DOI: 10.1590/1809-2950/22007629032022EN

Effects of muscle tendon vibration on balance after stroke: systematic review

Efeitos da vibração do tendão muscular no equilíbrio após acidente vascular cerebral: revisão sistemática

Efectos de la vibración del tendón muscular en el equilibrio después del accidente cerebrovascular: una revisión sistemática

Angélica Yumi Sambe[1], Joyce Karla Machado da Silva[2], Camila Costa de Araujo Pellizzari[3], Paola Janeiro Valenciano[4]

ABSTRACT | After cerebrovascular accident (CVA), people have complex combinations of sensory, motor, cognitive, and emotional deficits, which can affect static and dynamic balance. This study aimed to compile and summarize the main features and findings of protocols used in research that investigated the effects of muscle tendon vibration on static and dynamic balance in adults with stroke. This is a systematic review, registered in PROSPERO (CRD42022303874), in which searches were performed in the databases PubMed, Cochrane, LILACS, SciELO, MEDLINE, Science Direct, and PEDro, during the month of January 2022, using the combination of keywords related to "stroke," "balance," "muscle tendon vibration," "randomized controlled trial." Methodological quality was assessed using the PEDro scale. A total of 1,560 studies were identified, 11 of which were included, between the years 1994 to 2020, involving 242 post-stroke adults. Only five studies used vibration as an intervention and found an improvement in static and dynamic balance. Six studies analyzed the interference of vibration on postural control, showing that balance was affected during the application of vibration and that individuals needed more time to recover or did not experience significant differences. We found that the effects of muscle tendon vibration may be able to improve balance in people with stroke and influence postural control by proprioceptive mechanisms of vibration. However, more studies of high methodological quality are needed to reach a consensus regarding muscle tendon vibration treatment protocols and their recommendation in clinical practice.

Keywords | Postural Control; Balance; Muscle Tendon Vibration.

RESUMO | Após o acidente vascular cerebral (AVC), as pessoas apresentam combinações complexas de déficits sensoriais, motores, cognitivos e emocionais que podem afetar o equilíbrio estático e dinâmico. O objetivo do estudo foi compilar e resumir as principais características e achados de protocolos utilizados em pesquisas que investigaram os efeitos da vibração no tendão muscular no equilíbrio estático e dinâmico em adultos com AVC. Trata-se de uma revisão sistemática, registrada na PROSPERO (CRD42022303874), em que foram realizadas buscas nas bases de dados PubMed, Cochrane, LILACS, SciELO, MEDLINE, Science Direct e PEDro, durante o mês de janeiro de 2022, por meio da combinação de palavras-chave relacionadas a "*stroke*", "*balance*", "*muscle tendon vibration*" e "*randomized controlled trial*". A qualidade metodológica foi avaliada através da escala PEDro. Foram identificados 1.560 estudos, dos quais 11foram incluídos, publicados entre 1994 e 2020, envolvendo 242 adultos pós-AVC. Apenas cinco estudos utilizaram a

Work carried out at the Universidade Estadual do Norte do Paraná (UENP), Campus Jacarezinho, Centro de Ciências da Saúde, Jacarezinho (PR), Brazil.
[1]Universidade Estadual do Norte do Paraná (UENP) – Jacarezinho (PR), Brazil. E-mail: angelicasambe@gmail.com. ORCID-0000-0002-4545-2110
[2]Universidade Estadual do Norte do Paraná (UENP) – Jacarezinho (PR), Brazil. E-mail: jksilva@uenp.edu.br. ORCID-0000-0003-2688-7028
[3]Universidade Estadual do Norte do Paraná (UENP) – Jacarezinho (PR), Brazil. E-mail: camilaaraujo@uenp.edu.br. ORCID-0000-0002-4382-9375
[4]Universidade Estadual do Norte do Paraná (UENP) – Jacarezinho (PR), Brazil. E-mail: paola_jv3@hotmail.com. ORCID-0000-0002-8363-0475

Corresponding address: Paola Janeiro Valenciano – Rua Werner Goldberg, 77, apt 131 sabiá – Barueri (SP), Brazil – ZIP Code: 06414-025 – E-mail: paola_jv3@hotmail.com –
Financing source: nothing to declare – Conflict of interests: nothing to declare – Presentation: Jun. 9th, 2022 – Accepted for publication: Aug. 9th, 2022.

vibração como intervenção e verificaram melhora no equilíbrio estático e dinâmico. Seis estudos analisaram a interferência da vibração no controle postural, observando que o equilíbrio foi afetado durante a aplicação da vibração e que os indivíduos precisaram de mais tempo para se recuperar ou não sofreram diferenças significativas. Verificou-se que os efeitos da vibração do tendão muscular podem melhorar o equilíbrio em pessoas com AVC e influenciar o controle postural através de mecanismos proprioceptivos da vibração. Entretanto, são necessários mais estudos de alta qualidade metodológica para atingir um consenso em relação aos protocolos de tratamento com vibração do tendão muscular e sua recomendação na prática clínica.
Descritores | Controle Postural; Equilíbrio; Vibração do Tendão Muscular.

RESUMEN | Después del accidente cerebrovascular, las personas tienen combinaciones complejas de déficits sensoriales, motores, cognitivos y emocionales que pueden afectar el equilibrio estático y dinámico. El objetivo de este estudio fue recopilar y resumir las principales características y hallazgos de los protocolos utilizados en los estudios que investigaron los efectos de la vibración del tendón muscular sobre el equilibrio estático y dinámico en adultos con accidente cerebrovascular. Se trata de una revisión sistemática, registrada en PROSPERO (CRD420223874), en la que se realizaron búsquedas en las Bases de Datos PubMed, Cochrane, LILACS, SciELO, MEDLINE, Science Direct y PEDro, durante el mes de enero de 2022, mediante la combinación de palabras clave relacionadas con "*stroke*", "*balance*", "*muscle tendon vibration*" y "*randomized controlled trial*". La calidad metodológica se evaluó mediante la escala PEDro. Se identificaron un total de 1.560 estudios, de los cuales se incluyeron 11, publicados entre 1994 y 2020, con 242 adultos después del accidente cerebrovascular. Solo cinco estudios utilizaron la vibración como intervención y verificaron la mejoría en el equilibrio estático y dinámico. Seis estudios analizaron la interferencia de la vibración en el control postural, señalando que el equilibrio se vio afectado durante la aplicación de la vibración y que los individuos necesitaron más tiempo para recuperarse o no sufrieron diferencias significativas. Se encontró que los efectos de la vibración del tendón muscular pueden mejorar el equilibrio en personas con accidente cerebrovascular e influir en el control postural a través de mecanismos propioceptivos de vibración. Sin embargo, se necesitan más estudios de alta calidad metodológica para llegar a un consenso con respecto a los protocolos de tratamiento con vibración del tendón muscular y su recomendación en la práctica clínica.
Palabras clave | Control Postural; Equilibrio; Vibración del Tendón Muscular.

