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Whole Body Vibration Exercises on Physiological and Hemodynamic Parameters of Spinal Cord Injury Individuals: A Systematic Review

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Abstract

Background: Spinal cord injury (SCI) is a devastating clinical disorder that results in permanent and undesirable neurologic deficit. Exercises could bring benefits as the whole body vibration (WBV) exercises.

Objective: The aim of this review is describe the effects of the WBV exercises on physiological and hemodynamic parameters of SCI individuals.

Methods: Searches in PubMed and PEDRo databases with specific keywords were performed. Fifteen studies met the inclusion criteria to be evaluated and the level of evidence and the methodological quality (PEDRo scale) were determined.

Results: Although many variations of the WBV exercise protocols, responses were found on physiological and hemodynamic parameters.

Conclusion: Previous studies suggest that the WBV exercise can be a possible tool to be incorporated in rehabilitation programs of the SCI individuals.

Keywords: Whole body vibration exercises; Physical activity; Spinal cord injury; Muscle activity, Spasticity

Introduction

Spinal cord injury (SCI) is a devastating event often resulting in permanent neurologic deficit [1,2]. A spinal cord lesion may be suspected when there are bilateral motor and sensory signs or symptoms that do not involve the head or face. Motor deficits are manifested by weakness related to the involvement of the long fiber tracts in the spinal cord [3-5]. Other so-called segmental signs include lower motor neuron findings (atrophy, flaccid weakness, loss of reflexes) in a myotomal distribution at the specific level of involvement [5,6].

SCI occurs through various countries throughout the world with an annual incidence of 15 to 40 cases per million [7]. Despite to the advances made in the understanding of the pathogenesis and improvements in early recognition and treatment, it remains an undesirable clinical condition, often producing severe and permanent disability [8].

Non traumatic and traumatic SCI can be observed [9-11]. Several diseases have a predilection for targeting specific areas or tracts within the spinal cord [12] and consequently, they can lead to the appearance of non-traumatic SCI. With a peak incidence in young adults, traumatic spinal cord injury (TSCI) remains a costly problem for society; direct medical expenses accrued over the lifetime of one patient range from 500,000 to 2 million US dollars [7]. The incidence in USA is higher than in most other countries. The main causes of TSCI in the United States are: motor vehicle accidents (48%); falls (16%); violence, especially gunshot wounds (12%); sports accidents (10%) and other (14%) [13].

Individuals with TSCI often have associated brain and systemic injuries (e.g., hemothorax, extremity fractures, and intra-abdominal injury) that may limit the patient's ability to report localized pain [14]. Moreover, Deitrick and coauthors [15] have reported skin breakdown lesions of the legs in SCI patient. This fact would be associated with deficient sensitivity and immobility of the limbs, which result in areas subjected to prolonged pressures and poor circulation, with blood flow reduction.

It has been suggested that small vessel circulation is decreased in SCI. These also complicate the initial evaluation and management of patients with TSCI, and affect prognosis. About half of the TSCIs involves the cervical cord and as a result present quadriparesis or quadriplegia [16,17]. The severity of cord syndromes is classified using the American Spinal Injury Association (ASIA) Scale [18].

The ASIA Impairment Scale (AIS) is a clinician-administered scale used to classify the severity (completeness) of injury in individuals with SCI, based on the Frankel scale [19,20]. It identifies sensory and motor levels indicative of the highest spinal level demonstrating "unimpaired" function. Preservation of function in the sacral segments (S4-S5) is a key for determining the AIS grade [19,20].

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In general, many authors have been concerned with investigating the motor and sensory dysfunctions of these individuals with SCI and the compromises resulting from these dysfunctions. However, this review seeks to investigate, besides musculoskeletal disorders, the possible hemodynamic complications that arose after the injury. Cardiovascular disturbances after SCI, such as blood pressure (BP) instability [21] and this hemodynamic compromise should be strongly countered by some type of intervention that involves the rescue of the motor and sensory functions of these individuals, like the exercises.

Considering the exercises as a modality of procedure of the physiotherapy to be used in the management of patients with SCI, Basso and Hansen [8] reported that exercises elicit both beneficial and deleterious biophysical effects after SCI. Moreover, they described that modulating the type, intensity, complexity, and timing of training it is possible to minimize risk and induce greater recovery. Nevertheless, Bizzarini and coauthors [22] report that an exercise program for people with SCI in the subacute phase might consider the inability in responding to the training program (bedrest syndrome). This would be related to the heart, lung, and muscles above the lesion would be not conditioned to exercise. Whole body vibration (WBV) exercise, as a modality of exercise has been used to manage the SCI individuals [11,23,24].

