Physical Exercise for Individuals With Spinal Cord Injury: Systematic Review Based on the International Classification of Functioning, Disability, and Health

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Introduction: Considering the reduction of physical activity performed daily in people with spinal cord injury, it is necessary to analyze the interventions based on physical exercises in order to provide recommendations based on evidence. **Objectives:** To review and evaluate the literature on physical exercise interventions for individuals with SCI, based on the International Classification of Functioning, Disability and Health, as well as physiological parameters for exercise prescription. **Method:** A systematic review of the literature produced from August 2016 to February 2017 within the PubMed, Embase, Cochrane Library, and MEDLINE databases. **Results:** Two independent examiners conducted a search in which 223 articles were initially found. A third evaluator verified possible divergences and generated a final list of 25 articles that strictly met the inclusion criteria, 5 of which investigated the effects of aerobic exercise, 2 of resistance training, 2 of balance training, 12 of gait training, and 4 evaluating the combined effect of 2 or more forms of training. **Conclusion:** Considering studies classified as of high and moderate quality of evidence, positive effects were observed in the domains of structures and functions, in aerobic, resistance training and combined exercises, and in some studies with gait training. In the domain of activities and participation, positive effects were observed in the studies with gait training, balance training, and combined interventions.

Keywords: paraplegia, tetraplegia, resistance, balance, gait, training, aerobic

Spinal cord injury (SCI) is a devastating health condition, which is associated with permanent disability and reduction in life expectancy.¹ Global data state a high annual incidence between 12.1 and 57.8 per million inhabitants, the same with prevalence that ranges between 236 and 1009 per million inhabitants.²

Spinal cord injury results in sensory, motor, and autonomic dysfunction. Consequently, it affects the physical, psychological, and social well-being of suffering individuals.³ In addition, SCI causes a lack of control of somatic and autonomic systems, resulting in a reduction in physical activity and cardiovascular response to exercise.⁴

The reduction in physical activity level and the systemic impairments after injury encourage sedentarism in subjects with SCI.^{5,6} Among the most significant consequences of reduction in physical activity level are musculoskeletal changes—that is, muscular atrophy, osteopenia/osteoporosis, hypertonia, and restrictions of joint mobility—body composition changes, and metabolic and cardiorespiratory disorders, which increase the risk of comorbidity secondary to injury.⁷⁻⁹

Decline in muscle strength, endurance, and functional capacity are the main health concerns among SCI individuals and have been linked to decreased quality of life in those with SCI.¹⁰ According to Dunlop et al,¹¹ sedentary behavior and inactivity are the main risk factors associated with the development of metabolic and

cardiovascular disorders and have been associated with reduction in muscle strength and reduced aerobic capacity.

Therefore, it is necessary to offer therapeutic activities, exercise programs, sports modalities, and adequate recreational activities to individuals suffering from SCI in order to promote their participation in physical exercise programs.^{12,13} However, there is a lack of scientific literature providing information on how to develop appropriate exercise training programs for SCI individuals based on evidence.

Given the diversity of clinical pictures presented after SCI and the different functional impairments associated, it is necessary to analyze interventions based on available physical exercises in order to provide evidence-based recommendations.¹⁴⁻¹⁶

The ability to describe, classify, and code information and measures on a wide range of health issues requires common structures and language. The International Classification of Functioning, Disability and Health (ICF) developed by the World Health Organization constitutes a useful framework for understanding the complex interaction between the various factors that may affect the performance of activities and participation, including barriers for community-based skills after SCI.¹⁷

Therefore, the present study intends to review and critically appraise the literature regarding the physical exercises intervention to subjects with SCI.

The data analysis and critical appraisal were conducted based on the ICF framework as well as physiological parameters for exercise prescription.

Method

A systematic review of the literature was conducted from August 2016 to February 2017.

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Eligibility Criteria

The review of the literature was performed within the PubMed, Embase, Cochrane Library, and MEDLINE databases.

The following terms were used: spinal cord injury AND aerobic exercise, spinal cord injury AND resistance training, spinal cord injury AND balance training, and spinal cord injury AND gait training. Only research on human beings, published in English, which had the keywords in the titles and/or abstracts were considered in the search.

In this review, the studies included were randomized clinical trials, controlled clinical trials, observational studies, and case studies published by February 2016. Excluded studies were studies, which did not specifically investigate physical exercise and its effects, those that did not use data collected from subjects after SCI, and those in which the full version of the article was not found within database or by contacting the author.

The selected articles were categorized according to the type of intervention: aerobic exercise, resistance training, balance training, and gait training. Furthermore, we considered the category “combined exercises,” which presented more than one associated intervention.

Studies are presented following these descriptions: characteristics of the sample, purpose of the study, intervention time, intervention parameters, adherence to FITT (frequency, intensity, type, and time) principles, and effects. The components of exercise prescription are frequency, intensity, time, and type (or modality), which are often referred to as the FITT principle. The components of the FITT principle constitute the exercise dose or quantity needed to improve health similar to a pharmacologic intervention.¹⁸ The ICF framework was also considered for data analysis, selecting the body structure and function, activity and participation level.

Data Collection and Analysis

Two independent examiners conducted the search. After this survey, a third evaluator verified possible divergences and generated a final list.