INTRODUCTION

A cerebrovascular accident (CVA), or stroke, consists of a cerebrovascular disease with clinical signs of focal (or global) brain function disorder, which develops rapidly and persists for more than 24 hours[1]. Worldwide, stroke was considered the second leading cause of death and the third leading cause of disability in 2019[2]. One of these disabilities is imbalance, affecting about 70% of stroke survivors, who report falling at home within one year after the stroke, and up to 15.9 out of every 1,000 people with stroke, who have falls daily[3,4].

Postural balance is the position in which an optimal distribution of body mass is achieved and that provides the body with stability and conditions for functionality in a stationary or moving position, with strategies that may include "reaction" (feedback), "anticipation" (feed-forward) or a combination of both[5]. Therefore, postural control represents a complex sensory-motor ability, whose body orientation is based on the internal representation of the body scheme derived from interactions between multiple sensorimotor processes, including peripheral and central components of the visual, somatosensory, and vestibular systems[6].

However, post-stroke individuals present complex combinations of sensory, motor, cognitive, and emotional deficiencies that can affect static and dynamic balance[7]. In the uncompromised nervous system, descending supraspinatus control regulates spinal reflex activity, but, after stroke injuries, this supraspinatus control is interrupted. Thus, the affected threshold of the stretch reflex pathway and impaired reflex adaptations are observed in people after a stroke[8]. The balance impairment can increase the risk of falls, reduce the individual's confidence in their mobility, decrease functional independence, activity, and participation, negatively impacting the quality of life[9].

Therefore, several rehabilitation therapies have been used to improve the balance capacity of people who have had a stroke, for example, proprioceptive stimuli such as whole-body vibration (WBV). Reviews performed with WBV use, in which the individual stands or makes vigorous movements on a vibration platform placed on a static surface, indicated an improvement in the body balance of people with stroke in the short-term[4] or with little effect[10,11]. Another similar therapy is the use of Flexibar, a stick that when moved quickly with the hands reaches vibrations of approximately 5Hz, which are transferred to the arm and the rest of the body[12]. Other procedures are more directed to a certain region of the body, such as muscle tendon vibration, in which a vibratory stimulus is applied to a specific muscle or to its tendon by a device[13]. In addition to facilitating muscle contraction, reducing spasticity, improving postural control and functional recovery, this technique stimulates proprioceptive afferent pathways, thus increasing the sensory influence on cortical motor control systems[9,14].

Although previous evidence has highlighted the use of WBV to improve balance, gait, and mobility outcomes[11,15], a systematic review of the findings and protocols used for the use of tendon vibration in post-stroke individuals is of scientific interest. To advance this theme, this systematic review aimed to compile and summarize the main characteristics and findings of protocols used in research that investigated the effects of muscle tendon vibration on static and dynamic balance in adults with stroke. The hypothesis of the study is that the use of WBV improves outcomes related to balance in adults with stroke.

METHODOLOGY

This is a systematic review based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Supplementary Material A). For the methodological procedures, the recommendations of the Cochrane collaboration were followed to elaborate systematic reviews of intervention studies[16]. The review was recorded on the PROSPERO database (CRD42022303874), and the complete search strategy is available in Supplemental Material B.

During January 2022, the databases: PubMed, Cochrane Central Register of Controlled Trials, Latin America and the Caribbean Health Sciences Literature (LILACS), Scientific Electronic Library Online (SciELO), MEDLINE, Science Direct and Physiotherapy Evidence Database (PEDro) were searched. For the search structure, the PICO method (Population, Intervention, Comparison and Outcome) was used, with P: people with stroke; I: vibration of the muscular tendon; C: comparison between periods, group without vibration or other intervention; and O: static or dynamic balance outcome. Thus, the combination of keywords related to "stroke," "balance," "muscle tendon vibration" and "randomized controlled trial" was used for the research (Supplemental Material B).

Inclusion criteria

Randomized clinical trials were included, both with randomized participants for an experimental group or a control group and with randomized participants for different experimental groups. There was no restriction of date of publication and language of the studies. Study participants, regardless of gender, should be older than 18 years, with clinical diagnosis of stroke, at any stage of the disease (acute, subacute, chronic). Studies that used muscle tendon vibration as an intervention, which had static or dynamic balance after the intervention as an outcome, which compared periods or groups without vibration in the muscular tendon, which compared muscle tendon vibration between people with and without stroke, and which compared muscle tendon vibration with another rehabilitation technique were also included.

Exclusion criteria

Exclusion criteria were: reviews, cohort studies or case-control; study protocols; studies published in books and as summaries of events; studies unavailable in full; and studies with duplicate information in another randomized clinical trial. Studies that analyzed other diseases or mixed population groups were excluded, except for those whose results were reported separately for each diagnosis. In this case, only the specific stroke results were included.

Selection of studies

The titles and abstracts were independently evaluated by two reviewers (PJV and AYS) according to the inclusion and exclusion criteria. Then, all studies potentially relevant to the evaluation were read in full. Rayyan free software[17] was used to gather the results obtained in the databases and delete duplicate articles. Disagreements were resolved by consulting a third reviewer.

Data extraction

The information extracted included the characteristics of the study (author and year of publication) and the participants (sample size, gender, age, type of stroke and its stage), methodological details related to interventions (location of vibration, frequency, duration, balance assessment) and results (before, during and after the intervention, intra- or intergroup analysis). These data were extracted and presented in a table.

Assessment of the risk of bias (quality)

The risk of bias and methodological quality were evaluated by two evaluators (PJV and AYS), independently, using the PEDro scale. The items were classified as "yes" or "no" (receiving scores 1 or 0, respectively) according to the satisfaction analysis of each of them, thus, the total score ranged from 0 to 10, resulting in a PEDro score, in which: <4 was considered "bad," 4 to 5 was "regular," 6 to 8 was "good," and 9 to 10 was "excellent"[18].

RESULTS

The searches resulted in 1,560 articles, but 222 duplicate studies were excluded and another 1,322 after title and abstract analysis. Of the 16 studies selected for full reading, 5 were eliminated for not meeting the eligibility criteria, resulting in 11 articles included in this review, as shown in Figure 1.