WBV exercise is generated when a subject is exposed to mechanical vibrations produced in oscillating/vibratory platforms (OVP) [25]. The mechanical vibration produced in an OVP is a physical agent with an oscillatory, sinusoidal and deterministic motion about an equilibrium point [26]. Frequency (f), amplitude (A), peak-to-peak displacement (D) and peak acceleration (aPeak) are biomechanical parameters that can be used to characterize the mechanical vibration. The peak acceleration of the mechanical vibration is calculated by the formula [25-27]:

$$(aPeak = 2 \times \pi^2 \times f^2 \times D)$$

Other parameters must be also considered in the protocols related to the WBV exercise, such as the type of the platform, duration of the bout (working time), rest time between bouts, periodicity of the sessions or even the position adopted by the subject in the base of the OVP [26].

Cochrane [27] considers WBV exercise as a potential safe modality of physical activity in sport [28] fitness and health sectors. Patients with neurodegenerative disease [29], with stroke [30], with cerebral palsy [31], with multiple sclerosis [32], with osteogenesis imperfect [33], with Duchenne muscular dystrophy [34] and with SCI [24,35,36] have had clinical improvements with protocols involving WBV exercise. It is reported that strength [31] and power muscle [35] are increased after WBV exercise in individuals with diseases.

Regarding the involvement of WBV exercises in individuals with SCI, circulatory, functional and neuro-musculoskeletal effects have already been described [23,35,37-40]. Considering that this kind of exercise could be suggested as an effective strategy to manage SCI individuals, the aim of the current study is to review the effects and the feasibility of WBV exercise in these clinical conditions.

Literature Review

This study conforms to all Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and reports the required information.

Search strategy used to find the publications involving WBV and SCI

Three reviewers independently accessed the bibliographical PubMed and PEDro databases on January 28th 2017 with the keywords

- Spinal cord injury
- Whole body vibration
- Spinal cord injury and physiotherapy
- Spinal cord injury and exercise
- Spinal cord injury and whole body vibration.

The number of publications (NP) was determined to each item searched in the two databases. About the databases used, briefly, PubMed comprises more than 25 million citations for biomedical literature from MEDLINE, life science journals and online book (http://www.ncbi.nlm.nih.gov/pubmed) and PEDro is the Physiotherapy Evidence Database and it is a free database of over 36,000 randomized trials, systematic reviews and clinical practice guidelines in physiotherapy. PEDro is produced by the Centre for Evidence-Based Physiotherapy at The George Institute for Global Health. (http://www.pedro.org.au).

Inclusion criteria to select the publications

Preliminary evaluation allowed the elimination of unnecessary publications. To be included in this review, all studies investigating effect of WBV in persons with spinal cord injury needed to comply with the following criteria: be a randomized controlled trial (RCT); in the absence of RCT's, single group experimental studies were also considered (cross-over designs); published in the English language. Studies were included if they included individuals with "spinal cord injury" who performed exercises on an OVP. Data were independently abstracted by three of the reviewers and disagreements were resolved by consensus.

Exclusion criteria to select the publications

Papers were excluded if they were:

- Replies
- Review articles
- Performed with animals
- With combined techniques
- Case report
- Others techniques
- Unpublished data
- Others databases

Keywords	PubMed	PEDRo
"Spinal cord injury"	28,964	319
Physiotherapy	151,796	2,916
"Spinal cord injury" and physiotherapy	1,929	34
Exercises	364,206	3,313
"Spinal cord injury" and exercises	2000	11
"Whole body vibration"	1,592	257
"Spinal cord injury" and "whole body vibration"	26	01

Table 1: Number of publications in PubMed and PEDRo databases.

Level of evidence (LE) and methodological quality (MQ) of the publications

The included studies were classified according to the National Health and Medical Research Council hierarchy of evidence [41]. Each article was assigned to a one reviewer, cross-checked by a second reviewer and where there was disagreement a third party was consulted and the issue discussed until consensus was reached.

The methodological quality (MQ) of these studies was determined by the PEDRo scale [42]. In the PEDRo scale, each item (2 up to 11) has the value of one point. The scale has a maximum score of 10 points. Publications with a score of seven or greater are considered of 'high' MQ those with five to six are 'fair' quality and a score of four or below is classified as 'poor' quality [42].

Data analysis

Data were not comparable and the statistical analysis was not performed. The results of the findings of this review were summarized in a narrative form by the (Tables 1-4).

Results

As it is shown in Table 1, considering the findings in the PubMed, the publications with:

- Spinal cord injury and physiotherapy are 1.27% of the publications with physiotherapy.
- Spinal cord injury and exercises are 0.55% of articles with exercises.
- Spinal cord injury and whole body vibration are 1.82% of the papers with whole body vibration. In the PEDRo database, the publications involving "spinal cord injury" and physiotherapy, or exercises or "whole body vibration" are 1.16%, 0.33% and 0.77% of the publications, respectively. Twenty-seven articles were searched with the keywords "spinal cord injury" and "whole body vibration" to be analyzed.

