BJMVB 2023; 1(2):60-74

Systematic review

Local vibratory stimulation in increasing corticospinal excitability of healthy individuals: systematic review.

Alves-Pereira, T.M.[1*], Siqueira-Brito, J.I.[1], Silva-Nascimento, L.[1], Silmar Silva- Teixeira, S.[2,3], Soares-Teles, A.[2], Orsini, M.[4], Nader, S.[5], Ribeiro, P.[6], Velasques, B.[6], Moraes- Silva, J.[7], Vale- Bastos, V.H.[3,8]

1 Program in Biotechnology, Universidade Federal do Delta do Parnaíba, Parnaíba, Brazil;
2 Laboratory of Neuroscience and Techonology Innovation (NITLAB), Universidade Federal do Delta do Parnaíba, Parnaíba, Brazil;
3 Program in Biotechnology, Universidade Federal do Delta do Parnaíba, Parnaiba, Brazil;
4 Department of Medicine, Universidade Iguaçu, Rio de Janeiro, Brazil;
5 Masters in Neurology, Universidade Severino Sombra, Rio de Janeiro, Brazil;
6 Laboratory of Brain Mapping and sensorimotor integration, Universidade Federal do Delta do Parnaíba, Rio de Janeiro, Brazil;
7 Post-doctorate in Biomedical Sciences, Universidade Federal do Delta do Parnaíba, Parnaíba, Brazil;
8 Brain Mapping and Functionality Laboratory, Universidade Federal do Delta do Parnaíba, Parnaíba, Brazil;

*Corresponding author: tassiane.alves07@gmail.com / ORCID: 0000-0002-8876-7438

Received: June 17th, 2023 / Revised: August 19, 2023 / Accepted: December 21st, 2023

Abstract

Introduction: Vibratory stimulation is a therapeutic intervention that uses somatosensory inputs, activating peripheral receptors and causing a neurophysiological mechanism that activates the tonic vibration reflex and increases the firing rate of muscle spindles. These changes promote positive physiological repercussions on functional capacity and on motor impairment resulting from neurological diseases. **Aim:** The objective of this systematic review is to understand the alterations produced in the corticospinal excitability promoted by the vibratory stimulus. **Methods:** The systematic review was developed through searches in the PubMed, Scopus and Web of Science databases using the terms local vibration AND cortical excitability. Articles that presented clinical trials published in the last ten years in the English language, which used local vibratory stimulation in healthy individuals with outcomes related to corticospinal excitability, were included. The articles were evaluated for both the intended outcomes, the methodological quality with the PEDro scale and the level of evidence with the GRADE system. **Results:** Two reviewers independently selected the studies according to the criteria listed. A total of 15 articles were included where they showed an increase in corticospinal excitability through facilitation arising from afferent inputIa and intracortical motor circuits, which also showed improvements in maximum functional performance in young people and adults through neural modulations, increased proprioceptive integration and of the motor learning rate. **Conclusions**: Given the results presented, it was possible to conclude that local vibration increases corticospinal excitability in healthy individuals, which can contribute to muscular and motor performance, and can be attributed to other perspectives in pathological conditions as a therapeutic resource in neuromotor rehabilitation.

Keywords: local vibration; excitability cortical; neurofunctional rehabilitation

1. Introduction

Voluntary movement requires the integration of cortical motor areas or supraspinal motor centers, which, associated with spinal reflex circuits, have the function of controlling efferent activities in motor tasks, that is, they perform the voluntary command through the execution of muscle contraction (1,2).

Learning or developing a new motor task requires a cognitive stage that increases the level of effort to concentrate on performing the task, which leads to an increase in corticospinal excitability (3,4). This increase promotes changes at both the cortical and spinal levels, with changes in the somatosensory cortex preceding those in the primary motor cortex (5).

The somatosensory cortex receives information from peripheral receptors through sensory stimuli in order to interpret, process and store this information, in order to integrate with other brain regions and promote the individual's interaction responses with their environmental stimuli (6). There are therapeutic interventions that use resources with somatosensory inputs to promote changes in cortical excitability, which may increase or decrease it. These changes vary according to stimulus intensity, frequency, duration and duty cycle. Among these interventions are vibratory stimulation, electrical stimulation and tactile stimulation, which mainly cause changes in motor evoked potential (7).

Vibratory stimulation, specifically, is a therapeutic intervention that promotes a neurophysiological mechanism relating the activation of the tonic vibratory reflex and rapid stretching stimulation with triggering of muscle spindles that lead to the involuntary production of muscle contraction, increase corticospinal excitability and intracortical processes (8,9,10), and can be used locally, applied directly to specific muscles or tendons, or to the entire body (11,12,13,14,15)

Local vibratory stimulation has shown promising results in neurofunctional rehabilitation, including reduced spasticity (8,16,17,18,19) and ataxia (20), increased muscle strength (21), improved gait and postural control (22,23,24) and easier motor control tasks (11,13,25). Research has been developed to elucidate new responses to vibratory stimuli, mainly related to changes in corticospinal functions. In this perspective, it is relevant to seek evidence on the practice of this intervention, in order to fill gaps and favor new insights into the therapeutic repercussions of this intervention. Thus, the aim of this study is to seek scientific evidence on local vibratory stimulation in increasing corticospinal excitability in healthy individuals.

