirect LMV techniques tend to generate positive results. However, there is currently not enough evidence to say which form of vibration application is more effective for eliciting a change in the various performance parameters investigated.

Another significant discrepancy that was found throughout the literature was related to the type of sham / control group used. There is no known, validated sham procedure for local vibration therapy. Some authors simply provided no treatment whereas others applied vibration to a different body location. One must consider that the various methods used among researchers may have an impact on the observed results or lack thereof.

Aside from differing methods of vibration application, the specific vibration parameters were also quite heterogeneous across trials. The frequency of local vibration ranged from five to 300 Hz, and the amplitude from 0.12 to 12 mm.[16,19] Similarly, the duration of the intervention period also spanned time frames of six seconds up to 30 minutes.[9] These discrepancies are perhaps some of the greatest limitations in the existing literature on local vibration therapy and changes in muscular performance parameters. For example, Lou *et al*.[23,24] and Moran, McNamara and Luo[1] demonstrated that utilization of vibration at 65 Hz and 1.2 mm was not effective. On the other hand, studies utilizing a higher frequency of 100 [21,22], 150 [16-17,20] and 300[3,8] Hz showed a positive result. However, those studies that applied LMV at a higher frequency also seemed to use a longer duration of LMV application, with lengths of 15[8], 30[3] and 60[21-22] minutes per session being reported. This is in contrast to the studies applying LMV at lower frequencies ranging from five to 50 Hz and shorter durations of one to two minutes[1-2,4-7,14,18-19,23-25], but who also typically reported positive results[2,4-7,14,18]. These observations may provide some understanding of the relationship between the frequency and duration of LMV application required to elicit beneficial results, as higher frequencies paired with longer treatment durations, and lower frequencies paired with shorter treatment durations both typically yielded positive clinical outcomes. Interestingly, one study by Tankisheva *et al*.[14] applied LMV at a lower frequency of 30 to 45 Hz, but for a longer duration of up to 30 minutes per session. They reported that this LMV protocol improved isometric quadriceps muscle strength when compared to the control group.[14] This challenges the previous observation and may suggest that the application of lower frequency LMV may be effective regardless of whether short or long treatment durations are used. Further research must be done to clarify this discrepancy and should seek to investigate the clinical efficacy of high frequency – short duration LMV treatments in order to better define any relationship that may exist between these two variables.

The inconsistencies among LMV protocols also breeds difficulty when trying to investigate the potential mechanisms through which LMV generates its muscular response. For instance, it has been proposed that "mechanical vibration (10± 200 Hz) applied to muscle belly or tendon" has been shown to elicit a tonic vibration reflex (TVR) contraction of the muscle.[2,15] As mentioned previously, this mechanism is thought to be stimulated by a sequence of rapid muscle stretching that occurs when applying vibration, consequently triggering muscle spindles and causing an involuntary production of strength.[2] However, some of the authors investigating this proposed mechanism also explain that "it is not known whether it [the TVR] can be elicited by low vibration treatment (30 Hz)".[15] Such observations have caused some to hypothesize that a muscle's electrical and mechanical responses could vary depending on the frequency of vibration and the differing damping characteristics of the soft tissues across subjects.[2]

Despite the inconsistencies among the aforementioned parameters of vibration application, statistically significant results were yielded by the majority of the studies across the performance outcome measures.[2-6,7-8,14,15-22] It is hypothesized that musculoskeletal structures respond to vibration because of the requirement of the tissue to adapt to or modulate muscle tonicity so as to accommodate the waves of vibration.[26] This adaptation to the frequency is regulated by afferent pathways which generate hormonal responses.[26] As a result of altering the hormonal response, it is theorized that neuromuscular performance could be improved in the subject.[26] Additionally, physiological analysis of vibration therapy has found that it is possible to stimulate more muscle receptors both in number and type.[27] The stimulation of these additional receptors could, at least in the short term, result in increased motor fiber recruitment.[27] When more receptors are primed via vibratory therapy, more muscle fibers are thought to be available for recruitment.[27] This can ultimately result in a higher peak contraction force and an overall increase in muscular performance.