Assessment of Methodological Quality of Studies and Outcomes Classification

The methodological quality of the articles was evaluated through the GRADE (grading of recommendations, assessment, development, and evaluation) system. The GRADE system was used as substitute for the Physiotherapy Evidence Database (PEDro) scale, because PEDro only allows the assessment of randomized clinical trials, and this review included other scientific study designs.

The GRADE provides a quality rating system for evidence in systematic reviews and guidelines and for grading strength of recommendations. The system is designed for reviews and guidelines that examine alternatives of strategic management or interventions, which may include no intervention or the best current practice.

In the GRADE approach, the quality of evidence is classified into 4 levels: high, moderate, low, and very low. Randomized controlled trials begin as high-quality evidence and observational studies as low-quality evidence and rise or fall in ranking depending on estimates of intervention effects.¹⁹

After initial classification, methodological limitations (risk of bias), inconsistency, indirect evidence, inaccuracy, and publication bias may lower the quality of evidence. Additionally, if the level of

evidence has not been rated down due to the above factors, the evidence from observational studies may be rated up based on 3 factors: effect of high-magnitude, dose–response gradient, and factors of residual confounding, which increase confidence in estimates.¹⁹

Results

After the search, 223 articles were found. Of this total, 113 articles were excluded because they were duplicates, and another 15 articles were excluded due to lack of access to the full text, even after contacting the author. Of the 95 remaining articles, 70 were excluded because they did not present the keywords in the titles or abstracts or did not specifically address the effects of physical exercises. Finally, 25 articles were included, 5 of which investigated the effects of aerobic exercise, 2 of resistance training, 2 of balance training, 12 of gait training, and another 4 evaluating the combined effect of 2 or more forms of training (Figure 1).

Of the 25 selected articles, 7 were classified as high-quality evidence, 6 as moderate, 11 as low, and only 1 as very low. In addition to the methodological classification, the selected studies were classified according to the outcomes within the domains of ICF. Table 1 presents an overview of selected and classified studies according to the quality of evidence, categorizing the outcomes according to the ICF aspects.

Five selected studies were categorized as aerobic exercise; among these, the studies classified as moderate were those with the best quality of evidence. The study populations were heterogeneous in terms of the level of injury, but homogeneous in terms of Frankel’s classification, given that all the subjects had injuries classified as ASIA A. The times and parameters of activity were varied, as were the presented outcomes, which are illustrated in Table 2.

Only 2 studies presented resistance training interventions, of which one was classified as high and the other as low quality as well as aerobic exercise studies were heterogeneous in relation to intervention parameters; however, both groups of subjects suffered from incomplete SCI (tetraplegia and paraplegia) classified as ASIA C and D (Table 3).

Of the selected studies, 2 presented balance training interventions, of which one was classified as high and the other as low quality, similar to the findings for resistance training. These studies presented heterogeneous samples in terms of functional classification of SCI. In both studies, participants performed balance training 3 times a week, with study times varying in duration from 4 to 6 weeks. Different tests were used to evaluate improvement in balance (Table 4).

Of the 25 selected studies, 12 studies used gait training intervention. Of these, 6 were classified as low, 2 as moderate, and 4 as high quality. The studies were homogeneous in terms of the level of injury (quadriplegia and paraplegia) and the functional classification of SCI as incomplete, with the exception of one study with low-quality evidence that used subjects with injuries classified as “complete” and “incomplete” in their sample. The studies were heterogeneous concerning the parameters and equipment used; 4 studies used robotic devices, and 4 studies used functional electrical stimulation (FES). The main outcomes mentioned were gait parameters, such as speed and resistance (Table 5).

Table 6 presents the 4 studies that used a combination of interventions in their methodology. These studies have investigated the effects of aerobic exercise and resistance training. These studies

Figure 1 — Flowchart of the study selection procedure.

were heterogeneous in terms of activity parameters. Of the 4 studies, 1 was classified as low, 2 as moderate, and 1 as high quality.

Discussion

This review included 25 studies that investigated the effects of different physical exercise programs for SCI subjects. Of the 25 studies, 5 presented aerobic exercise intervention, 2 presented resistance training, 2 used balance training, 11 presented gait training, and 5 presented 2 or more types of exercise within the same intervention.

Most authors have investigated outcomes related to the components of structures and body functions. Some have investigated outcomes in terms of parameters such as gait performance (tests of 10-m walk, 6-min walk, Timed Up and Go, and Walking Index for SCI) and balance tests (Berg Scale) and a few in terms of effects on quality of life and depression. There is a lack of studies investigating the effects of exercise on the SCI population, especially on quality of life as the primary outcome.

Characteristics of Subjects

The participants included in the studies were heterogeneous in relation to age, type/level of injury, and time after injury. The studies included young and elderly, individuals with tetraplegia and paraplegia with complete and incomplete injuries and different degrees of impairment, based on the ASIA Impairment Scale.