2. Materials and Methods

The study was a systematic review of the literature registered in the International Prospective Register of Systematic Reviews (PROSPERO) registration number 186680, following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

2.1 *Research Protocol*

The search for articles was performed in the PubMed, Scopus and Web of Science databases, based on the PICO strategy (P-population: healthy individuals; I-Intervention local vibratory stimulation; C-Comparison: not applicable to this study; O: Outcomes corticospinal excitability), used to formulate the research's guiding question, which asks "Does local vibratory stimulation increase corticospinal excitability in healthy individuals?". The search strings created are presented in Table 1, formulated using MeSH keywords and similar terms that enable answers to the proposed research problem.

Databases	**Strings**	**Search within**	**Number results**
PUBMED/Medline	local vibration AND cortical excitability [MeSH]	Article title, abstract	107
	tendon OR muscle vibration AND cortical excitability [MeSH]		96
Scopus	local vibration AND cortical excitability[MeSH]	Article title, keywords, abstract	8
	tendon AND muscle AND vibration/ AND cortical excitability[MeSH]		15
Web of science	local vibration AND cortical excitability[MeSH]	All fields	12
	tendon AND muscle AND vibration/ AND cortical excitability[MeSH]		33

2.2 *Selection Criteria*

The articles included were those that presented clinical trials published in the last ten years in the English language, which used local vibratory stimulation in healthy individuals, published from the last 10 years. Articles that used whole-body vibration or association with other therapies, duplicate articles and other study designs were excluded.

2.3 *Selection of Studies and Data Extraction*

Two independent reviewers (TMAP and JISB) selected the studies according to the criteria listed, initially by reading the title and then reading the abstracts to identify the type of study and inclusion criteria used. Disagreements between reviewers during the analysis were decided by a third reviewer (JMS). After selection, data on the profile of the participants, characteristics and protocols of the intervention, evaluated measures and results were extracted and analyzed.

2.4 *Quality Assessment*

To assess the methodological quality of the selected articles, the PEDro scale was used, which qualifies randomized controlled clinical trials following 11 criteria with scores from one to ten, with the first criterion not being scored. Studies with a score greater than or equal to six are considered to be of high quality.

2.5 *Level of Evidence*

The quality of evidence of the articles was assessed using the GRADE scale (Grading of Recommendations Assessment, Development and Evaluation). The study used the table GRADE quality assessment to assign a level of evidence and present the quality of the studies presented. The table attributes levels of evidence representing confidence in the information used in each outcome analyzed, classifying into high, moderate, low and very low defined levels according to the study outline (26,27).

3. Results

Through the search, 271 articles were found, of which 256 were excluded using established criteria. Thus, 15 studies were included for a careful evaluation, of which met the appropriate inclusion criteria. The PRISMA flow diagram used for the study selection process is shown in Figure 1. In total, 15 articles were included with data from 270 volunteers with a mean age of 35.5 years. The details of the selected studies are listed in Table 2.

The application of vibratory stimulation was through focal devices such as Custom Made (miniature electromagnetic solenoid) (28), C-3 Tractor (29), CroSystem electromagnetic transducer (13) VB 115 (30,31,32,34,36,38,39,40)Vibralgic Model (33, 37, (Electronic Conseil, V100 Ling Dynamic Systems Electromagnetic Mechanical Stimulator (35,41).

The intervention protocol was heterogeneous with respect to the stimulated region, vibratory parameters and duration of the intervention, varying in regions such as abductor pollicis brevis (28,37,41), flexor carpi radialis muscle (13), extensor carpi radialis (39), wrist (29), tibialis anterior (30,34) rectus femoris (31,32) and in tendons: extensor pollicis brevis tendon (33), Achilles tendon (36,38,40) and flexor carpi radialis tendon (35).

The applied frequency ranged from 50 to 120 Hz with intensity from 0.2 mm to 1.5 mm or according to the individual's sensitivity threshold. The duration of the protocols varied between single sessions and sessions for up to 8 weeks, with a stimulus with a determined time of 500 milliseconds to 1 hour per intervention (13,28,41).