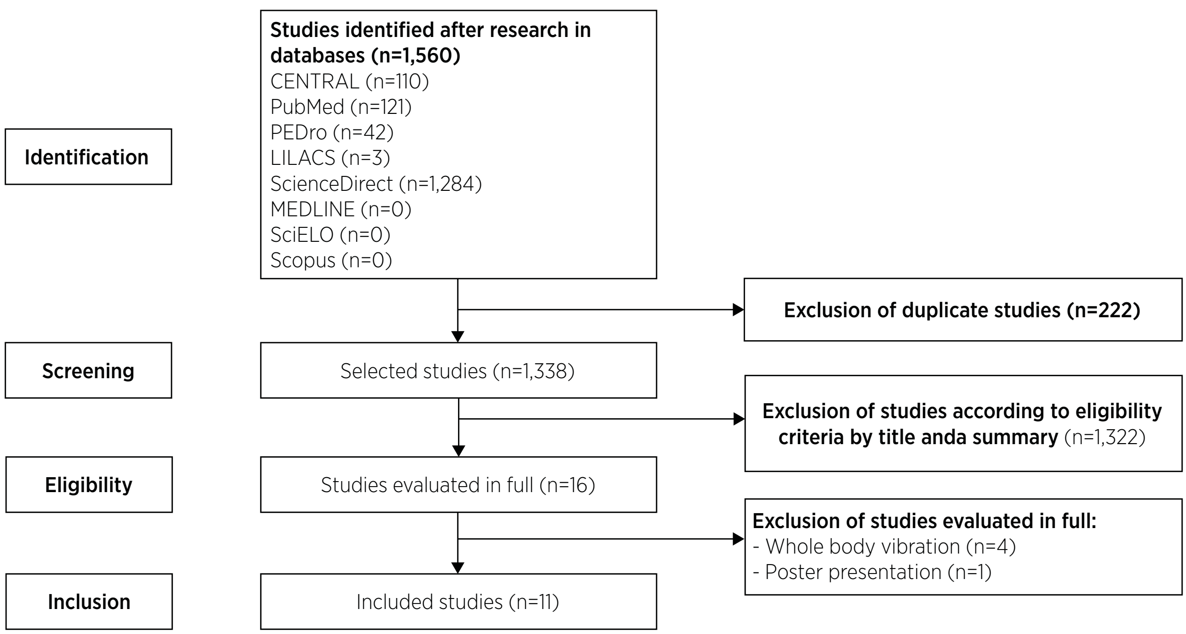

Figure 1. Flowchart

After the analysis of the risk of bias (Table 1), all included studies presented a high risk of bias in one or more criteria, so that confidence in their result decreased substantially. Thus, the methodological quality ranged from 3 to 7, and six studies presented poor quality, three regular, and two good.

All clinical trials were published between 1994 and 2020 and, of these, 10 have been published in the last eight years. Note that different countries have conducted research using the muscle tendon vibration technique to investigate postural balance in people with stroke, most of them from France[7,23,24,26], followed by South Korea[20,22], Iran[9,25], Sweden[19], Canada[21], and Turkey[27].

Some of the studies analyzed the application of the muscle tendon vibration technique as a form of balance disturbance[7,19,23-25], whereas others as a proposal for balance rehabilitation[9,20,22,26,27]. Vibration was used in different muscle tendons – fibular[23], tibialis anterior[7,20], plantar flexors of the foot[9,27], gluteus medius[7,24], posterior neck muscles[21,26] –, but mostly in the triceps surae[7,19,20-23,25]. For the rehabilitation proposal, vibration was applied to the tendons of the plantar flexors[9,27], the triceps surae[20,22], and the posterior neck muscles[26]. A total of 242 people with stroke participated in the clinical trials. Table 2 shows the characterization of the included studies.

Table 1. Bias risk analysis

Authors/Year	Criteria											Total
	1	2	3	4	5	6	7	8	9	10	11	
Magnusson, Johansson, and Johansson, 1994[19]	NO	YES	NO	NO	NO	NO	NO	NO	NO	YES	YES	3*/10
Bonan et al., 2013[7]	YES	NO	NO	NO	NO	NO	NO	YES	NO	YES	YES	3/10
Lee, Cho, and Lee, 2013[20]	NO	YES	YES	YES	NO	NO	YES	YES	NO	YES	YES	7*/10
Mullie and Duclos, 2014[21]	NO	NO	NO	YES	NO	NO	NO	NO	NO	YES	YES	3/10
Afzal et al., 2015[22]	YES	NO	NO	YES	NO	NO	NO	YES	NO	YES	YES	4/10
Duclos et al., 2015[23]	YES	NO	NO	YES	NO	NO	NO	NO	NO	YES	YES	3/10
Bonan et al., 2017[24]	YES	NO	NO	YES	NO	NO	NO	NO	NO	YES	YES	3/10
Karimi-AhmadAbadi et al., 2018[9]	YES	NO	NO	YES	NO	NO	NO	YES	YES	YES	YES	5/10
Jamali et al., 2019[25]	YES	NO	NO	YES	NO	NO	NO	NO	NO	YES	YES	3/10
Jamal et al., 2020[26]	YES	NO	NO	YES	NO	NO	NO	YES	YES	YES	YES	5/10
Önal, Karaca, and Sertel, 2020[27]	YES	YES	YES	YES	NO	NO	NO	YES	NO	YES	YES	6/10

1: non-specified eligibility criteria; 2: random allocation; 3: concealed allocation; 4: comparability of baseline; 5: blind subjects; 6: blind therapists; 7: blind assessors; 8: adequate follow-up (>85%); 9: analysis of the intention to treat; 10: statistical group-to-group comparisons; 11: point measures and variability measures.
*Score provided by PEDro scale evaluators.

Table 2. Characterization of the included studies

Author/Year/ Country	Groups	Characteristics of participants	Methodology	Parameters and vibration dosage	Evaluation	Results
Magnusson, Johansson, and Johansson, 1994[19] Sweden	Healthy control group (n=23) CVA vibration/ galvanic stimulation group (n=22) CVA control group (n=26)	Sex: unreported Age: on average 74 years CVA stage: chronic	Application as balance disturbance: standing, eyes open and closed, use of vibrator in the tendon of the triceps surae muscle.	1st mode: five periods of vibration with frequencies of 20, 40, 60, 80, or 100Hz, and amplitude of 0.4mm. 2nd mode: constant frequency of 60Hz (PRBS programming) with pulses between 0.5 and 8sec. by 205sec., preceded by 30sec. rest.	Force platform. Evaluation: before, during, and after vibration.	The three groups showed no difference in equilibrium velocity and anteroposterior oscillation. The CVA control group needed more time to reassume the initial balance after vibration than the other groups.
Bonan et al., 2013[7] France	CVA vibration group and control group (n=20)	Sex: 7F+13M; Age: 51.4±10.5 years CVA stage: subacute	Application as balance disturbance: standing, eyes open, with the use of perpendicular electromagnetic vibrators in the tibialis anterior and triceps surae tendons.	Frequency: 50Hz in the tibialis anterior and triceps surae and 90Hz in the gluteus medius, in this order and separately, with amplitude of 1mm. Duration: 35sec., 1 session.	Two force platforms with two inertia sensors (head and trunk). Evaluation: before, during, and after vibration.	About 65% of the subjects were sensitive to vibratory stimulation, which affected postural control.
Lee, Cho, and Lee, 2013[20] South Korea	CVA vibration group (n=16) CVA placebo group (n=15)	Sex: Vib.=3F+13M and Plac.=4F+11M Age: Vib.=53.31±8.37 years and Plac.=55.73±8.27 years CVA stage: chronic	Application as intervention: weightlifting and weight change training in paretic LL with two vibrators fixed in the heel, in the triceps surae and tibialis anterior.	Frequency: 90Hz. Amplitude: 15µm. Duration: 30min./day, 3×/week, 6 weeks.	Force platform. Rating: pre-test, one week before the start, and post-test, one day after the end.	Significant improvement in balance in CVA vibration group.