For example, for the authors who investigated the effects of aerobic exercise, the population was mostly composed of individuals with paraplegia,^{21,22,24} and only one study involving aerobic training had a sample composed only of subjects with tetraplegia.²⁰ This preference for individuals with lower level injuries is probably

due to the difficulties in developing aerobic exercise programs for individuals with tetraplegia. There are barriers to selection of equipment and/or ergometers adapted to higher-level injuries. In addition, the use of ergometers for upper limbs is not always possible for this population. There are other possible reasons, such as reports of these individuals experiencing muscle fatigue prior to cardiorespiratory fatigue and impairments in the autonomic nervous system that make it difficult to control the heart rate. For individuals with this impairment, the main measure of intensity used was the subjective perception of effort based on the original Borg Scale (6–20) and the modified Borg Scale (0–10), as described in the study of Paulson et al,⁴⁵ which showed a relationship between subjective perception of exertion and VO_2 in athletes with cervical injuries.

The studies evaluating aerobic exercise presented a wide variety of FITT principles.¹⁸ The most common type was a cycle ergometer for the upper limbs^{22–24} and an ergometric bicycle assisted by functional stimulation.²³ The intensity was prescribed based on percentage of maximal oxygen uptake (60% $\text{VO}_{2\text{max}}$)²² and percentage of heart rate reserve (50%–80% HRR).^{19,20,23} Regarding the duration of the session, the range was from 30 to 45 minutes, and the general frequency of 3 times a week.^{20,21,23,24}

The 2 studies that evaluated resistance training interventions^{25,26} were directed to segments affected by injury. Therefore, only individuals with incomplete injuries (ASIA C and D) who had voluntary muscle activity were selected. The presented results do not allow generalizing results to people with complete SCI, and may be considered a limitation for this review.

In the gait training interventions, there is a predominance of studies with incomplete SCI patients, given the greater potential for functional gait recovery for these individuals. In addition, 2 studies^{33,36} indicate that ambulating individuals—who present the highest initial gait deficits, as indicated by a lower speed and resistance of the initial gait—present greater potential for

Table 1 Methodological Quality and Outcomes Related to the Domains of ICF

Grade	Study	Outcomes (ICF)		
		Structures and body functions	Activity	Participation
Aerobic training				
Very low	Tawashy et al ²⁰	X		
Low	Silva et al ²¹	X		
Low	Vasiliadis et al ²²	X		
Moderate	Brurok et al ²³	X		
Moderate	Rosety-Rodriguez et al ²⁴	X		
Resistance training				
Low	Jayaraman et al ²⁵	X	X	
High	Harvey et al ²⁶	X		
Balance training				
Low	Sayenko et al ²⁷	X	X	
High	Boswell-Ruys et al ²⁸	X	X	
Gait training				
Low	Postans et al ²⁹	X		
Low	Thrasher et al ³⁰	X	X	
Low	Schwartz et al ³¹		X	
Low	Benito-Penalva et al ³²		X	
Low	Fleerkotte et al ³³	X	X	
Low	Sharif et al ³⁴		X	
Moderate	Labruyère and Van Hedel ³⁵	X	X	
Moderate	Mirbagheri et al ³⁶	X		
High	Nooijen et al ³⁷		X	
High	Giangregorio et al ³⁸	X		
High	Kapadia et al ³⁹	X	X	
High	Lam et al ⁴⁰		X	
Combined exercises				
Low	Bizzarini et al ⁴¹	X		
Moderate	Ginis et al ⁴²	X		X
Moderate	Hicks et al ⁴³	X		X
High	Totosy de Zepetnek et al ⁴⁴	X		

Abbreviation: ICF, International Classification of Functioning, Disability and Health.

improvement from the interventions. Interventions that focused on balance training included individuals with tetraplegia and paraplegia with incomplete SCI (classified ASIA Impairment Scale C–D).

Regarding the time of injury, it was observed that the studies include individuals in the chronic stage of SCI. This may happen possibly because they tend to present a stable picture in terms of clinical aspects, functional recovery as well as secondary problems. Besides choosing chronic patients, the spontaneous recovery process does not affect the end results because this mechanism occurs only in the acute and subacute phase of injury. Therefore, only 2 studies^{29,31} involved gait training used in individuals in the acute and subacute phases.

Methodology and Effects of Interventions

In aerobic exercise, the main outcomes observed were improvement in the endurance of the ventilatory musculature, increase in cardiorespiratory fitness, and its influence on the sex hormone

levels of individuals with SCI. The findings indicate that aerobic exercises performed in cycle ergometers, at times associated with FES are a safe strategy for individuals who have a complete injury. Exercise intensity can be controlled through heart rate measurement, however, in individuals with injury above the sixth thoracic level it is essential to use subjective scales, such as the Borg, since these individuals have an impaired cardiovascular response due to loss of sympathetic innervations.⁴⁵

Regarding resistance training, according to Table 3, exercise intensity was based on percent of 1 maximal repetition (65% RM) and on specific ranges of maximal repetitions, in this case, 10 maximal repetitions. In addition, both studies report a progression of intensity throughout the intervention. Only the study of Harvey et al²⁶ reports the frequency of training, which was 3 times a week. Duration of each session was not reported in any study. The proposed interventions resulted in increased isometric and dynamic muscle strength of the lower limbs in individuals with incomplete SCI who had some degree of voluntary control. One of the authors