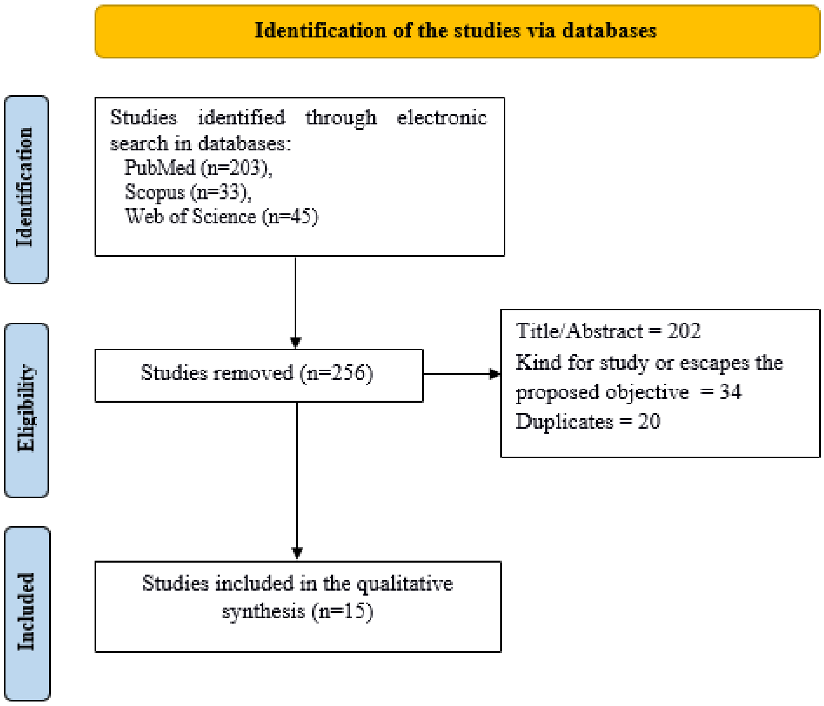
The outcome evaluated in the studies were changes in corticospinal excitability as a result of local vibratory stimulation, analyzed through information arising from interpretations of the electroencephalogram (EEG) (13) or single pulse Transcranial Magnetic Stimulation (TMS) (28-41), which showed an increase in Motor evoked potential and intracortical facilitation (CIF) and short interval intracortical inhibition (SICI) (13, 28-41)

The methodological quality of the articles ranged between four and eight as shown in Table 3. Five articles had high quality with scores ≥ 6. Concealed allocation, blinding and adequate follow-up were the most frequently omitted study characteristics. GRADE showed that most articles were at risk of bias due to the lack of allocation and blinding, as well as the lack of intention to treat with small samples, without comparisons between groups, also presenting indirect evidence, which was not fully related to the outcome expected (Table 4).

4. Discussion

This study sought scientific evidence on the effect of local vibratory stimulation at corticospinal excitability in healthy individuals. Heuvelen et al, 2021 (41) published guidelines to use the mechanical vibration on Whole-Body Vibration Studies in Humans, animals and Cell Cultures, that is suggest being utilized in investigations with local vibratory therapy (41).

Figure 1. Study selection flowchart based on PRISMA.



Corticospinal excitability reflects on the excitation of the pathway between corticocortical motor axons and spinal motor neurons that innervate the specific muscle to produce the action, including changes in cortical and spinal evoked potentials. Studies have revealed that the corticospinal pathway is related to feedback control of human posture, being altered according to the current state of posture, as well as being modulated by gaps in temporal feedback, in which the integration between sensorimotor information depends on signals proprioceptive to direct the correct movement (43,44).

The studies included in this review reported that local vibration was able to increase corticospinal excitability in the population studied (13,28,29,33-40). The application of vibration to the human body is followed by activation of skin cells and specific muscle receptors, which evoke the tonic vibration reflex and provide various proprioceptive stimuli to the somatosensory and motor cortex via Ia afferent nerves. Motor evoked potential mediated by afferent input Ia and intracortical motor circuits (intracortical facilitation and short-range intracortical inhibition) resulting from vibratory stimulation, whether at rest (28,34-40) or in muscle contraction (13,29,33).

The effect of vibration on corticospinal excitability may reflect the activity of GABA-mediated inhibitory circuits and their function on motor control and coactivation of cortical regions (16), also demonstrating an increase in the expression of the cortical representation area associated with the vibrated muscle, in addition to allow sensory inputs to excite neural circuits and control the motor output of the stimulated muscle (46).

Studies have also observed that vibration can promote the activation of the vibrated muscle and its antagonist (35,46), as well as activate the cortical area contralateral to the stimulus (13,47). The explanation for this action may be associated with the involvement of proprioceptive information induced by vibration that occurs at the cortical level, which may activate contralateral motor cortical areas through the kinesthetic illusion in the non-vibrated,

Table 2. Summary of included studies presenting sample size, vibration parameters, intervention protocol, analyzed variables and results obtained in the studied population.