Figure 1 shows the PRISMA [43] flowchart and twelve publications were excluded due to two were in duplicate, two were revisions, four with animals; one was a case report, one with other technique, two with combined techniques. Fifteen articles were assessed for eligibility and included in this qualitative synthesis (Figure 1).

Table 2 shows some characteristics of the individuals and two hundred and ten individuals have participated in these investigations and the ages of the individuals varied from 20 [11,24,44-46], up to 65 years old [47,48]. The LE of the publications shown: two [49,50] were in the Level II; Four [11,36,44,51] were in the Level III-2; four [23,35,45,52] were in the Level III-3 and five [24,46-48,53] were in the Level IV according to the NHMRC 2003-2007. All these publications were considered to have a "poor" MQ in the PEDRo scale. The side alternating OVP was used in four publications [23,50,52,53]. The range of the frequency of the vibrations generated in the platforms varied from 10 Hz up to 50 Hz; and A/PPD was 0.2 mm up to 5 mm.

Considering the effects of the WBV exercise to SCI individuals in Table 3, the authors used different tools to evaluate the hemodynamic responses (main outcomes), such as improvement of the popliteal artery blood velocity [50,53] arterial resting diameter [50] increase

References	Individuals (number, sex)	Age (years)	LE	MQ	Device of Platforms	Type of OVP	Frequency (Hz)	A/PPD (mm)
Menéndez et al. [50]	10 (8 men /2 women) with SCI	46.3 ± 12.9	II	Poor	Galileo Home, Galileo, Novotec	Alternated	10	PPD-5
Menéndez et al. [53]	17 (12 men/ 5 women) SCI (ASIA A or B)	49.9 ± 12.5	II	Poor	Galileo Home, Galileo, Novotec	Alternated	10	PPD-5
Da Silva et al. [52]	15 individuals with SCI (injury level beneath T3)	46 ± 20	III-3	Poor	Galileo Advanced Novotec Medical	Alternated	30	A-4
Wuermser et al. [24]	4 women and 5 men with motor complete SCI	20-50	IV	Poor	Juvent 1000	Synchronous	34	-----------
Bosveld & Field-Fote [49]	25 (20 men) with motor incomplete SCI	49.7 ± 12.5	II	Poor	Power Plate Northbrook IL	Synchronous	50	A-2
Yarar-Fisher et al. [36]	11 men with SCI 10 able-bodied	49.4 ± 6.9 48.2 ± 7.6	III-2	Poor	WAVE™ Wave Manufacturing Inc., Whole-body Advanced Vibration Exercise, Windsor, Canada	Synchronous	30, 40, 50	PPD- 2
Masani et al. [46]	7 men with chronic SCI	20-60	IV	Poor	WAVE Pro Plate	Synchronous	45	PPD-0.6- 0.7
Alizadeh-Meghrazi et al. [35]	10 men (4 with chronic SCI)	28.8 ± 7.7	III-3	Poor	Juvent Medical, Somerset, NJ and WAVE, WAVE Manufacturing, Windsor, Ontario, Canada	Synchronous	25, 35, 45	A-0.2,0.6,1.2
Alizadeh-Meghrazi et al. [44]	12 men (5 with chronic SCI and 7 without SCI)	20-50	III-2	Poor	Juvent Medical, Somerset, NJ and WAVE, WAVE Manufacturing, Windsor, Ontario, Canada	Synchronous	25, 35, 45	A-0.6,1.2 (WAVE)
Hadi et al. [11]	18 men (8 with SCI)	20-50	III-2	Poor	Juvent Medical, Somerset, NJ and WAVE, WAVE Manufacturing, Windsor, Ontario, Canada	Synchronous	25, 35, 45	A-0.7, 1.1 (WAVE)
Bernhardt et al. [45]	11 (6 men/5 women) SCI (T3 to T12)	20-50	III-3	Poor	Juvent 1000 Juvent Medical Somerset	Synchronous	34	-----------
Herrero et al. [23]	8 (6 men/2 women) with SCI	36.1 ± 5.0	III-3	Poor	Galileo Home, Galileo, Novotec	Alternated	10, 20, 30	PPD-5
Sayenko et al. [51]	14 men (8 non-SCI and 6SCI)	23-53	III-2	Poor	WAVE vertical WBV plate	Synchronous	35	PPD-1
Ness & Field-Fote [47]	16 (8 women/4 men) with SCI	28-65	IV	Poor	Power Plate Northbrook, IL	Synchronous	50	PPD-2 - 4
Ness & Field-Fote [48]	3 women and 14 men with motor (depending on incomplete SCI)	28-65	IV	Poor	Power Plate Northbrook. IL	Synchronous	50	PPD-2 - 4

Table 2: Description of the individuals (number, sex, and age), LE, MQ, the type of platform, the frequency and the amplitude used in the oscillating/vibratory platforms used in these studies.