Table 2 Methodological Quality and Aerobic Exercises

Grade	Study	Subject description	Objective	Intervention time	FITT principles	Effects of intervention
Very low	Tawashy et al ²⁰	N = 1 subject SCI level: C5-C6 AIS A	Presenting the process of prescribing aerobic exercise during the initial rehabilitation of an individual who suffered cervical SCI.	8 wk	F: 3× per week I: 50%–80% HRR and RPE 12–18 Borg Scale T: aerobic training T: 30 min	Improved exercise tolerance. Increase in peak oxygen consumption (20%). Improves orthostatic tolerance. Psychological benefits reported by the individual.
Low	Silva et al ²¹	N = 12 subjects SCI level: T1-T12 AIS A	Compare VME of individuals without SCI to individuals with complete SCI and to evaluate the effect of an aerobic training program on muscular endurance respiratory muscle.	6 wk	F: 3× per week I: HR corresponding to the anaerobic threshold T: aerobic training T: 30 min	Improvement in FVC and respiratory muscle endurance. 70% increase in test time. 70% increase in MVV).
Low	Vasiliadis et al ²²	N = 8 subjects SCI level: T6-T12 AIS A	To evaluate the response of angiogenic molecules in individuals with SCI and without injury during an exercise session performed on a cycle ergometer for upper limbs.	2 d	F: NM I: 60% VO ₂ max T: aerobic training T: NM	Acute increase in the concentration of angiogenic molecules in individuals with and without SCI.
Moderate	Brurak et al ²³	N = 6 subjects SCI level: C7-T5 AIS A	To evaluate the effect of high-intensity and interval program training performed with upper body cycle ergometer and ergometer assisted by functional electrical stimulation on the stroke volume and peak oxygen consumption peak for individuals with SCI.	8 wk	F: 3× per week I: 85%–95% peak work capacity T: aerobic training T: NM	Increased peak systolic volume (33%), increased HR (27.7%), significant increase in peak oxygen consumption (25.3%), compared with the control group.
Moderate	Rosety-Rodriguez et al ²⁴	N = 17 subjects SCI level: T4 or below EG: 9 subjects CG: 8 subjects	Check the influence of an exercise program in manual cycle ergometer, the level of sex hormones, the effects on muscle strength and body composition of individuals with chronic SCI.	12 wk	F: 3× per week I: 50%–65% HRR T: aerobic training T: 30–45 min	Significant increase in circulating testosterone levels. No difference in LH and FSH levels. Increased isometric force estimated at hand dynamometer. Decrease in waist circumference.

Abbreviations: AIS, ASIA Impairment Scale; CG, control group; EG, experimental group; FITT, frequency, intensity, type, and time; FSH, follicle-stimulating hormone; FVC, forced vital capacity; HRR, heart rate reserve; LH, luteinizing hormone; MVV, maximum voluntary ventilation; NM, not mentioned; RPE, ratings of perceived exertion; SCI, spinal cord injury; VME, ventilatory muscle endurance.

found an improvement on balance capacity after the intervention, even not providing specific balance training, which suggests that lack of muscle strength influences balance deficit.

On the other hand, the interventions based on balance training, as described in Table 4, present a frequency of 3 times a week, and only one of the studies²⁷ reports a duration of 60 minutes per session. Taken together, these results indicate that interventions focused specifically on balance training are effective. The study that performed the intervention in the sitting position resulted in improvement to sit without assistance, and the one that performed the intervention using standing balance training with visual feedback (VBT) showed improvements in dynamic and static balance. However, it is not possible to establish the parameters for its prescription due to the low number of included studies. Progressively complex exercises can be adapted to the specific tasks and this may influence to develop and maintain independence, such as transfers from sitting to standing and maintaining sitting posture.

All studies that used gait training were performed in association with other devices, such as FES, electromechanical tools (such as robotic exoskeletons), and treadmills with partial weight support. The duration of the sessions ranges from 45 to 60 minutes, with a frequency of 2 to 5 times a week. Only one study³⁰ presented the intensity of the training, which was based on the percent of the maximum velocity (120% of the initial auto selected gait velocity) of each individual. The results observed with gait training were consistent. In general, interventions resulted in increased speed, endurance (the total distance walked in 6 min),²⁹ and gait control. The parameters used for progression of the training overload involved modifications in the percentage of the body weight supported, the speed of the treadmill, and the duration of the exercise.

In one study,³⁹ no difference was observed between a specific gait training program and a training program which combined aerobic exercises and resistance training in relation to improvement of gait and balance of participants. These results may indicate that

Table 3 Methodological Quality and Resistance Training

Grade	Study	Subject description	Objective	Intervention time	FITT principles	Effects of intervention
Low	Jayaraman et al ²⁵	N = 5 subjects SCI level: C2-T7 4 tetraplegics/1 paraplegics AIS C-D	Evaluate the effects of a 4-wk high-intensity strength training program using repeated maximal isometric contractions in functionality and strength of the lower limbs in individuals with incomplete SCI, comparing it to a conventional force training program.	4 wk	F: NM I: maximal isometric contraction 50%–65% MR T: strength training T: NM	Significant increase in distance traveled (6MWT). Improving balance (Berg Balance Scale). Increased maximum isometric strength of the muscle groups of the lower limbs.
High	Harvey et al ²⁶	N = 20 subjects EG: 10 subjects CG: 10 subjects (without intervention) SCI level: C5-L2 AIS C-D	To determine the effectiveness of progressive strength training program assisted by functional electrical stimulation (EF) to increase muscle strength of the quadriceps of individuals with SCI.	8 wk	F: 3× per week I: 12× of 10 MR T: strength training T: NM	Increased voluntary quadriceps muscle strength, however, it is unclear whether this improvement promotes significant clinical benefits.