Author/ Sample	Vibration Parameters	Intervention Protocol	Analyzed Variables	Results
Vidakovic *et al* [28] - 11 individuals	**Frequency** - 120 Hz **Intensity** - Above individual's perception limit);	**Application location:** Upper end of finger II **Device:** Custom Made (Miniature Electromagnetic Solenoid) **Time:** 500 ms per stimulation **Action:** Rest	MEP, EMG (short thumb abductor)	Increased MEP amplitude after vibration;
Seo *et al*[29] - 46 individuals	**Frequency** - 50 Hz **Intensity** - 60% of the sensory threshold	**Application location:** left volar fist **Device:** C-3 Tractor **Time:** 25 min **Action:** Rest and movement (hand grip)	RMT, SICI, CIF, MEP TMS (short abductor of the thumb), EEG (alpha and beta power)	Changes in SICI, and in sensory motor activity both at rest and during prehension
Lopez *et al*[13] - 22 individuals	**Frequency** - 100 Hz **Intensity** - 300 lm	**Application location:** Flexor radial muscle of the carpus; **Device:** CroSystem electromagnetic transducer **Time**: n/a **Action:** Isometric contraction	EEG (alpha, beta and MRRP), EMG AND CVM, RC	Increase in alpha, suggesting increased excitability of contralateral S1-M1
Souron *et al*[30] - 44 individuals	**Frequency** - 100 Hz **Intensity** - 1 mm	**Application location:** Muscular tissue of the Right Anterior Tibialis **Device:** VB 115 **Time**: 1 hour / week (for 8 weeks) **Action:** Rest	CVM, VA, MEG, MEP TMS (anterior tibial and soleus), RC	No significant changes were observed in either leg
Souron *et al*[31] - 23 individuals	**Frequency** - 100 Hz **Intensity** - 1 mm	**Application location:** Right Femoral muscular tissue **Device:** VB 115 **Time**: n/a **Action:** Rest	CVM, VA, MEP TMS (vastus femoris and rectus femoris), EMG (vastus femoris, rectus femoris and biceps femoris) CPS, MEPT	The vibration did not change the TMS. It suggests that modulations in the CNS would be accompanied by a reduction in voluntary muscle strength
Souron *et al*[32] - 17 individuals	**Frequency** - 110 Hz **Intensity** - 1 mm	**Application location:** Right Rectus Femoral Muscle Belly **Device:** VB 115 **Tempo**: 1 hour/ week (for 4 weeks) **Action:** Rest	CVM, MEP TMS (vastus femoris and rectus femoris), EMG (vastus lateralis, rectus femoris and biceps femoris), CPS, VA	Vibration improves maximum functional performance in young people and adults through neural modulations
Bisio *et al*[33] - 30 individuals	**Frequency** - 80- 30 Hz **Intensity** - 1-5 mm	**Application location:** Short Thumb Extender Tendon **Device:** Vibralgic Model, Electronic Conseil **Time**: (1 h 30 min) **Action:** illusory movement	MEP, RC, EMG (short thumb abductor)	Responses evoked in M1 plasticity with increased excitability

(*continued on next page*)

Table 2. (continued)

Author/ Sample	Vibration Parameters	Intervention Protocol	Analyzed Variables	Results
Farabet *et al*[34] - 13 individuals	**Frequency** - 100 Hz **Intensity** - 1 mm	**Application location:** Belly of the tibialis anterior muscle **Device:** VB 115 Techno Concept **Time**: 30 min **Action:** Rest	CVM, VAtms, CPS, EMG (dorsiflexion) MEG (contralateral anterior tibial)	Increased corticospinal excitability of the lower limbs
Mancheva *et al*[35] - 15 individuals	**Frequency** - 80 Hz **Intensity** - 0.5 – 1.5 mm	**Application location:** Carpal Radial Flexor Tendon **Device:** LingDynamic Systems V100 Electromagnetic Mechanical Stimulator) **Time**: 30 min **Action:** Rest	MEP (Carpal Radial Flexor and Carpal Radial Extensor)	Changes in the facilitation of corticospinal excitability in vibrated muscles and their antagonists
Lapole *et al*[36] - 16 individuals	**Frequency** - 50 Hz **Intensity** - 1 mm	**Application location:** Achilles tendon **Device:** VB 115 techno Concept **Time**: 60 s per stimulation **Action:** Rest	MEP (Soleus), EMG (Soleus), CIF E SICI	Increased corticospinal excitability induced by soleus muscle vibration
Lapole *et al*[37] - 10 individuals	**Frequency** - 80 Hz **Intensity** - 0.8-1 mm	**Application location:** Belly of the abductor short muscle of the thumb **Device:** Vibralgic 5 Ysy Medical **Time**: (15 min) **Action:** Rest	MEP (short abductor of the thumb), SICI, CIF, M wave (Nerve stimulation), EMG (short abductor of the thumb)	Vibration increases sensorimotor integration via decreased inhibition and increased facilitation
Lapole *et al*[38] - 12 individuals	**Frequency** - 50, 80, 110Hz **Intensity** - 1 mm	**Application location:** Achilles tendon **Device:** VB 115 Techno Concept **Time**: (60 sec per series/8 series) **Action:** Rest	MEP and EMG (Soleus, medial and anterior tibial gastrocnemius)	Increased MEP of the soleus and gastrocnemius, suggesting increased corticospinal excitability due to vibration
Mancheva *et al*[39] - 19 individuals	**Frequency** - 80 Hz **Intensity** - 0.5 mm	**Application location:** Carpal Radial Extensor Muscle **Device:** VB 115, Techno Concept **Time**: (4 sec per series) **Action:** Rest	MEP (Carpal Radial Extender), MEG (Carpal Radial Extender and Flexor), CIF, SICI	Vibration is a prolongation of the effect of SICI and ICF
Lapole *et al*[40] - 12 individuals	**Frequency** - 50 Hz **Intensity** - 0.2 mm	**Application location:** Achilles tendon **Device:** VB 115, Techno Concept **Time**: (1 h) **Action:** Rest	MEP (soleus and tibialis anterior), reflexes X (tibial nerve stimulation) and wave F, EMG (soleus and tibialis anterior)	Vibration led to changes in cortical excitability that may contribute to increased muscle activation capacity