(continues)

Table 2. Continuation

Author/Year/ Country	Groups	Characteristics of participants	Methodology	Parameters and vibration dosage	Evaluation	Results
Mullie and Duclos, 2014[21] Canada	Healthy vibration group (n=12) CVA vibration group (n=12)	Sex: unreported Age: 47.8±11.8 years CVA stage: not reported	Application as balance disturbance: standing, eyes open, walking on the treadmill, using electromechanical vibrators in the posterior muscles of the neck and in the tendon of the triceps surae of the non-dominant/ paretic side.	Mode: continuous or phasic (when heel was in contact with the ground). Frequency: 80Hz. Amplitude: 0.5 and 1mm. Duration: 1min., 1 session.	Three-dimensional kinematic analysis of the whole body and the ground reaction force by using an instrumented treadmill. Evaluation: before, during, and after vibration.	The balance did not change during the gait in the CVA vibration group.
Afzal et al., 2015[22] South Korea	Healthy vibration group (n=5) CVA vibration group (n=4)	Sex: 1F+3M Age: 64.75 years CVA stage: chronic	Application as intervention: use of Velcro belt with six vibrators attached between the knee and calf.	Modulation: CVMbp, CVMst, and PVMsr Frequency: 200Hz. Amplitude: 1.4G. Duration: time of the walk test 6m; 1 session.	Six meters walk test. Evaluation: before, during, and after vibration.	Significant improvement in the CVA vibration group in gait symmetry and gait speed.
Duclos et al., 2015[23] France	Healthy vibration group (n=20) CVA vibration group RBI (n=12) and LBI (n=14)	Sex: RBI=2F+10M and LBI=6F+8M Age: RBI=69.2 years and LBI=65.4 years CVA stage: chronic	Application as balance disturbance: standing, eyes closed, with the use of perpendicular electromagnetic vibrators in the tibialis anterior and triceps surae tendons.	Application: separated, under three conditions (paretic, non-paretic, and bilateral limb). Frequency: 80Hz. Amplitude: 0.2-0.5mm Duration: 20sec., 1 session.	Force platform. Evaluation: before (4sec.), during, and after (24sec.) vibration.	Greater disturbance in the triceps surae tendon, and greater displacement in non-paretic LL than in the paretic. RBI group suffered significant disruption and needed more time to restore balance.
Bonan et al., 2017[24] France	Healthy vibration group (n=40) CVA vibration group in the right (n=21) and left (n=19) hemiparetic	Sex: 16F+24M Age: 54.7±10.6 years CVA stage: subacute	Application as balance disturbance: standing, use of vibrator on the tendon of the non-paretic gluteus medius (right GM for left hemiparesis and left GM for right hemiparesis), maintained by a band around the waist.	Frequency: 90Hz. Amplitude: 0.4mm. Duration: 35sec., 2 sessions.	Two force platforms. Evaluation: initial and in the 4th and 6th week (session 2) after the first test (session 1).	Greater disturbance in the CVA vibration group on the right hemiparetic than on the left.
Karimi-AhmadAbadi et al., 2018[9] Iran	Same placebo and vibration CVA group (n=22)	Sex: 8F+14M Age: 55.82±11.87 years CVA stage: chronic	Application as an intervention: in supine position, arms next to the torso, with flexed knees, and bare feet, supported and fastened with three Velcro straps on the upper surface of a box with two vibration panels, in the tendons of the plantar flexors of the ankle.	Frequency: 100Hz. Duration: 5min., 1 session.	Mini-BESTest. Evaluation before and immediately after placebo or active vibration.	Significant improvement in balance in vibration group.
Jamali et al., 2019[25] Iran	Healthy vibration group (n=18) CVA vibration group with low anxiety (LA) (n=18) and high anxiety (HA) (n=18)	Sex: LA and HA=4F+14 M Age: LA=55.11±10.93 years and HA=51.89±10.90 years CVA stage: chronic	Application as balance disturbance: a pair of vibrators applied to the triceps surae tendon standing still and during a visual task of anticipation/virtual visual environment (they should avoid the collision of visual stimuli by moving the head and torso).	Frequency: 80Hz. Amplitude: 0.3mm Duration: 60sec. for each condition, 1 session.	Force platform. Evaluation: before, during, and after vibration.	Significant reduction in the variability of postural oscillation in the healthy group. CVA LA needed more time to restore balance and CVA HA required even more time.

(continues)

Table 2. Continuation

Author/Year/ Country	Groups	Characteristics of participants	Methodology	Parameters and vibration dosage	Evaluation	Results
Jamal et al., 2020[26] France	CVA vibration group with RBI (n=16) and LBI (n=16)	Sex: 6F+26M Age: 60.9±10 years CVA stage: chronic	Application as an intervention: seated and blindfolded, with vibrator device manually positioned by the examiner in the tendons of the neck muscles (semispinalis and splenius); site depended on the side of the lesion: left on RBI and right on LBI.	Frequency: 80Hz. Amplitude: 0.4mm. Duration: 10min., 5 sessions/week, 2 weeks.	Two force platforms, BBE and TUG Evaluation: two weeks before, immediately before the 1st intervention, one week and one month after.	Significant improvement in balance in both groups.
Önal, Karaca, and Sertel, 2020[27] Turkey	CVA vibration group (n=15) CVA placebo group (n=15)	Sex: 7F+23M Age: on average 58 years CVA stage: chronic	Application as intervention: in supine position, using a vibration device in both plantar regions.	Frequency: 80Hz for 10sec. and 5sec. of rest. Duration: 15min., 1 session.	Biodex balance system. Evaluation: before the intervention and up to 5min. after.	Immediate significant improvement in the vibration group.

CVA: stroke; BBE: Berg balance scale; F: female; G: acceleration of gravity; GM: gluteus medius; Hz: Hertz; RBI: right brain injury; LBI: left brain injury; M: male; LL: lower limb; µm: micrometer; mm: millimeter; min.: minute; CVMbp: constant vibration mode of balance phase; CVMst: constant vibration mode of matching support time; PVMsr: proportional vibration mode of matching symmetry ratio; Plac.: placebo; PRBS: pseudorandom binary sequence programming; sec.: seconds; TUG: timed up and go test; Vib.: vibration.

DISCUSSION

Characterization of the studies

In this systematic review, studies from different countries and with different forms and regions of application of muscle tendon vibration were identified, allowing the determination of the main characteristics of protocols used in research investigating the stability of body balance in people with stroke after the application of muscle tendon vibration. However, due to the high risk of bias, outcomes related to the efficacy of this method as a rehabilitation resource to improve postural balance should be interpreted with caution.

