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Impacts of home-based physical exercises on the health of people with spinal cord injury: a systematic review

Impactos do exercício físico em ambiente doméstico sobre a saúde de pessoas com lesão medular: uma revisão sistemática

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ABSTRACT

The confinement period caused by the SARS-COV2 pandemic is another barrier to the practice of physical exercise by people with spinal cord injury (SCI). In view of the countless therapies targeted at this public, it is necessary to highlight the benefits of exercises performed at home. Thus, our objective was to determine the main characteristics of physical exercise training modes performed at home and their effects on people with SCI. We searched for intervention studies in five databases (PubMed, ScienceDirect, SPORTDiscus, Scopus and Cochrane CENTRAL) by including the terms and descriptors: "spinal cord injury", "home-based", exercise", "video game", "home-based physical activity". The selected studies were described by means of a narrative synthesis. Of 69,843 studies, only 10 met the eligibility criteria, totaling 153 investigated individuals (25 women and 128 men). Regarding the type of injury, 118 participants were paraplegic and 33 tetraplegic. The studies addressed functional electrical stimulation (n = 4), electronic assistive devices (n = 5) and stretching exercises (n = 1). We observed that the focus of the interventions was the morphological, motor neuron, quality of life and functional aspects. The studies showed improvements in muscle strength and morphology, in the ability to perform daily activities, in quality of life and in functional capacities, with no reported adverse situations. Although our review included a low number of randomized studies, we can conclude that several modes of exercise in the home environment promote benefits for people with SCI and can be options for maintaining or developing the health of this population.

Keywords: Physical exercise; People with disabilities; Human physical conditioning.

RESUMO

O período de confinamento ocasionado pela Pandemia do SARS-COV2, constitui-se em mais uma barreira para a prática de exercício físico por pessoas com lesão medular (LM). Diante das inúmeras terapias realizadas para este público, surge a necessidade de se evidenciar os benefícios de exercícios realizadas em casa. Assim, nosso objetivo foi determinar as principais características dos modos de treinamento do exercício físico realizados em casa e seus efeitos em pessoas com LM. Consultas a cinco bases de dados foram realizadas (PubMed, Science Direct, Sport Discus, Scopus e a Cochrane Central), em busca de estudos de intervenção, por meio da inclusão dos termos e descritores: "spinal cord injury", "home-based", "exercise", "video game", "home-based physical activity". Os selecionados foram descritos realizando uma síntese narrativa. De 69.843 estudos, apenas 10 atenderam os critérios de elegibilidade, que totalizaram 153 indivíduos investigados (25 mulheres e 128 homens). Considerando o tipo de lesão, 118 participantes eram paraplégicos e 33 tetraplégicos. Os estudos estiveram relacionados a estimulação elétrica funcional (n = 4), dispositivos assistidos eletrônicos (n = 5) e exercícios de alongamento (n = 1). Observou-se que o foco das intervenções foram os aspectos morfológicos, neuromotores, de qualidade de vida e funcionais. Os estudos demonstraram melhoras na força e morfologia musculares, nas capacidades de realizar atividades diárias, na qualidade de vida e em capacidades funcionais, sem situações adversas relatadas. Embora com baixa quantidade de estudos randomizados, podemos concluir que diversos modos de exercício em ambiente domiciliar promovem benefícios para pessoas com LM, podendo ser alternativas para manutenção ou desenvolvimento da saúde dessa população.

Palavras-chave: *Exercício físico; Pessoas com deficiência; Condicionamento físico humano.*

Introduction

Spinal cord injury (SCI) is a chronic problem caused by traumas or diseases that affect the spinal cord. The most common limitations that derive from SCI are total or partial paralysis of the lower and upper limbs and of the trunk, respiratory problems, alteration of the autonomic reflexes, reduction in physical capacity, and metabolic disorders[1–3]. SCI can cause a paralysis effect on two (paraplegia) or on the four (tetraplegia) limbs of the locomotor apparatus. Thus, international organizations and agencies defend that this public should practice physical exercises[4,5], and recommendations to increase this population's levels of exercise and physical activity were published in 2018[6]. However, with the advent of the COVID-19 pandemic ("new coronavirus"), people with SCI cannot follow their normal routines, including their regular practice of physical activities, as they are a risk group for the development of respiratory problems[7].