Abbreviations: AIS, ASIA Impairment Scale; CG, control group; EG, experimental group; FITT, frequency, intensity, type, and time; 6MWT, 6-min walk test; MR, maximal repetition; NM, not mentioned; SCI, spinal cord injury.

Table 4 Methodological Quality and Balance Training

Grade	Study	Subject description	Objective	Intervention time	FITT principles	Effects of intervention
Low	Sayenko et al ²⁷	N = 6 subjects SCI level: C4-T12 2 tetraplegics/4 paraplegics AIS C-D	Evaluate the potential for learning and performance improvement in the balance using standing balance training with visual feedback (VBT) in individuals with incomplete SCI and determine whether the balance in the standing position and the dynamic stability while performing tasks not related to training can be improved after use of VBT.	4 wk	F: 3× per week I: NM T: balance training T: 60 min	Improved performance of the participants to the different referred games. Improved static and dynamic postural stability.
High	Boswell-Ruys et al ²⁸	N = 30 subjects EG: 15 subjects CG: 15 subjects SCI level: T1-T12	To determine the effectiveness of a training program using a specific task to improve the ability to sit without support individuals with SCI.	6 wk	F: 3× per week I: NM T: balance training T: NM	Improved ability to remain seated without support in individuals with SCI, as assessed by: maximum amplitude balance of the test (maximal balance range) and trunk oscillation test (upper-body sway full length).

Abbreviations: AIS, ASIA Impairment Scale; CG, control group; EG, experimental group; FITT, frequency, intensity, type, and time; NM, not mentioned; SCI, spinal cord injury.

lack of muscle strength is a limiting factor for gait functionality in these individuals. Three of the included studies that involved gait training^{29,34,40} found a transfer of the benefits obtained with the interventions using FES or electromechanical devices for over-ground gait.

Studies with combined interventions, which include 2 or more types of training in the same program, have used from ergometers to resistance exercises with cables and machines. The main measures to control the intensity of aerobic training were based on percent of maximum heart rate (70%–80% HR_{max}) and subjective effort perception (measured as 3–6 on a modified Borg Scale). The weekly frequency of the programs ranged from 2 to 5 sessions and the duration ranged from 45 to 120 minutes per session.^{41–44}

In addition to the observed benefits such as increase in muscle strength, work capacity, and improvement of body composition, such

as visceral fat reduction, the interventions also resulted in benefits in the quality of life, for example, stress reduction, decrease in perception of pain and depression, and an increase in physical self-concept, which is fundamental since the injury has a negative impact on the participation level.⁴⁶ A striking fact of the great majority of studies is the lack of training parameters for the progression of the intensity and volume, which may limit the benefits of the proposed exercises.

Quality of Studies and Outcomes According to ICF

Our results suggest that there is more evidence available for gait training, with more methodological rigor comparing to other types of exercise. In addition, a large volume of research involves gait training in SCI, probably because this is the main priority of this population as related in previous studies.^{47,48}