(*continued on next page*)

Table 2. (continued)

Author/ Sample	Vibration Parameters	Intervention Protocol	Analyzed Variables	Results
Rosenkrank *et al*[41] - 8 individuals	**Frequency** - 80 Hz **Intensity** - 0.2 – 0.5 mm	**Application location:** Muscular belly of the Abductor brevis or first dorsal interosseous **Device:** V100 Ling Dynamic Systems **Time**: (15 seg) **Action:** Rest	MEP (short abductor of the thumb), SICI	The vibration provided an increase in proprioceptive integration and an increase in the motor learning rate

Legend: MEP (Motor Evoked Potential); MEPT (Thoracic Motor Evoked Potential); EMG (electromyography); CIF (Afferent Facilitation); SICI (inhibition); RC (Recruitment curve); CVM (Maximum Voluntary Contraction); VAtms (voluntary cortical activation); CPS (Cortical Silence Period); M1 (primary motor cortex), S1-M1 (somatosensory cortex); RMT (Rest Motor Threshold), EEG (Electroencephalogram), TMS (Transcranial Stimulation); CNS (Central Nervous System).

Table 3. Methodological quality of articles based on the PEDro scale.

Studies	1*	2	3	4	5	6	7	8	9	10	11	Total
Vidagovic *et al* (28)	S	N/E	N/E	S	N/E	N/E	N/E	S	N	S	S	4/10
Seo *et al* (29)	S	N/E	N/E	S	N/E	N/E	N/E	S	S	S	S	5/10
Lopez *et al* (13)	S	N/E	N/E	S	N/E	N/E	N/E	S	S	S	S	5/10
Souron *et al* (30)	S	S	S	S	S	N/E	N/E	S	S	S	S	8/10
Souron *et al* (31)	S	S	S	S	S	N/E	N/E	S	S	S	S	8/10
Souron *et al* (32)	S	S	S	S	S	N/E	N/E	S	S	S	S	8/10
Bisio *et al* (33)	S	S	S	S	S	N/E	N/E	S	S	S	S	8/10
Farabet *et al* (34)	S	S	S	S	S	N/E	N/E	S	S	S	S	8/10
Mancheva *et al* (35)	S	N	N	S	N	N/E	N/E	S	S	S	S	5/10
Lapole *et al* (36)	S	N	N	S	N	N/E	N/E	S	S	S	S	5/10
Lapole *et al* (37)	S	N	N	S	N	N/E	N/E	S	S	S	S	5/10
Lapole *et al* (38)	S	N	N	N	N	N/E	N/E	S	S	S	S	5/10
Mancheva *et al* (39)	S	N	N	S	N/E	N/E	N/E	S	S	S	S	5/10
Lapole *et al* (40)	S	N	N	S	N/E	N/E	N/E	S	N	S	S	4/10
Rosenkrank *et al* (41)	S	N/E	S	S	N/E	N/E	N/E	S	N	S	S	5/10

Legend: N/E: Not specified. Criteria: 1- specific eligibility criteria; 2- random allocation; 3- secret allocation; 4- comparison of baseline characteristics; 5- blind patients; 6- blind therapists; 7- blind evaluators; 8- description of patient follow-up; 9- intention-to-treat analysis; 10- comparison between groups; 11- measures of variability and precision; *Item 1 is not included in the total score.Legend: N/E: Not specified. Criteria: 1- specific eligibility criteria; 2- random allocation; 3- secret allocation; 4- comparison of baseline characteristics; 5- blind patients; 6- blind therapists; 7- blind evaluators; 8- description of patient follow-up; 9- intention-to-treat analysis; 10- comparison between groups; 11- measures of variability and precision; *Item 1 is not included in the total score.