References	Aim	Protocol	Findings	Conclusion
Menéndez et al. [53]	To analyze the acute effects of isolated and simultaneous application of WBV and ES on popliteal artery blood velocity and ST of the calf in individuals with SCI.	One familiarization session, and four interventions were applied in random order; WBV, ES, WBV+ES. Each intervention consisted of 10 sets x 1min ON +1 min OFF. Individuals were seated on their own wheelchairs with their feet on the vibration platform, and ES was applied on the gastrocnemius muscle of the both legs.	WBV+ES produced the greatest increase in MBV; 36% and 42%, and PBV; 30% and 36%, during the intervention. This intervention produced the greatest mean increases in MBV (21%) and PBV (19%) during the recovery period, and also produced the highest increase in ST during the intervention (2.1ºC).	The simultaneous application of WBV+ES seems to produce a greater increase in MBV and PBV on the popliteal artery and ST.
Menéndez et al. [50]	To analyze the adaptations on the popliteal artery MBV, PBV, RD and BF induced by 12 weeks of WBV+ES in individuals with SCI. The musculoskeletal effects of this therapy on the gastrocnemius MT and femoral neck BMD also were analyzed.	SCI individuals ASIA A or B were randomly assigned to the EG=9 or the control group CG=8. Each subject was assessed at baseline, after 6 weeks (Post-6) and 12 weeks of the treatment (Post-12) and 8 weeks after the end of the treatment (Post-20). Subjects in the EG performed 30 10-min sessions of WBV+ES during 12 weeks.	In the EG, RD increased compared with the baseline value at Post-6, Post-12 and Post-20; BF increased compared with the baseline value and with CG only at Post-12 and WBV+ES increased the MT of the gastrocnemius. BMD of both hips remained invariable during the study. CG showed no change.	WBV+ES improved popliteal artery BF, RD and MT after 12 weeks in SCI patients. This increase in RD remained above baseline after 8 weeks. WBV+ES could be considered a promising alternative to reverse the musculoskeletal atrophy and improve peripheral vascular properties in SCI individuals.
Wuermser et al. [24]	To examine the effect of low-magnitude WBV on bone density and microstructure in women and men with SCI	Individuals stood on a low-magnitude vibration late within a standing frame for 20 minutes per day, 5 days a week and for 6 months. Bone density was assessed in baseline, at 3 months and 6 months while on intervention and after 6 months off intervention.	Standing on the low-magnitude vibration plate with a standing frame was well tolerated by individuals. Most individuals did not show an improvement in bone density or microstructure after 6 months of intervention.	Longer duration of use may be necessary for to identify an improvement in either bone density and it is possible that WBV intervention is of limited benefit following chronic SCI
Yarar-Fisher et al. [36]	To investigate the acute effects of WBV on central hemodynamic responses, muscles oxygenation and oxygen consumption in individuals with SCI versus sex, age and activity-matched able-bodied individuals. And assess the effect of three WBV frequencies on all outcome measures.	Individuals completed three WBV exercise sessions at 30, 40 and 50 Hz. HR, MAP, SV, CO, VO_2 and relative changes in oxygenated, desoxigenated and total heme groups were obtained when VO_2 steady state was achieved for: pre-WBV sitting, pre-WBV standing, WBV and post-WBV standing.	Both groups demonstrated small but significant increases in VO_2, deoxygenated and total heme groups; but the increases were larger in the SCI group. No frequency effect was observed.	The WBV responses do not appear sufficient to induce cardiovascular benefits in the SCI population. WBV may be helpful for individuals with SCI in improving lower limb peripheral blood flow and coping with orthostatic hypotension symptoms earlier in their rehabilitation programs.
Alizadeh-Meghrazi et al. [44]	To identify the optimal WBV conditions among men with chronic SCI during PS and facilitate the implementation and future evolution of the efficacy of WBV and PS for prevention and treatment of SLOP in men with SCI	The EasyStand standing frame was fitted on to 2 available vibration platforms. Accelerometers were attached to the individual's forehead, hip, and ankle to measure vibration propagation. The individuals were exposed to all combinations of posture, frequencies and amplitudes.	Variations in frequency generated the most noticeable changes in propagation characteristics, followed by variations in knee angle and amplitude.	WBV therapy delivered with use of the WAVE platform with a knee angle of 140º, plate frequency of 45 Hz and amplitude of 1.2mm met our a priori criteria for the optimal WBV condition.
Hadi et al. [11]	To assess feedback from SCI and non-SCI individuals on the usability of PS and WBV devices using a priori specified knee postures, plate amplitudes and frequencies.	Individuals underwent intermittent WVB during PS for 45 minutes the optimized WAVE and Juvent plates. WBV parameters were sequentially altered every 2 minutes and included parameter combinations of postures of 140, 160 and 180º knee extension; amplitudes of 0.7 and 1.1mm and frequencies of 25, 35 and 45Hz.	SCI individuals reported a greater frequency of positive descriptions than non-SCI individuals during WBV, regardless of plate, posture, amplitude or frequency, with the exception of 1 combination of parameters. Non-SCI subject reported the highest frequency of negative effects with the Wave plate at 160º, 1,1mm, 25 and 35 Hz. Non-SCI individuals preferred the Juvent, whereas SCI subject preferred the Wave plate.	SCI and non-SCI individuals reported differing frequencies of positive and negative descriptors and indicated divergent device preferences. SCI individuals preferred Wave plate and vibration at high frequency.
Bernhardt et al. [45]	To determine the proportion of BW borne trough the lower limbs in persons with SCI stood with and without support in their arms.	Vertical GRF were measured in individuals stood on a low-magnitude vibrating plate use a standing frame tray.	With vibration, mean GRF did not significantly differ from non-vibration conditions for either arm positions. Oscillation of GRF with vibration was significantly different from no-vibration conditions but similar in both arm positions.	Men and women with SCI using a standing frame bear the majority of their weight trough their lower limbs. Low-magnitude vibration provided additional oscillation of the load-bearing forces and was proportionally similar regardless of arm position.