In view of the recovery process approached by Bernhardt et al.[28], of the studies that reported the characterization of stroke patients, most were in the chronic stage of stroke (more than six months), and only in two studies the participants were in the subacute stage[7,24]. Regarding the age of the participants, they were over 41 years old, most being in the 50-year-old age group[7,9,20,24,25,27]. All studies showed a larger male population, which corroborates the study by Bensenor et al.[29], in which the punctual prevalence was 1.6% in men and 1.4% in women, and disability was 29.5% in men and 21.5% in women.

Vibration devices: application location and positioning of vibrators

The muscular tendon in which vibration was applied was not standardized in view of the two proposals: verifying the influence of proprioceptive mechanisms on the outcome of postural balance and, as an intervention strategy, improving postural balance.

When used to produce vibration interferences in postural control, the sites were chosen to provoke different amplitudes of instability in different directions: anteroposterior or mediolateral. Vibrations in the triceps surae[7,19,21,23,25], for example, may result in a backward postural response. Mulie and Duclos[21] observed in a study that individuals were inclined towards the posterior direction during the vibration of the triceps surae. This can be explained by the fact that vibration is generally interpreted by the kinesthetic illusion of stretching of the vibrated muscle and the back-up compensatory reaction generated to restore body posture[30]. Unlike the tibialis anterior tendon[7], which causes an illusion of inclination to the back of the body, causing the subjects to tilt forward in a corresponding way to correct the perceived inclination[31].

Fibular tendon vibration was applied in only one study[23], being the least used. This is because the vibration in this tendon causes a relatively small posterior displacement compared with the vibration of the triceps surae tendon[32], which is insufficient to stimulate muscle stretching and induce a postural control reaction[33].

In addition, vibrations can generate lateral displacement in the paretic limb in individuals with stroke. According to Biger et al.[34], the neck muscles are directly linked to the vestibular and oculomotor systems and can play a crucial role in the perception of the body in space. Thus, when applying vibration in these muscles, the information obtained from proprioceptive receptors, alongside that of the oculomotor muscles and vestibular system, is involved in the location of objects in relation to the body and, consequently, in the balance of the individual[26]. Thus, neck muscle vibrations can reduce lateral body weight asymmetry in individuals with hemiparesis. The same happens for vibratory stimulation in the tendon of the middle gluteus since in the standing position the pressure center is laterally displaced for the duration of the vibration, which produces the perception of a strong push at the level of the vibrated hip in the opposite direction[35] and, consecutively, the placement of more weight in the paretic leg[7,24]. This can both interfere with balance proprioception[21] and improve postural balance, as seen in the study by Jamal et al.[26].

However, for Liang et al.[8], afferents of the plantar region of the foot and the motor neurons that supply the leg muscles show a strong synaptic coupling between, thus, the afferents inputs mediate their effect on motor functions by modulating the excitability of the motor cortex, being more effective in balance, as observed in the studies by Karimi-AhmadAbadi et al.[9] and Önal, Karaca and Sertel[27] after applying vibration to plantar foot flexors as a balancing intervention.

The application forms were based on positioning the device on the muscle tendon or attaching it to the spot by a band around the waist[24], a Velcro belt[22], or three Velcro straps on the top surface of a box with two panels, one for each foot, to apply vibratory stimulation[9]. Whereas one study used a vibrator device manually positioned by the examiner in the neck muscles[26], and another used manually adjusted electromagnetic vibrators perpendicular to the muscle tendon[7].

Frequency of vibration, dosage, and application time

Dosage and application time are effective measures to achieve the best response to a given treatment. The two main parameters for defining the dosage include amplitude, which is the extent of oscillatory motion (peak-to-peak displacement in mm), and vibration frequency, which consists of the repetition rate of oscillation cycles. Studies indicate that the amplitude should be from 0.2 to 0.5mm, since a higher value tends to lead to the stimulus overflowing to the surrounding muscles and bones[36,37], which corroborates the use of this amplitude in most included studies[7,19,23-26]. However, one study[20] used a lower amplitude of vibration in the muscular tendon: 15μm, which corresponds to 0.015mm. Although most studies used amplitude by displacement (mm), Afzal et al.[22] applied it as gravity acceleration (G). Both are important units of measurement since the relationship between amplitude and acceleration depends on frequency, and the lower the frequency, the higher the peak-to-peak amplitude for a given peak-to-peak acceleration[38].

In the studies included in this review, the frequency ranged from 20Hz to 200Hz, but most used the application at 80Hz[21,23,25-27]. According to Kavounoudias, Roll, and Roll[39], when vibration is applied to a frequency above 80Hz, it can generate specific electromyographic (EMGs) activities, followed by full-body oriented inclinations, whose direction is always opposite and whose amplitude varies linearly with the frequency of vibration. Thus, when generating an afferent signal, a postural reaction occurs to “restore” muscle length and avoid illusory fall, which corroborates the findings of these studies, which mostly used this frequency.

According to Duclos et al.[32], at least 16 seconds of vibration are necessary to induce most postural effects in young adults, regardless of the vibration condition. However, the literature shows no support to indicate the time necessary to cause central sensory adaptations for the population after stroke, but, due to reduced motor production, they are slower and deficient regarding correction forces and present greater oscillation[7]. Of the studies included in this review that reported vibration time, most applied the vibration for more than 20 seconds[7,21,23-25].

Regarding the dosage of the intervention with muscle tendon vibration, the studies diverged, and dosages ranged from 18 sessions in six weeks[20], 10 sessions in two weeks[26], to only a single session[9,22,27]. These studies only carried out a short-term assessment, which means that the results may not persist when verified in the long term, and a greater number of sessions are required.

Main results

Studies that analyzed the interferences of vibration in postural control observed that the participants had the balance affected during the application of vibration[7] and needed more time to recover[25] or did not suffer significant differences[19]. The studies that separated the sample regarding the side of the brain injury observed that the time of balance recovery was longer when the lesion was on the right[23,24], with a stronger disturbance in the non-paretic hemibody[23]. This is because an injury in the right hemisphere can induce a pronounced interruption in the processing of spatial information, impair the internal representation of the body in space, and induce distortions in the coordinates used to distribute body weight across the two lower limbs while standing[40]. In addition, muscle tendon vibration was unable to disturb balance when analyzed during gait in most participants with stroke[21]. Therefore, tendon vibration is a useful tool to disturb proprioception in specific muscles – especially on the paretic side, in which somatosensory impairments are greater – considering that vibratory stimuli increase the sensitivity of the stretch reflex, stimulate cutaneous and proprioceptive receptors and afferent nerves and therefore generate positive effects on the sensory system, on neuromuscular responses and on the improvement of the central nervous system's ability to process signals[9].