Table 4. GRADE Evidence Profile

N° of participants and number of studies	Outcome: Corticospinal excitability					Evidence Quality Level
	Bias Risk	**Inconsistency**	**Indirect evidence**	**Imprecision**	**Publication Bias**	
270 volunteers (15 studies)	High risk[a]	High risk[b]	Moderate risk[c]	Moderate risk[d]	Not detected[e]	AAOO Low due to risk of bias, inconsistency

Legend: a. Unblinded allocation, patients, therapist, and unblinded evaluators, and lack of intent to treat.
b. Heterogeneity of studies and variety of samples.
c. Indirect comparison between groups
d. High confidence intervals with small samples
e. Not detected
Evidence Quality Level : AAAA (high risk); AAAO (moderate risk); AAOO (low risk)

muscle (46). According to Marconi *et al* 47, although their study inhibited the cortical representation of the target muscle and excited the non-vibrated, they believed that this result may have occurred due to the particular characteristics of the protocol used, since there are studies in which they demonstrate an increase in motor evoked potentials in the vibrated muscle.

In the study carried out by Souron and his collaborators (30) applying local vibration to the muscle belly of the anterior tibialis one hour a week for 8 weeks, they could observe that there were no significant changes in corticospinal excitability when analyzing the motor evoked potential. The absence of excitability during vibration may be due to changes in afferent feedback, which is known to modulate intracortical inhibition, so when the responsiveness of afferent spindles is diminished due to prolonged periods of stimulation it can lead to a relative reduction in excitability cortical (46).

Some studies did not show satisfactory outcomes regarding corticospinal excitability, however they showed changes in the central nervous system which may have been induced after intervention (31) such as improvements in maximum functional performance in young people and adults through neural modulations (32) and increased proprioceptive integration and rate of motor learning (42).

Limitations

It was not possible to perform a meta-analysis and compare the results due to the heterogeneity in the development of studies.

Strengths

New evidence on the physiological repercussions arising from local vibratory stimulation in the sensorimotor cortex by increasing the excitability of corticospinal pathways.

Facts and Perspectives

Local vibratory stimulation induces changes capable of promoting greater integration with the sensorimotor system, causing excitation of the corticospinal pathways. In this context, local vibration can provide new therapeutic alternatives and care proposals based on responses to the activation of corticospinal pathways and motor performance. It is necessary that new research is always developed, emphasizing the therapeutic efficacy of this intervention.

5. Conclusion

Given the results presented, it was possible to conclude that local vibration increases corticospinal excitability in healthy individuals, which can contribute to muscular and motor performance, and can be attributed to other perspectives in pathological conditions as a therapeutic resource in neuromotor rehabilitation.

Acknowledgements

The authors acknowledge support of the Coordination for the Improvement of Higher Education Personnel – Brazil (CAPES).

Conflict of interest

The authors have declared no conflict of interest.

References

1. Kalmar JM. On task: Considerations and future directions for studies of corticospinal excitability in exercise neuroscience and related disciplines. Appl Physiol Nutr Metab. 2018;43(11):1113-1121.

2. Kim K-M, Kim J-S, Cruz-Díaz D, Ryu S, Kang M, Taube W. Changes in Spinal and Corticospinal Excitability in Patients with Chronic Ankle Instability: A Systematic Review with Meta-Analysis. Journal of Clinical Medicine. 2019; 8(7):1037.

3. Holland L., Murphy B., Passmore S., Yielder P. Time course of corticospinal excitability changes following a novel motor training task. Neurosci. Letter 2015;591:81–85.

4. Lockyer EJ, Nippard AP, Kean K, Hollohan N, Button DC, Power KE. Corticospinal Excitability to the Biceps Brachii is Not Different When Arm Cycling at a Self-Selected or Fixed Cadence. Brain Sci. 2019;9(2):41.

5. Ohashi H, Gribble PL, Ostry DJ. Somatosensory cortical excitability changes precedes those in motor cortex during human motor learning. J Neurophysiol. 2019;122(4):1397-1405.

6. Raju H, Tadi P. Neuroanatomy, Somatosensory Cortex. [Updated November 19, 2020]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021

7. Kojima S, Onishi H, Miyaguchi S, et al. Modulation of Corticospinal Excitability Depends on the Pattern of Mechanical Tactile Stimulation. Neural Plast. 2018;2018:5383514.

8. Avvantaggiato C, Casale R, Cinone N, Facciorusso S, Turitto A, Stuppiello L, et al. Localized muscle vibration in the treatment of motor impairment and spasticity in post-stroke patients: a systematic review. Eur J Phys Rehabil Med. 2021 Feb;57(1):44-60.