Limitations

There are number of limitations to this review that should be considered. First, two independent reviewers gave analyses of the articles and came to a consensus over discrepancies in PEDro scores when they arose. However, reviewer agreement statistics are not provided. Second, the study authors and publication details were not withheld from the reviewers, which could introduce a factor of reviewer bias. Third, it is also possible that despite efforts to obtain all relevant articles on the subject up to February 2018, some studies may have escaped the search strategy. Lastly, because of time and logistic considerations, no attempts were made to contact the original authors of each study to gather more detailed data not included in the official report. Each study was judged based on the information contained in the published articles alone.

Conclusion

This literature review was conducted in order to determine what is known about the effects of local vibration therapy on various performance parameters. The average PEDro rating across all of the included studies (5.97/10) falls within the 'fair' category in terms of internal validity. The majority of the studies found that local vibration does seem to induce beneficial changes in outcome measures such as muscle activation / stimulation, muscle strength, muscle power, and joint flexibility / range of motion. With that said, the available literature is quite heterogeneous in terms of how local vibration therapy is applied (direct vs indirect), the type of control / sham procedure applied, and the frequency, amplitude, and duration settings used during vibration protocols. Future research should seek to better define the relationship between specific vibration parameters (frequency, amplitude, duration) and particular performance measures. Additionally, developing a more standardized procedure in terms of how vibration therapy is applied would allow the academic community to more confidently compare experimental results and draw more valuable conclusions.

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Appendix 1.
PEDro Scale Utilized for Study Evaluation

PEDro scale

1. eligibility criteria were specified no ❑ yes ❑ where:
2. subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received) no ❑ yes ❑ where:
3. allocation was concealed no ❑ yes ❑ where:
4. the groups were similar at baseline regarding the most important prognostic indicators no ❑ yes ❑ where:
5. there was blinding of all subjects no ❑ yes ❑ where:
6. there was blinding of all therapists who administered the therapy no ❑ yes ❑ where:
7. there was blinding of all assessors who measured at least one key outcome no ❑ yes ❑ where:
8. measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups no ❑ yes ❑ where:
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat" no ❑ yes ❑ where:
10. the results of between-group statistical comparisons are reported for at least one key outcome no ❑ yes ❑ where:
11. the study provides both point measures and measures of variability for at least one key outcome no ❑ yes ❑ where:

The PEDro scale is based on the Delphi list developed by Verhagen and colleagues at the Department of Epidemiology, University of Maastricht (*Verhagen AP et al (1998). The Delphi list: a criteria list for quality assessment of randomised clinical trials for conducting systematic reviews developed by Delphi consensus. Journal of Clinical Epidemiology, 51(12):1235-41*). The list is based on "expert consensus" not, for the most part, on empirical data. Two additional items not on the Delphi list (PEDro scale items 8 and 10) have been included in the PEDro scale. As more empirical data comes to hand it may become possible to "weight" scale items so that the PEDro score reflects the importance of individual scale items.

The purpose of the PEDro scale is to help the users of the PEDro database rapidly identify which of the known or suspected randomised clinical trials (ie RCTs or CCTs) archived on the PEDro database are likely to be internally valid (criteria 2-9), and could have sufficient statistical information to make their results interpretable (criteria 10-11). An additional criterion (criterion 1) that relates to the external validity (or "generalisability" or "applicability" of the trial) has been retained so that the Delphi list is complete, but this criterion will not be used to calculate the PEDro score reported on the PEDro web site.

The PEDro scale should not be used as a measure of the "validity" of a study's conclusions. In particular, we caution users of the PEDro scale that studies which show significant treatment effects and which score highly on the PEDro scale do not necessarily provide evidence that the treatment is clinically useful. Additional considerations include whether the treatment effect was big enough to be clinically worthwhile, whether the positive effects of the treatment outweigh its negative effects, and the cost-effectiveness of the treatment. The scale should not be used to compare the "quality" of trials performed in different areas of therapy, primarily because it is not possible to satisfy all scale items in some areas of physiotherapy practice.

Last amended June 21st, 1999

https://www.pedro.org.au/english/downloads/pedro-scale/