Only five studies used muscle tendon vibration as an intervention and verified a possible improvement in balance[9,20,26,27], even during gait[22]. In individuals with hemiparesis, the selectivity of sensory information of the paretic limb is reorganized and, in the acute stage of the stroke, they may become unable or reluctant to bear weight on the paretic side due to weakness, impaired motor control, impaired proprioception, or erroneous perception of orientation[23,41,42]. Therefore, in the chronic stages of a stroke, hemiparesis may cause disuse of the paretic limb, despite the improvement of motor function in the lower limb.

The balance deficit results from the asymmetry of body weight distribution characterized by unaffected leg overload and paretic leg underload and increased oscillation of the center of pressure[43]. However, obtaining good results for the outcome of postural control in post-stroke individuals is possible, since vibration has been shown to activate and alter the central mechanisms in the nervous system impaired by stroke and, thus, improve motor functions, probably by the increased somatosensory cortex activity[9]. Thus, the vibration of the muscular tendon can reduce sensory loss and play an important role in somatosensory integration, mainly due to the increased sensation of the paretic side, which causes the transfer of weight to the paretic side to increase and provides a symmetrical weight transfer[20,44], which corroborates the improvement of balance in the chronic stages of a stroke, as verified in the five studies[9,20,22,26,27].

The muscle tendon vibration affects the reduction of balance deficit in individuals after stroke – a condition related to severe physical impairments, disability, and low quality of life – decreasing the rates of falls, which represent a great burden for these individuals, their families, and the society[45].

Limitations

In view of this review, precautions are needed regarding the conclusions drawn, due to the small number of studies included, low sample number, and methodologies with high risk of bias. In addition, the studies were heterogeneous, with different sites of application, dosages, and duration of vibration in the muscular tendon, which made the meta-analysis in this study impossible. Therefore, further studies of high methodological quality are necessary to achieve more conclusive results.

CONCLUSION

The effects of muscle tendon vibration can benefit static balance, decreasing postural oscillation, and dynamic balance, improving cadence, step length and increasing unipedal support time in gait in adults with stroke. In addition, they can influence postural control by proprioceptive vibration mechanisms. However, more high methodological quality studies are needed to establish a consensus regarding treatment protocols and their recommendation in clinical practice.

REFERENCES

1. Arienti C, Lazzarini SG, Pollock A, Negrini S. Rehabilitation interventions for improving balance following stroke: an overview of systematic reviews. PLoS One. 2019;14(7):e0219781. doi: 10.1371/journal.pone.0219781.
2. GBD 2019 Stroke Collaborators. Global, regional, and national burden of stroke and its risk factors, 1990–2019: a systematic analysis for the Global Burden of Disease Study 2019. Lancet Neurol. 2021;20(10):795-820. doi: 10.1016/S1474-4422(21)00252-0.
3. Beyaert C, Vasa R, Frykberg GE. Gait post-stroke: pathophysiology and rehabilitation strategies. Neurophysiol Clin. 2015;45(4-5):335-55. doi: 10.1016/j.neucli.2015.09.005.
4. Yang F, Butler AJ. Efficacy of controlled whole-body vibration training on improving fall risk factors in stroke survivors: a meta-analysis. Neurorehabil Neural Repair. 2020;34(4):275-88. doi: 10.1177/1545968320907073.
5. Hugues A, Di Marco J, Ribault S, Ardaillon H, Janiaud P, Xue Y, et al. Limited evidence of physical therapy on balance after stroke: a systematic review and meta-analysis. PLoS One. 2019;14(8):e0221700. doi: 10.1371/journal.pone.0221700.
6. Paolucci T, Pezzi L, La Verde R, Latessa PM, Bellomo RG, Saggini R. The focal mechanical vibration for balance improvement in elderly – a systematic review. Clin Interv Aging. 2021;16:2009-21. doi: 10.2147/CIA.S328638.

7. Bonan IV, Marquer A, Eskiizmirliler S, Yelnik AP, Vidal PP. Sensory reweighting in controls and stroke patients. Clin Neurophysiol. 2013;124(4):713-22. doi: 10.1016/j.clinph.2012.09.019.

8. Liang JN, Ho KY, Hung V, Reilly A, Wood R, Yuskov N, et al. Effects of augmented somatosensory input using vibratory insoles to improve walking in individuals with chronic post-stroke hemiparesis. Gait Posture. 2021;86:77-82. doi: 10.1016/j.gaitpost.2021.01.016.

9. Karimi-AhmadAbadi A, Naghdi S, Ansari NN, Fakhari Z, Khalifeloo M. A clinical single blind study to investigate the immediate effects of plantar vibration on balance in patients after stroke. J Bodyw Mov Ther. 2018;22(2):242-6. doi: 10.1016/j.jbmt.2017.04.013.

10. Alashram AR, Padua E, Annino G. Effects of whole-body vibration on motor impairments in patients with neurological disorders: a systematic review. Am J Phys Med Rehabil. 2019;98(12):1084-98. doi: 10.1097/PHM.0000000000001252.

11. Yang X, Wang P, Liu C, He C, Reinhardt JD. The effect of whole body vibration on balance, gait performance and mobility in people with stroke: a systematic review and meta-analysis. Clin Rehabil. 2015;29(7):627-38. doi: 10.1177/0269215514552829.

12. Lee DK, Han JW. Effects of active vibration exercise using a Flexi-Bar on balance and gait in patients with chronic stroke. J Phys Ther Sci. 2018;30(6):832-4. doi: 10.1589/jpts.30.832.

13. Alashram AR, Padua E, Romagnoli C, Annino G. Effectiveness of focal muscle vibration on hemiplegic upper extremity spasticity in individuals with stroke: a systematic review. NeuroRehabilitation. 2019;45(4):471-81. doi: 10.3233/NRE-192863.

14. Conrad MO, Gadhoke B, Scheidt RA, Schmit BD. Effect of tendon vibration on hemiparetic arm stability in unstable workspaces. PLoS One. 2015;10(12):e0144377. doi: 10.1371/journal.pone.0144377.

15. Lu J, Xu G, Wang Y. Effects of whole body vibration training on people with chronic stroke: a systematic review and meta-analysis. Top Stroke Rehabil. 2015;22(3):161-8. doi: 10.1179/1074935714Z.0000000005.

16. Higgins JP, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, et al., editors. Cochrane handbook for systematic reviews of interventions. 2nd ed. Chichester: Wiley; 2019.

17. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan—a web and mobile app for systematic reviews. Syst Rev. 2016;5(1):210. doi: 10.1186/s13643-016-0384-4.

18. Cashin AG, McAuley JH. Clinimetrics: Physiotherapy Evidence Database (PEDro) Scale. J Physiother. 2020;66(1):59. doi: 10.1016/j.jphys.2019.08.005.

19. Magnusson M, Johansson K, Johansson BB. Sensory stimulation promotes normalization of postural control after stroke. Stroke. 1994;25(6):1176-80. doi: 10.1161/01.str.25.6.1176.