9. Germann D, El Bouse A, Shnier J, Abdelkader N, Kazemi M. Effects of local vibration therapy on various performance parameters: a narrative literature review. J Can Chiropr Assoc. 2018;62(3):170-181.

10. Moraes Silva J, Lima FP, by Paula Júnior AR, Teixeira S, by Vale Bastos VH, by Santos RP, by Oliveira Marques C, by Conceição Barros Oliveira M, by Sousa FA, Lima MO. Assessing vibratory stimulation-induced cortical activity during a motor task--A randomized clinical study. Neurosci Lett. 2015 Nov 3;608:64-70.

11. Murillo N, Valls-Sole J, Vidal J, Opisso E, Medina J, Kumru H. Focal vibration in neurorehabilitation. Eur J Phys Rehabil Med. 2014 Apr;50(2):231-42.

12. Celletti C, Suppa A, Bianchini E, Lakin S, Toscano M, La Torre G, Di Piero V, Camerota F. Neurol Sci. 2020 Jan;41(1):11-24.

13. Lopez S, Bini F, Del Percio C, Marinozzi F, Celletti C, Suppa A, Ferri R, Staltari E, Camerota F, Babiloni C. Electroencephalographic sensorimotor rhythms are modulated in the acute phase following focal vibration in healthy subjects. Neuroscience. 2017 Jun 3;352:236-248.

14.Campos, Monique Opuszcka, and Paulo Sergio Chagas Gomes. "Effects of whole body vibration on muscle strength and power in older adults: A systematic review." Motricity 10.1 (2014): 88-106.

15. Moggio L, by Sire A, Marotta N, Demeco A, Amendolia A. Vibration therapy role in neurological diseases rehabilitation: an umbrella review of systematic reviews. Disabled Rehabilitation 2021 Jul 5:1-9.

16. Seo HG, Oh BM, Leigh JH, Chun C, Park C, Kim CH. Effect of Focal Muscle Vibration on Calf Muscle Spasticity: A Proof-of-Concept Study. PM R. 2016 Nov;8(11):1083-1089.

17. Aprile I, Iacovelli C, Pecchioli C, Cruciani A, Castelli L, Germanotta M. Efficacy of focal muscle vibration in the treatment of upper limb spasticity in subjects with stroke

outcomes: randomized controlled trial. J Biol Regul Homeost Agents. 2020 Sep-Oct;34(5 Suppl. 3):1-9.

18. Casale R, Damiani C, Maestri R, Fundarò C, Chimento P, Foti C. Localized 100 Hz vibration improves function and reduces upper limb spasticity: a double-blind controlled study. Eur J Phys Rehabil Med. 2014 Oct;50(5):495-504.

19. Ayvat F, Özçakar L, Ayvat E, Aksu Yıldırım S, Kılınç M. Effects of low vs. high frequency local vibration on mild-moderate muscle spasticity: Ultrasonographical and functional evaluation in patients with multiple sclerosis. Mult Scler Report Disord. 2021 Jun;51:102930.

20. Özvar GB, Ayvat E, Kılınç M. Immediate Effects of Local Vibration and Whole-body Vibration on Postural Control in Patients with Ataxia: an Assessor-Blind, Cross-over randomized trial. Cerebellum. 2021 Feb;20(1):83-91.

21. Alghadir AH, Anwer S, Zafar H, Iqbal ZA. Effect of localized vibration on muscle strength in healthy adults: a systematic review. Physiotherapy. 2018 Mar;104(1):18-24. doi: 10.1016/j.physio.2017.06.006.

22. Lee SW, Cho KH, Lee WH. Effect of a local vibration stimulus training program on postural sway and gait in chronic stroke patients: a randomized controlled trial. Clin Rehabilitation 2013 Oct;27(10):921-31.

23. Serio F, Minosa C, De Luca M, Conte P, Albani G, Peppe A. Focal Vibration Training (Equistasi®) to Improve Posture Stability. A Retrospective Study in Parkinson's Disease. Sensors (Basel). 2019 May 7;19(9):2101.

24. Marazzi S, Kiper P, Palmer K, Agostini M, Turolla A. Effects of vibratory stimulation on balance and gait in Parkinson's disease: a systematic review and meta-analysis. Eur J Phys Rehabil Med. 2020 Jan 14. doi: 10.23736/S1973-9087.20.06099-2.

25. Percival S, Sims DT, Stebbings GK. Local vibration therapy increases oxygen re-saturation rate and maintains muscle strength following exercise-induced muscle damage. J Athl Train. 2021 Aug 17.

26. GRADE – From evidence to recommendations – transparent and sensible. Available at: <https://www.gradeworkinggroup.org/>. Accessed on: 05.Apr.2021.

27. Methodological guidelines: GRADE-maual grading system of the quality of evidence and strength of recommendation for decision-making in health. Ministry of Health, Department of Science, Technology and Strategic Inputs, Department of Science and Technology. – Brasília : Ministry of Health, 2014. 72 p.