Table 3: Main outcomes of hemodynamic parameters of SCI individuals after WBV exercise protocols.

References	Aim	Protocol	Findings	Conclusion
Menéndez et al. [53]	To analyze the acute effects of isolated and simultaneous application of WBV and ES on popliteal artery blood velocity and ST of the calf in individuals with SCI.	One familiarization session, and four interventions were applied in random order; WBV, ES, WBV+ES. Each intervention consisted of 10 sets x 1min ON +1 min OFF. Individuals were seated on their own wheelchairs with their feet on the vibration platform, and ES was applied on the gastrocnemius muscle of the both legs.	WBV+ES produced the greatest increase in MBV; 36% and 42%, and PBV; 30% and 36%, during the intervention. This intervention produced the greatest mean increases in MBV (21%) and PBV (19%) during the recovery period, and also produced the highest increase in ST during the intervention (2.1ºC).	The simultaneous application of WBV+ES seems to produce a greater increase in MBV and PBV on the popliteal artery and ST.
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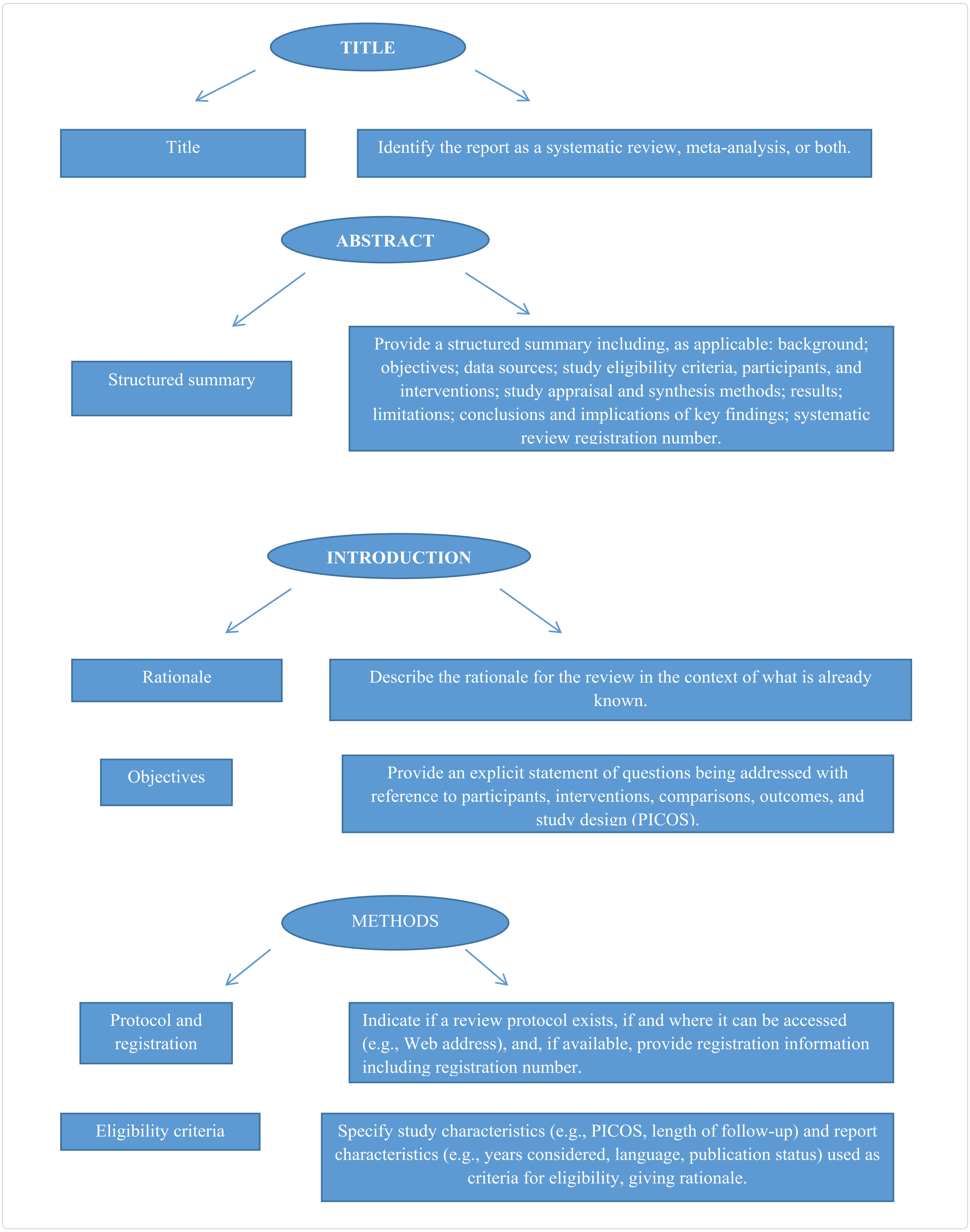
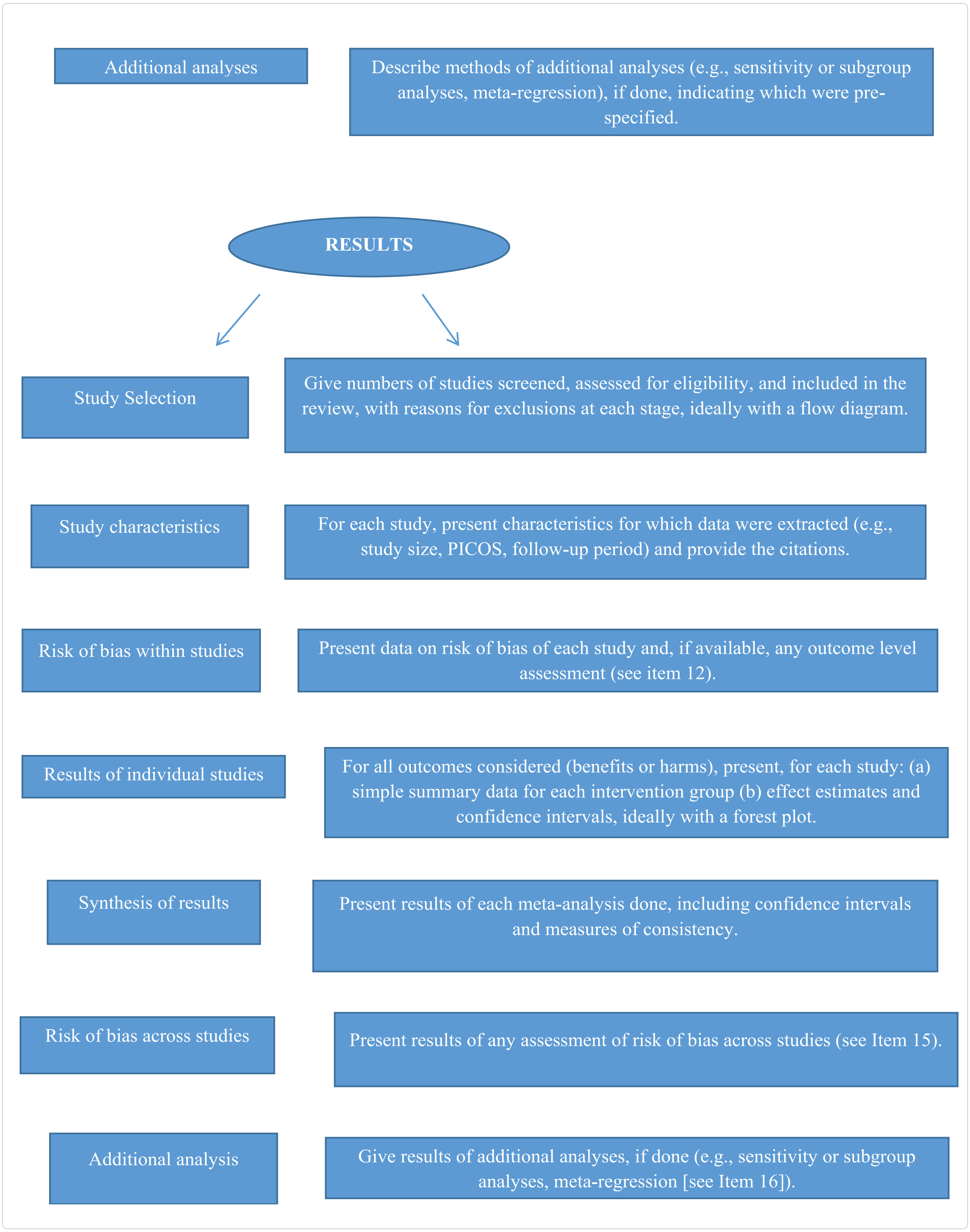
Table 4: Secondary outcomes (muscle activity, lower extremity strength, spasticity and walking function) of SCI individuals after WBV exercise protocols.