20. Lee SW, Cho KH, Lee WH. Effect of a local vibration stimulus training programme on postural sway and gait in chronic stroke patients: a randomized controlled trial. Clin Rehabil. 2013;27(10):921-31. doi: 10.1177/0269215513485100.

21. Mullie Y, Duclos C. Role of proprioceptive information to control balance during gait in healthy and hemiparetic individuals. Gait Posture. 2014;40(4):610-5. doi: 10.1016/j.gaitpost.2014.07.008.

22. Afzal MR, Oh MK, Lee CH, Park YS, Yoon J. A portable gait asymmetry rehabilitation system for individuals with stroke using a vibrotactile feedback. Biomed Res Int. 2015;2015:375638. doi: 10.1155/2015/375638.

23. Duclos NC, Maynard L, Abbas D, Mesure S. Hemispheric specificity for proprioception: postural control of standing following right or left hemisphere damage during ankle tendon vibration. Brain Res. 2015;1625:159-70. doi: 10.1016/j.brainres.2015.08.043.

24. Bonan I, Butet S, Jamal K, Yelnik A, Tasseel Ponche S, Leplaideur S. Difference between individuals with left and right hemiparesis in the effect of gluteus medius vibration on body weight shifting. Neurophysiol Clin. 2017;47(5-6):419-26. doi: 10.1016/j.neucli.2017.08.002.

25. Jamali S, Azad A, Mehdizadeh H, Doostdar A, Hoseinpour F, Mehdizadeh M, et al. Time-course investigation of postural sway variability: does anxiety exacerbate the sensory reweighting impairment in chronic stroke survivors? Neuropsychologia. 2019;127:185-94. doi: 10.1016/j.neuropsychologia.2019.01.023.

26. Jamal K, Leplaideur S, Rousseau C, Cordillet S, Raillon AM, Butet S, et al. The effects of repetitive neck-muscle vibration on postural disturbances after a chronic stroke. Neurophysiol Clin. 2020;50(4):269-78. doi: 10.1016/j.neucli.2020.01.005.

27. Önal B, Karaca G, Sertel M. Immediate effects of plantar vibration on fall risk and postural stability in stroke patients: a randomized controlled trial. J Stroke Cerebrovasc Dis. 2020;29(12):105324. doi: 10.1016/j.jstrokecerebrovasdis.2020.105324.

28. Bernhardt J, Hayward KS, Kwakkel G, Ward NS, Wolf SL, Borschmann K, et al. Agreed definitions and a shared vision for new standards in stroke recovery research: the Stroke Recovery and Rehabilitation Roundtable Taskforce. Int J Stroke. 2017;12(5):444-50. doi: 10.1177/1747493017711816.

29. Bensenor IM, Goulart AC, Szwarcwald CL, Vieira MLFP, Malta DC, Lotufo PA. Prevalence of stroke and associated disability in Brazil: National Health Survey – 2013. Arq Neuropsiquiatr. 2015;73(9):746-50. doi: 10.1590/0004-282X20150115.

30. Ivanenko YP, Grasso R, Lacquaniti F. Influence of leg muscle vibration on human walking. J Neurophysiol. 2000;84(4):1737-47. doi: 10.1152/jn.2000.84.4.1737.

31. Michel-Pellegrino V, Amoud H, Hewson DJ, Duchene J. Identification of a degradation in postural equilibrium invoked by different vibration frequencies on the tibialis anterior tendon. Proceedings of the 2006 International Conference of the IEEE Engineering in Medicine and Biology Society; 2006; New York. Piscataway: IEEE; 2006. p. 4047-50. doi: 10.1109/IEMBS.2006.259813.

32. Duclos NC, Maynard L, Barthelemy J, Mesure S. Postural stabilization during bilateral and unilateral vibration of ankle muscles in the sagittal and frontal planes. J Neuroeng Rehabil. 2014;11:130. doi: 10.1186/1743-0003-11-130.

33. Thompson C, Bélanger M, Fung J. Effects of bilateral Achilles tendon vibration on postural orientation and balance during standing. Clin Neurophysiol. 2007;118(11):2456-67. doi: 10.1016/j.clinph.2007.08.013.

34. Biguer B, Donaldson IM, Hein A, Jeannerod M. Neck muscle vibration modifies the representation of visual motion and direction in man. Brain. 1988;111(Pt 6):1405-24. doi: 10.1093/brain/111.6.1405.

35. Roden-Reynolds DC, Walker MH, Wasserman CR, Dean JC. Hip proprioceptive feedback influences the control of mediolateral stability during human walking. J Neurophysiol. 2015;114(4):2220-9. doi: 10.1152/jn.00551.2015.

36. Roll JP, Vedel JP. Kinaesthetic role of muscle afferents in man, studied by tendon vibration and microneurography. Exp Brain Res. 1982;47(2):177-90. doi: 10.1007/BF00239377.

37. Souron R, Besson T, Millet GY, Lapole T. Acute and chronic neuromuscular adaptations to local vibration training. Eur J Appl Physiol. 2017;117(10):1939-64. doi: 10.1007/s00421-017-3688-8.

38. Ghazi M, Rippetoe J, Chandrashekhar R, Wang H. Focal vibration therapy: vibration parameters of effective wearable devices. Appl Sci (Basel). 2021;11(7):2969. doi: 10.3390/app11072969.

39. Kavounoudias A, Roll R, Roll JP. Foot sole and ankle muscle inputs contribute jointly to human erect posture regulation. J Physiol. 2001;532(Pt 3):869-78. doi: 10.1111/j.1469-7793.2001.0869e.x.

40. Pérennou D. Weight bearing asymmetry in standing hemiparetic patients. J Neurol Neurosurg Psychiatry. 2005;76(5):621. doi: 10.1136/jnnp.2004.050468.

41. Rogind H, Christensen J, Danneskiold-Samsøe B, Bliddal H. Posturographic description of the regaining of postural stability following stroke. Clin Physiol Funct Imaging. 2005;25(1):1-9. doi: 10.1111/j.1475-097X.2004.00553.x.

42. Kamphuis JP, Kam D, Geurts AC, Weerdesteyn V. Is weight-bearing asymmetry associated with postural instability after stroke? A systematic review. Stroke Res Treat. 2013;2013:692137. doi: 10.1155/2013/692137.

43. Marigold DS, Eng JJ. The relationship of asymmetric weight-bearing with postural sway and visual reliance in stroke. Gait Posture. 2006;23(2):249-55. doi: 10.1016/j.gaitpost.2005.03.001.

44. Bronson-Lowe CR, Loucks TM, Ofori E, Sosnoff JJ. Aging effects on sensorimotor integration: a comparison of effector systems and feedback modalities. J Mot Behav. 2013;45(3):217-30. doi: 10.1080/00222895.2013.784239.

45. Li J, Zhong D, Ye J, He M, Liu X, Zheng H, et al. Rehabilitation for balance impairment in patients after stroke: a protocol of a systematic review and network meta-analysis. BMJ Open. 2019;9(7):e026844. doi: 10.1136/bmjopen-2018-026844.