Table 5 Methodological Quality and Gait Training

Grade	Study	Subject description	Objective	Intervention time	FITT principles	Effects of intervention
Low	Postans et al ²⁹	N = 14 subjects SCI level: C4-T9 AIS C-D 8 tetraplegics/6 paraplegics DO: 2	To determine the efficacy of gait training using treadmill with partial body weight support associated with FES rehabilitation of patients with acute incomplete SCI compared with conventional physiotherapy.	4 wk	F: 5× per week I: NM T: gait training T: 60 min	Greater effect on increasing the gait speed and endurance as compared with conventional therapy.
Low	Thrasher et al ³⁰	N = 5 subjects SCI level: C5-T12 AIS C-D 1 tetraplegics/4 paraplegics DO: 0	Demonstrate the feasibility and effectiveness of a gait training program in patients with chronic incomplete SCI.	12–18 wk	F: NM I: 120% of the initial and auto selected gait velocity T: NM T: NM	Improved gait function: increase speed and reduce the use of walking aids.
Low	Schwartz et al ³¹	N = 56 subjects AIS A-D EG: 28 subjects -13 tetraplegics/15 paraplegics CG: 28 subjects -13 tetraplegics/15 paraplegics DO: 0	To evaluate the effect of gait training robotic assisted by using the Loko system in neurological and functional variables of individuals with subacute SCI, comparing it to conventional therapy alone.	12 wk	F: 2–3× per week I: NM T: gait training T: NM	The proposed program is not superior to the isolated physical therapy to improve walking ability (WISCI II and Functional Ambulation Category Scale), however, promotes greater functional improvements (SCIM).
Low	Benito-Penalva et al ³²	N = 130 subjects NE = 105 subjects -45 tetraplegics/60 paraplegics AIS A and B = 11 AIS C and D = 94 DO: 25 subjects	Report clinical improvements associated with an intensive gait training using electromechanical systems according to the characteristics of individuals with SCI.	8 wk	F: 5× per week I: NM T: gait training T: NM	Increase in walking speed (10MWT). Improvements in walking ability, (WISCI II). The significant improvements have occurred in individuals who had an incomplete injury and started the intervention within a shorter period of time after the injury (<6 mo).
Low	Fleerkotte et al ³³	N = 12 subjects SCI level = C2-L2 4 tetraplegics/8 paraplegics AIS C-D DO: 2 subjects	Assess the feasibility and effectiveness of a gait program assisted by robotic controlled impedance in the ability and gait quality of individuals with SCI.	8 wk	F: 3× per week I: NM T: gait training T: 60 min	Significant improvement in functionality and gait quality (10MWT, 6MWT, TUG, and WISCI II). Increased muscle strength verified by the LEMS.
Low	Sharif et al ³⁴	N = 8 subjects NE = 6 subjects SCI level: C4-L3 -3 tetraplegics/3 paraplegics AIS D DO: 2 subjects	To assess the effects of a 12-wk program of gait training assisted by FES on locomotor function and quality of life of individuals with SCI.	12 wk	F: 3× per week I: NM T: gait training T: NM	Improved overground gait resistance (6MWT). Greater gait independence (WISCI). Tendency to higher gait speed (10MWT). Pain reduction and improved mental health (SF-36).
Moderate	Labruyère and Van Hedel ³⁵	N = 9 subjects SCI level: C4-T11 5 tetraplegics/4 paraplegics AIS C-D DO: 0	To compare the effects of strength training to the lower limbs with a gait training with specific tasks on variables associated with walking in incomplete SCI individuals and to evaluate the effect of these interventions on pain control.	8 wk	F: 4× per week I: EG: NM CG: strength training = 70% MR T: gait training and strength training T: 45 min	The gait training with resistance not shown more effective than strength training to improve gait performance. The maximum walking speed increased more significantly after strength training for the lower limbs. Decreased pain after both interventions with greater effect with strength training.

(continued)

Table 5 (continued)

Grade	Study	Subject description	Objective	Intervention time	FITT principles	Effects of intervention
Moderate	Mirbagheri et al ³⁶	N=46 subjects EG: 23 subjects CG: 23 subjects (no intervention) SCI level: C2-T9 AIS C-D	To evaluate the therapeutic effects of a gait training assisted by robot on neuromuscular abnormalities associated with spasticity through the characterization of their pattern of recovery in individuals with SCI.	4 wk	F: 3× per week I: NM T: gait training T: 45 min	Increased belt speed 1.5–2.8 km/h. Decrease the assistance provided by the robot 100%–20%. Reduction of the partial support of 95%–25% weight, varying according to the ability of each individual. Decreased muscle stiffness and intrinsic reflex.
High	Nooijen et al ³⁷	N=51 subjects SCI level: C3-T11 32 tetraplegics/19 paraplegics AIS C-D DO: 24 subjects	Compare the changes in gait quality measurements associated with 4 different types of gait training with partial body weight support in patients with incomplete and chronic SCI, and identify how these parameters are different from those seen in individuals without injury.	12 wk	F: 5× per week I: NM T: gait training T: 60 min	Improved gait ability (increase in gait cadence of the stride length). There was no difference in any of the variables between groups.
High	Giangregorio et al ³⁸	N=34 subjects EG: 17 subjects CG: 17 subjects SCI level: C2-T12 AIS C-D DO: 7 subjects (6 CG/1 EG)	To evaluate the effect of a gait training assisted by FES on body composition, comparing it to a conventional training in individuals with SCI.	16 wk	F: 3× per week I: EG: NM CG: strength training = 12–15 MR Aerobic training = 3–5 on the Borg modified scale. T: EG: gait training (Loko 70 + FES) CG: strength and aerobic trainings T: 45 min	No changes were observed in body composition of individuals from both groups. The intervention (gait assisted by EF) cannot increase muscle mass and decrease body fat in the short term, but it can prevent muscle atrophy in the long term.
High	Kapadia et al ³⁹	N=34 subjects EG: 17 subjects CG: 17 subjects SCI level: C2-T12 AIS C-D DO: 7 subjects (6 CG/1 EG)	Assessing whether a gait training program assisted by FES is greater than a conventional exercise program to improve performance in gait and balance in individuals with chronic incomplete SCI.	16 wk	F: 3× per week I: EG: NM CG: strength training = 12–15 MR Aerobic training = 3–5 on the Borg modified scale. T: EG: gait training (Loko 70 + FES) CG: strength and aerobic trainings T: 45 min	Improved gait resistance (6MWT). Balance improvement (TUG). No difference between the groups. No changes were observed in gait speed and spasticity (10MWT and Ashworth Scale modified, respectively).
High	Lam et al ⁴⁰	N=15 subjects SCI level: C1/2-T10 AIS C-D EG: 8 subjects -4 tetraplegics/4 paraplegics CG: 7 subjects -6 tetraplegics/1 paraplegics DO: 3 (2 CG/1 EG)	Determine the feasibility and evaluate the effects of gait training program assisted by robot (Loko-R) on gait functionality, focusing on the ability to walk on the ground, in individuals with incomplete and chronic SCI.	12 wk	F: 3× per week Gait training T: 45 min	Greater improvement in walking skill in the intervention group (SCI-FAP) than in the control group. Increased overground walking speed (10MWT) and the walking resistance (6MWT). No difference between groups.