TITLE
Title
Identify the report as a systematic review, meta-analysis, or both.
ABSTRACT
Structured summary
Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.
INTRODUCTION
Rationale
Describe the rationale for the review in the context of what is already known.
Objectives
Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).
METHODS
Protocol and registration
Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.
Eligibility criteria
Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.

Information sources	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.
Search	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.
Study selection	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).
Data collection process	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.
Data items	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.
Risk of bias in individual studies	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.
Summary measures	State the principal summary measures (e.g., risk ratio, difference in means).
Synthesis of results	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.
Risk of bias across studies	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).


Additional analyses
Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.
RESULTS
Study Selection
Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.
Study characteristics
For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.
Risk of bias within studies
Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).
Results of individual studies
For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.
Synthesis of results
Present results of each meta-analysis done, including confidence intervals and measures of consistency.
Risk of bias across studies
Present results of any assessment of risk of bias across studies (see Item 15).
Additional analysis
Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).

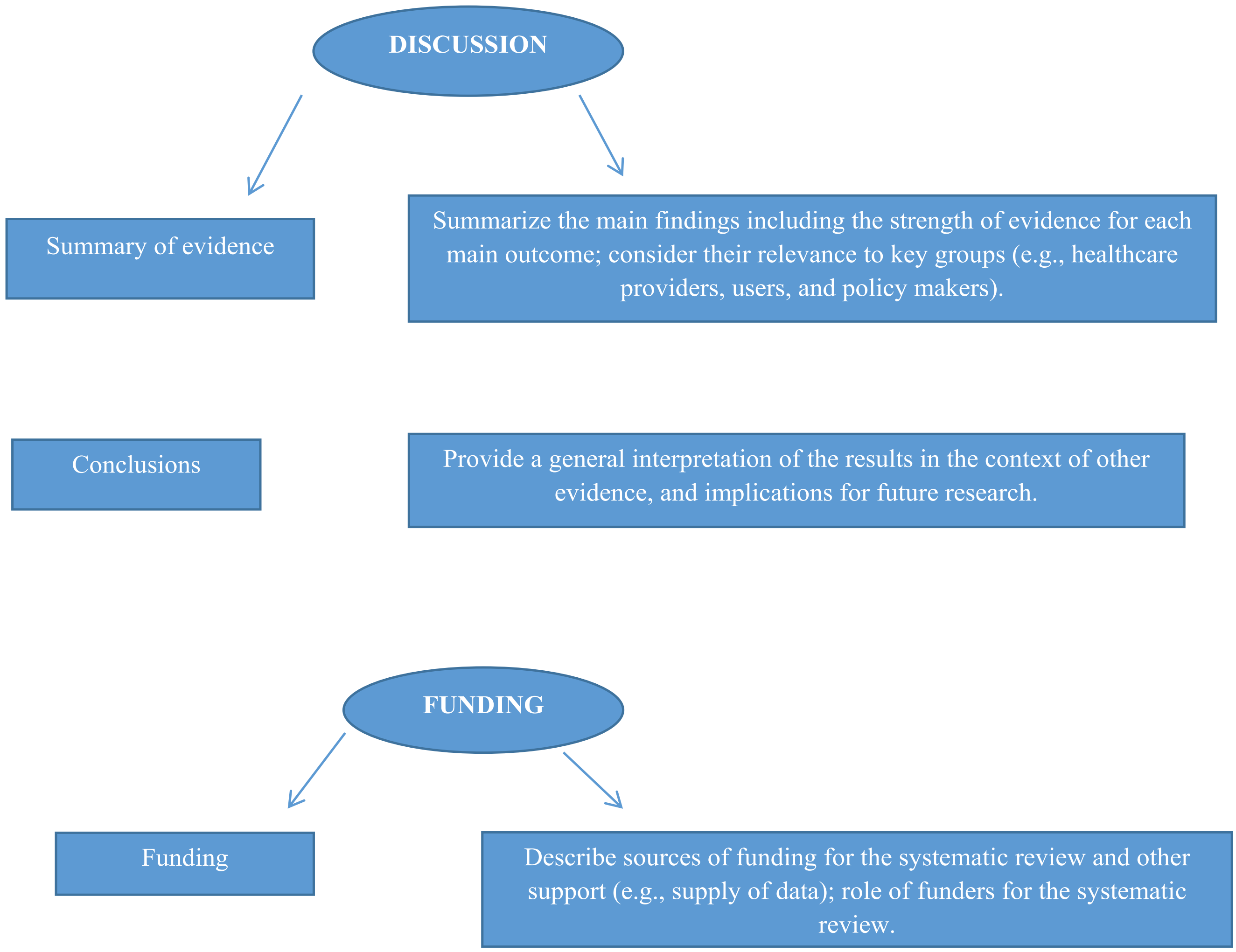


Figure 1: Flowchart indicating the steps to select the full papers analyzed in this systematic review.

of the general blood flow [36,50] muscle oxygenation and oxygen consumption 36 skin temperature [53] Also were pointed changes in the bone microstructure and prevention and treatment of sublesional osteoporosis (SLOP) [44] and the proportion of body weight (BW) borne through the lower limbs [45]. However, Wuermser and coauthors [24] show no improvement of the BMD in their used protocols. The SCI individuals were sat in wheelchair [53] or stood vibrating platform [11,24,36,44,45,50]. Table 4 shows some findings (related to the secondary outcomes of the current study) already described in previous reviews [39,40] such as, electrophysiological activity of lower extremity muscles, lower extremity strength, quadriceps spasticity, soleus H-reflex and walking function are presented.

Discussion

In general, little is known about which exercise interventions and which dosing schedules will promote relearning and recovery for different SCI severities [8]. In this current systematic review the hemodynamic parameters in SCI population were determined with primary results by the need for a recent investigation of the relationship between these parameters and the WBV exercises. Although the hemodynamic data is actually quite scant, for Yarar-Fisher and coauthors [36] longer duration of use the WBV plate is necessary for improvement bone density. But they observed in their studies an increased muscle oxygenation and blood flow observations in response to WBV suggest a possible application of WBV for increasing lower extremity blood flow and/or oxygen saturation in individuals with SCI. WBV exercise may be incorporated into the rehabilitation programs for reducing thrombosis susceptibility in individuals with SCI; blood pressure in individuals with SCI appeared to be maintained much better in the upright position when WBV is applied and this could be helpful in the rehabilitation of SCI patients by allowing them to avoid the difficulties of orthostatic hypotension earlier in their rehabilitation programs.