SUPPLEMENTARY MATERIAL A

Section and topic	Item #	Checklist item	Location where item is reported
Title			
Title	1	Identify the report as a systematic review.	Page 1
Abstract			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Page 4-5
Introduction			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Page 7
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Page 7
Methods			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Page 8
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Page 7
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Page 28
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Page 8
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Page 8-9
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Page 8
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Page 8
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Page 9
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Page 10-11
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Page 8
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Page 8-9
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Page 9
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Page 8
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	-
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	-
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Page 9
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Page 9
Results			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Page 9 and 10
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Page 10
Study characteristics	17	Cite each included study and present its characteristics.	Page 13-16
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Page 11
Results of individual studies	19	For all outcomes, present, for each study: (1) summary statistics for each group (where appropriate) and (2) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	-

(continues)

Supplementary material A. Continuation

Section and topic	Item #	Checklist item	Location where item is reported
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Page 13-16
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	-
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Page 13-16
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	-
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Page 11
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Page 17-21
Discussion			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Page 17
	23b	Discuss any limitations of the evidence included in the review.	Page 22
	23c	Discuss any limitations of the review processes used.	Page 22
	23d	Discuss implications of the results for practice, policy, and future research.	Page 22
Other information			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Page 7
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Page 7
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Page 7
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Page 22
Competing interests	26	Declare any competing interests of review authors.	Page 22
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Page 7

Source: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. doi: 10.1136/bmj.n71. For more information, visit: http://www.prisma-statement.org/.

SUMPLEMENTAR MATERIAL B

Database search formulation – PubMed (121 results)

A. Condition of the disease: CVA

(1) Stroke
(2) Post-stroke
(3) After stroke
(4) Cerebrovascular disorders
(5) Hemiparetic stroke
(6) Hemiplegia
(7) Brain ischemia

#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7

B. Outcome: Balance

(8) Balance
(9) Postural balance
(10) Postural control
(11) Equilibrium
(12) Sway

#8 OR #9 OR #10 OR #11 OR #12

C. Intervention:

(13) Sensory feedback
(14) Vibrotactile feedback
(15) Vibratory feedback
(16) Tendon vibration
(17) Neck muscle vibration
(18) Localized muscle vibration
(19) Muscle tendon vibration
(20) Vibration
(21) Focal vibration
(22) Focal Muscle Vibration

#13 *OR* #14 *OR* #15 *OR* #16 *OR* #17 *OR* #18 *OR* #19 *OR* #20 *OR* #21 *OR* #22

D. Study design:

(23) Randomized controlled trial
(24) Randomised controlled trial
(25) Controlled clinical trial
(26) Comparative study
(27) Randomized
(28) Randomly
(29) Placebo

(30) Control groups
(31) Random allocation
(32) Trial
(33) Groups

#23 OR #24 OR #25 OR #26 OR #27 OR #28 OR #29 OR #30 OR #31 OR #32 OR #33

Database search formulation – Cochrane Central Register of Controlled Trials (CENTRAL) (110 results)

#1: Stroke OR post-stroke OR after stroke OR Cerebrovascular Disorders OR Hemiparetic Stroke OR Hemiplegia OR Brain Ischemia
#2: Balance OR postural balance OR postural control OR equilibrium OR Sway
#3: sensory feedback OR vibrotactile feedback OR vibratory feedback OR Tendon vibration OR Neck muscle vibration OR Localized muscle vibration OR muscle tendon vibration OR Vibration OR focal vibration OR Focal Muscle Vibration

Database search formulation – LILACS (3 results)

#1: Stroke OR post-stroke OR after stroke OR Cerebrovascular Disorders OR Hemiparetic Stroke OR Hemiplegia OR Brain Ischemia

#2: Balance OR postural balance OR postural control OR equilibrium OR Sway

#3: sensory feedback OR vibrotactile feedback OR vibratory feedback OR Tendon vibration OR Neck muscle vibration OR Localized muscle vibration OR muscle tendon vibration OR Vibration OR focal vibration OR Focal Muscle Vibration

#1 AND #2 AND #3

Database search formulation – MEDLINE (0 results)

#1: Stroke OR post-stroke OR after stroke OR Cerebrovascular Disorders OR Hemiparetic Stroke OR Hemiplegia OR Brain Ischemia

#2: Balance OR postural balance OR postural control OR equilibrium OR Sway

#3: sensory feedback OR vibrotactile feedback OR vibratory feedback OR Tendon vibration OR Neck muscle vibration OR Localized muscle vibration OR muscle tendon vibration OR Vibration OR focal vibration OR Focal Muscle Vibration

#4: randomized controlled trial OR randomised controlled trial OR controlled clinical trial OR comparative study OR randomized OR randomly OR placebo OR control groups OR Random Allocation OR trial OR groups

#1 AND #2 AND #3 AND #4

Database search formulation – PEDro (42 results)

Abstract & Title: vibration AND stroke
Therapy: no selection
Problem: no selection
Body part: no selection

Subdiscipline: neurology
Method: clinical trial
When searching: match all search terms (AND)

Database search formulation – ScienceDirect (1,284 results)

(Stroke OR Hemiplegia) AND (Balance OR postural control OR equilibrium OR Sway) AND (vibratory feedback OR Tendon vibration) AND (trial)

Database search formulation – SciELO (0 results)

#1: "Stroke" OR "post-stroke" OR "after stroke" OR "Cerebrovascular Disorders" OR "Hemiparetic Stroke" OR "Hemiplegia" OR "Brain Ischemia"
#2: "Balance" OR "postural balance" OR "postural control" OR "equilibrium" OR "Sway"
#3: "sensory feedback" OR "vibrotactile feedback" OR "vibratory feedback" OR "Tendon vibration" OR "Neck muscle vibration" OR "Localized muscle vibration" OR "muscle tendon vibration" OR "Vibration" OR "focal vibration" OR "Focal Muscle Vibration"
#4: "randomized controlled trial" OR "randomised controlled trial" OR "controlled clinical trial" OR "comparative study" OR "randomized" OR "randomly" OR "placebo" OR "control groups" OR "Random Allocation" OR "trial" OR "groups"

Database search formulation – Scopus (0 results)

(TITLE-ABS-KEY (stroke OR post-stroke OR after AND stroke OR cerebrovascular AND disorders OR hemiparetic AND stroke OR hemiplegia OR brain AND ischemia) AND TITLE-ABS-KEY (balance OR postural AND balance OR postural AND control OR equilibrium OR sway) AND TITLE-ABS-KEY (sensory AND feedback OR vibrotactile AND feedback OR vibratory AND feedback OR tendon AND vibration OR neck AND muscle AND vibration OR localized AND muscle AND vibration OR muscle AND tendon AND vibration OR vibration OR focal AND vibration OR focal AND muscle AND vibration))

No documents were found.