Abbreviations: AIS, ASIA Impairment Scale; 10MWT, 10-m walk test; 6MWT, 6-m walk test; CG, control group; DO, drop out or excluded for analysis; EG, experimental group; FAP, functional ambulation profile; FES, functional electrical stimulation; FITT, frequency, intensity, type, and time; LEMS, lower-extremity motor score; Loko, Lokomat; MR, maximal repetition; NE, experimental number of subjects; NM, not mentioned; SCIM, spinal cord independence measure; TUG, Timed Up and Go; WISCI, Walking Index for spinal cord injury.

Table 6 Methodological Quality and Combined Exercises

Grade	Study	Subject description	Objective	Intervention time	FITT principles	Effects of intervention
Low	Bizzarini et al ⁴¹	N=21 subjects SCI level: C4-L2 6 tetraplegics /15 paraplegics AIS B-C	To evaluate the effects of a rehabilitation program training with ergometers in subacute SCI individuals.	6 wk	F: 5× per week I: aerobic training 70%–80% of maximum HR. Strength training 40%–60% MR T: aerobic training and strength training for upper limbs T: 90 min	Increase of the work capacity during the ergometers exercises in the first 4 wk. There was no statistical difference between the corporal body weight by the beginning and the end of the intervention. The body fat percentual remained the same, except in male individuals with low level of injury (paraplegia). Hematologicals alterations were not observed.
Moderate	Ginis et al ⁴²	N=34 subjects EG: 21 Subjects CG: 13 subjects SCI level: NM AIS: complete and incomplete DO: 4 (2 EG, 2 CG)	Evaluate whether exercise can be used as a strategy for the reduction of pain and improvement of subjective perception of well-being of individuals with SCI.	12 wk	F: 2× per week I: aerobic training = 70% of maximum capacity. T: aerobic and strength training T: 65–95 min	Stress and pain perception reduction of individuals with SCI. Improved quality of life, greater satisfaction with the appearance and physical capacity, and improvement of depression frame.
Moderate	Hicks et al ⁴³	N=34 subjects EG: 21 subjects CG: 13 subjects SCI level: C4-L1 AIS A-D DO: 11 (10 EG/11 CG)	Evaluate the effects of a program of 9-mo exercise on strength, performance in manual cycle ergometer, psychological variables, and quality of life.	36 wk	F: 2× per week I: aerobic training = 70% of maximum HR or 3–4 in the adapted scale of Borg. Strength training = 50–80% MR T: strength and aerobic training T: 90–120 min	Increased muscle strength. Improved performance in manual cycle ergometer. Improved quality of life and psychological well-being (decreased pain, depression, and stress self-reported).
High	Totosy de Zepetnek et al ⁴⁴	N=23 subjects EG: 12 subjects CG: 11 subjects SCI level: C3-T11 AIS A-C DO: 6 subjects	To assess the effects of a physical exercise program following the physical activity guidelines for adults with SCI for 16 wk.	16 wk	F: 2× per week I: aerobic training = 3–6 in the adapted scale of Borg. Strength training = 50%–70% MR T: aerobic and strength training T: 60 min (20 min minimum for aerobic training)	Improvement in parameters of body composition (decreased visceral fat). Improvement in carotid artery distensibility. There was no change in blood markers of cardiovascular risk (ie, in the fasting insulin level).

Abbreviations: AIS, ASIA Impairment Scale; CG, control group; DO, drop out or excluded for analysis; EG, experimental group; FIIT, frequency, intensity, type, and time; HR, heart rate; MR, maximal repetition; NM, not mentioned; SCI, spinal cord injury.

Regarding the characteristics of the interventions, the FITT principles are described in more detail within the gait training studies. It is observed the weekly frequency was mostly 3 times a week, and the variables used to modulate the intensity were primarily the speed of the treadmill and the percent of partial weight support. The duration of trainings ranged from 45 to 60 minutes. The studies of Kapadia et al³⁹ and Sharif et al³⁴ used protocols with very similar FITT characteristics. Both observed improvement in gait endurance, assessed by the 6-minute walk test, whereas, in the study by Sharif et al,³⁴ there was a tendency to increase gait speed, which was not verified by Kapadia et al.³⁹

Considering the outcomes presented according to the ICF domains, the authors who propose combined interventions (aerobic exercise and resistance training) are more concerned with outcomes in terms of body structures and functions. Totosy de Zepetnek et al⁴⁴ evaluated the effect of a 16-week program combining aerobic exercise with resistance training—following the guidelines for physical exercise prescription for adults with SCI—and verified positive effects on some parameters of body composition and distensibility of the carotid artery. However, there was no improvement in several parameters associated with increased cardiovascular risk.⁴⁹

The main outcomes evaluated the body structures and functions that ranged from general and specific muscle strength to

lower-extremity motor score (the sum of the score for muscular strength of the 10 muscles of the lower limb), physical capacities (vital capacities, peak oxygen consumption, cardiac output, maximum voluntary ventilation, etc.), anthropometric measures (body composition, weight, percentage of fat, and waist circumference), and cardiovascular and hormonal markers.