The secondary outcomes were showed in this study, have already been discussed in previous systematic reviews [39,40] about the effects of WBV exercise on neuromodulation of the musculoskeletal system of individuals with SCI. Neural factors are thought to be the main contributor involved in the effects of the WBV exercise related to the increase of the physiological responses of reflex and muscle activity, and muscle function [46,51,52].

Putting together the reported findings, the authors of this current revision agree with Bizzarini and coauthors [22] that are highly desirable that SCI patients begin active physical therapy programs as soon after injury as possible. However, two important problems should be addressed when dealing with SCI patients, the reduction in cardiovascular fitness and in work capacity, by loss of sympathetic control and functional muscle mass. Moreover, for Herrero and coauthors [23] the WBV exercise responses do not appear sufficient for this, but represents an option to induce a reflex muscle contraction in individuals with difficulties or inability to evoke voluntary contractions such as SCI patients. Considering previous studies and the data pointed out by the authors selected in this revision, there is a suggestion that the WBV exercise can be a possible tool to be incorporated in rehabilitation programs of the SCI individuals.

Some scientific limitations that must be considered in the interpretation of the findings. It is necessary attention and caution should be taken when generalizing the results due to the methodological variations concerning to biomechanical parameters, type of the oscillating/vibratory platform, or the variability of the protocols used. Although the authors have tried to retrieve the articles involving WBV and SCI with the selected keywords, it is not sure that all studies on this topic have been identified, including articles that were not published in English and articles published in journals that were not indexed in the databases searched. In addition, the limited number of publications with high methodological quality (RCTs) must also be considered and this fact could of course affect the evidence of the findings. Therefore, studies with a higher methodological quality and focusing specifically on certain types of population would be desirable.

Conclusion

The increasing incidence of spinal cord injury in young and potentially active individuals who were victims of global violence, together with the increasing appearance of scientific evidence regarding the effects of WBV exercises on hemodynamic and systemic changes in the individual, were the main motivators for the construction of this review. However, further investigations with more controlled protocols related to the frequency and the amplitude/peak-to-peak displacement of the mechanical vibration, type of the OVP and groups of SCI individuals with similar ages and clinical conditions in RCT trials are recommended to determinate other hemodynamic and physiological effects of this kind of exercise in SCI individuals. Better done studies need to be done since the current research is far from conclusive.

Conflict of Interest

The authors declare that they have no conflict of interest.

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