28. Vidaković, M.R., Kostović, A., Jerković, A. Using Cutaneous Receptor Vibration to Uncover the Effect of Transcranial Magnetic Stimulation (TMS) on Motor Cortical Excitability. Medical Science Monitor: International Medical Journal of Experimental and Clinical Research 2020; 26, e923166-1.

29. Seo, N.J., Lakshminarayanan, K., Lauer, A.W., Ramakrishnan, V. et al. Experimental brain research 2019;237 (3),805–816.

30. Souron, R., Farabet, A., Féasson, L., Belli,A., Millet, G Y, Lapole, T. Eight weeks of local vibration training increases dorsiflexor muscle cortical voluntary activation. Journal of Applied Physiology 2017a;122(6) 1504-1515.

31. Souron, R., Besson, T., Mcneil, C.J., Lapole, T., Millet, GY. An Acute Exposure to Muscle Vibration Decreases Knee Extensors Force Production and Modulates Associated Central Nervous System Excitability. Frontiers in human neuroscience 2017b; (11) 519.

32. Souron R, Besson T, Lapole T, Millet Gy. Neural adaptations in quadriceps muscle after 4 weeks of local vibration training in young versus older subjects. Appl Physiol Nutr Metab 2017c;43(5)427-436.

33. Bisio, A., Biggio, M., Avanzino, L., Ruggeri, P. et al. Kinaesthetic illusion shapes the cortical plasticity evoked by action observation. The Journal of Physiology 2019;597 (12):233-3245.

34. Farabet A, Souron R, Millet Gy, Lapole T. Changes in tibialis anterior corticospinal properties after acute delayed muscle vibration. Eur J Appl Physiol 2016;116(6)1197-205.

35. Mancheva, K., Rollnik, J.D., Wolf, W. et al. Vibration-induced kinesthetic illusions and corticospinal excitability changes. J Mot Behav 2016;49(3)299-305.

36. Lapole, T., Temesi, J., Arnal, P.J. Gimenez, P., Petitjean, M., Millet GY. Modulation of soleus corticospinal excitability during Achilles tendon vibration. Exp Brain Res 2015a;233(9)2655-2662.

37. Lapole, T., & Tindel, J. Acute effects of muscle vibration on sensorimotor integration. Neuroscience letters 2015b; 587, 46-50.

38. Lapole, T., Temesi, J., Gimenez, P. Petitjean, M., Millet GY. Achilles tendon vibration-induced changes in plantar flexor corticospinal excitability. Exp Brain Res 2015c; 233(2)441-448.

39. Mancheva, K., Schrader, C., Christova, L., Dengler, R. European journal of applied physiology 2014;114 (10)2073-2080.

40. Lapole, T., Deroussen, F., Pérot, C., & Petitjean, M. Acute effects of Achilles tendon vibration on soleus and tibialis anterior spinal and cortical excitability. Appl Physiol Nutr Metab 2012;37(4)657-663.

41. Van Heuvelen MJG, Rittweger J, Judex S, Sañudo B, Seixas A, Fuermaier ABM, Tucha O, Nyakas C, Marín PJ, Taiar R, Stark C, Schoenau E, Sá-Caputo DC, Bernardo-Filho M, van der Zee EA. Reporting Guidelines for Whole-Body Vibration Studies in Humans, Animals and Cell Cultures: A Consensus Statement from an International Group of Experts. Biology (Basel). 2021 Sep 27;10(10):965. doi: 10.3390/biology10100965

42. Rosenkranz, K., & Rothwell, J.C. Modulation of proprioceptive integration in the motor cortex shapes human motor learning. J. Neurosci 2012; 32 (26) 9000-9006.

43. Fujio K, Obata H, Kitamura T, Kawashima N, Nakazawa K. Corticospinal Excitability Is Modulated as a Function of Postural Perturbation Predictability. Front Hum Neurosci . 2018; 12:68.

44. Suzuki T, Suzuki M, Hamaguchi T. Corticospinal excitability is modulated by temporal feedback gaps. Neuroreport. 2018;29(18):1558-1563.

45. Smith L, Brouwer B. Effectiveness of muscle vibration in modulating corticospinal excitability. J Rehabil Res Dev. 2005 Nov-Dec;42(6):787-94.

46. Forner-Cordero A, Steyvers M, Levin O, Alaerts K, Swinnen SP. Changes in corticomotor excitability following prolonged muscle tendon vibration. Behav Brain Res. 2008 Jun 26;190(1):41-9.

47. Marconi B, Filippi GM, Koch G, Pecchioli C, Salerno S, Don R, Camerota F, Saraceni VM, Caltagirone C. Long-term effects on motor cortical excitability induced by repeated muscle vibration during contraction in healthy subjects. J Neurol Sci. 2008 Dec 15;275(12):51-9.