Activity is defined as the execution of a task or action by an individual. Participation is understood as “involvement in life situations” and is considered a key component of human functioning, as described in the ICF.⁵⁰ Although most of the objectives of people with SCI are in the areas of activity and participation, the studies of this review focused on outcomes of structures and functions.

A few studies have associated activity outcomes, such as general tests of gait performance (10-meter walk, 6-min walk test, Timed Up and Go), specific tests for populations with SCI; Walking Index for SCI and Functional Ambulation Category Scale, general balance tests (Berg Scale, maximal balance range, and upper-body sway total length), and specific tests of functional independence (SCIM III).

In general, studies with gait and balance training present outcomes targeted to the scope of activities, with the exception of one study of resistance training,²⁵ whose authors assessed outcomes related to gait (6-min walk test) and balance (Berg test).

In the study of Boswell-Ruyset et al,²⁸ after an intervention based on balance training with specific tasks, there was an improvement in the ability to sit without support. The authors reported benefits for the accomplishment of a series of daily life activities independently, such as dressing and feeding, resulting in less activity limitations.

Of the 12 studies that assessed outcome of activity, 9 were studies of gait training. This shows a greater relation between this type of exercise program and activity outcomes. Only 2 studies assessed aspects of participation. Both studies evaluated combined exercise program and used the SF-36 scale of secondary outcome.

The SF-36 scale is a generic outcome measure reported by the patient, designed to be applied to all health conditions. Its objective is to quantify health status and measure health-related quality of life. It is considered an instrument to evaluate some aspects of participation, used in studies with this population since the subject is evaluated on some items, such as “accomplishing less than you would like and limitations in the kind of work,” “accomplishing less than you would like,” and “didn’t do work as carefully as usual.” However, it is not considered a specific scale regarding the aspects of the participation, not addressing all important aspects of this domain.⁵⁰

Although there are many participatory evaluation tools conceptually based on ICF, Ruoronen et al⁵¹ express that despite apparently clear and comprehensive lists of categories, the ICF’s definition of participation as “involvement in a life situation” does not specify how participation relates to other concepts, such as social integration, nor does it clarify what participation restrictions actually mean to persons with disabilities. For this reason we consider the absence of specific outcomes of participation an important limitation of the studies found.

The various choices of measures and scales of evaluation may suggest a difficult selection or even a limitation in the selection of appropriate tools for the outcomes of interest, in particular the specific tools used within the SCI population including different domains of the ICF.

In this context, Padula et al⁵² discuss the need to evaluate the effectiveness of intervention programs in all ICF domains,

considering not only the domains of body structure and body function but also activities and social participation, and the need to use specific assessment tools for SCI.

Barrier and Facilitators Related to Adherence for Physical Exercise in Individuals With SCI

Most of the studies have a low sample size, which results in a low external validity of the findings. This fact is probably associated with the barriers to joining an intervention program and/or research protocol. For example, one of the main barriers those individuals with SCI face is mobility restrictions, especially in individuals with tetraplegia, which makes it difficult to adhere to the proposed programs.

In addition to the mobility restrictions, another limiting factor would be the high costs involved in the particular treatments, together with a possible lower financial independence of these individuals. A factor that could facilitate the adherence of this population to physical exercise programs would be a low frequency of training sessions (eg, 2 times per week) associated with home program and the increase of intensity, which taken together may not interfere in the end result.

Limitations of the Study

The main limitation of the present review is the low quality of the included studies, according to the GRADE system, which limits clinical decisions based on strong evidence. The studies presented a small sample size and very heterogeneous characteristics with respect to age and time after injury, which may affect the validity of data.

Directions for Future Research

The results of the present review highlight the need for studies with greater methodological rigor, mainly in relation to the homogeneity of the sample characteristics, since they exert a great influence on the potential of functional recovery. Sample size may also be considered, because it can compromise the external validity, limiting the generalization of the results.

In addition, precision and specificity in the parameters of the training interventions, which includes the FITT principles, are highly recommended, as well as other variables, such as the level of supervision, the environment in which the interventions were performed, and the possible adverse events that occur during the intervention, such as high blood pressure peaks associated with autonomic dysreflexia or hypotension. Such information is fundamental considering the lack of evidence on the acute responses to exercise and the greater risk during the practice of physical activity to this population.

Finally, it is of great importance that future clinical trials select tools or scales adequate to the outcomes studied, which are specific to the population with SCI and sensitive to changes after short- or long-term interventions.

Conclusion

Considering studies classified as high and moderate quality of evidence, the positive effects were observed in the body structures and functions for aerobic, resistance training and combined exercises, and gait training. In the domain of activities and

participation, positive effects were observed for gait training, balance training, and combined interventions.

Due to the low methodological quality of most of the selected studies, as well as the variability in the outcomes—especially in studies that investigated aerobic exercise—it is difficult to establish parameters for the prescription of physical exercise programs for SCI people.

However, gait training is the modality with highest volume of publications, whereas balance training was the least frequently investigated program type. Therefore, there is a lack of controlled studies, mainly randomized clinical trials, which evaluate the potential effects of different types of physical exercises.

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