With the orientation to stay at home, it has become necessary to plan physical exercises that can be performed in the home environment, so that people with SCI can at least maintain the recommended physical activity levels. From the point of view of rehabilitation, home-based therapies have been prescribed in recent years[8], with the aims of enabling greater treatment adherence and reducing the chances of hospitalization or even contamination in the hospital environment. Among the activities proposed for the home environment, functional electrical stimulation has been used as a therapy targeted at the maintenance and enhancement of some muscle functions, even in individuals undergoing denervation procedures[9–12], and positive results have been obtained in different aspects of the skeletal muscle tissue.

Taylor et al[13] conducted a preliminary survey of the effects of home-based electrical stimulation therapies. They found positive results for different variables of muscle fitness[14–16] and greater acute responses in cardiologic and hemodynamic indicators[15,17] in people with SCI. It is important to mention that functional electrical stimulation is considered an effective therapy for the rehabilitation of people with spinal cord injury, especially to improve functional aspects of the paralyzed muscles. Similarly, other devices can be produced by means of open source technologies, which facilitates their use in periods of confinement. Some examples are compact dynamometers[18] or localized muscle resistance equipment[19]. Due to access difficulties related to the use of electrical stimulation devices at home, it is necessary to gather information on the effectiveness of other therapies and types of physical exercises, in order to provide greater accessibility and improve the effectiveness of their utilization in people with SCI.

In addition to traditional exercise strategies, other approaches can be included in physical training and rehabilitation routines at people's homes, a fact that increases motivation for practice and apparently enables this population to achieve important adherence levels. Home-based physical training for this population can incorporate different actions, given the logistic limitations of access to tools or even due to the health and functionality conditions that people with SCI may have. Thus, we consider that physical training is a complex attribute that can incorporate systematized and controlled actions of muscle, joint or cardiopulmonary overload in individuals, as well as use kinesiologic and technological resources to increase energy expenditure, similar to actions aimed at increasing the level of habitual physical activity.

Previous studies have proposed that video games and similar devices can guarantee higher adherence and motivation levels in exercise and rehabilitation programs[20–22]. However, as far as we know, no review studies have been published so far demonstrating the effects of home-based therapies on variables related to the health of people with SCI. In a complementary fashion, no reviews in progress have been registered about the theme, not even in the current context of the COVID-19 pandemics. Therefore, this systematic review aims to contribute to the organization of activities performed in the home environment, either for rehabilitation, treatment, or for improving the physical conditioning of people with SCI.

The question that guides this systematic review is: What are the effects of home-based physical exercise on the health of people with SCI? For the purposes of this review, we understand health as a generic term that encompasses different aspects of the daily life of the person with SCI. Thus, we consider that the aspects of this population's health are those related to the morphological, motor neuron, functional and quality of life dimensions. This review is justified by the need to plan home activities for people with SCI during the current period of confinement and by the number of researchers who defend and prescribe activities to be performed at home. Therefore, the study aimed to carry out a systematic review of intervention studies with the purpose of: a) investigating the effects of home-based interventions with physical exercises and/or physical activities on the general health of people with spinal cord injury, emphasizing aspects of individuals' physical fitness and functionality; b) analyzing the characteristics of the interventions and the health dimensions addressed by the interventions in this population.

Methods

The design of this review followed the presuppositions established by the COCHRANE collaboration[23]. The items contained in this review were formulated according to the criteria recommended by the PRISMA initiative[24]. The present review is registered in the PROSPERO platform under the code "CRD42020197607". A search strategy was used to identify possible studies. First, sensitive searches were performed in five electronic databases: PubMed, ScienceDirect, SPORTDiscus, Scopus and Cochrane CENTRAL. The search was performed without adding data limits and was closed in June-July 2020. The research strategies included the combination of two blocks of descriptors and terms: #1: "spinal cord injury", OR "paraplegic", OR "tetraplegic", #2 "home-based", OR "exercise", OR "video game", OR "home-based physical activity". The two blocks of synonymous terms were combined by the Boolean operator "AND" as search mechanisms. In addition, new searches were made in the list of references of the selected articles. Finally, systematic reviews about similar themes were consulted so that we could find other studies to include in this review.

The review included studies that: a) were published in English, Portuguese or Spanish, due to the linguistic limitation of the research team; b) included in the sample adults (>18 years of age) who suffer from spinal cord injury, with diagnosis of paraplegia or tetraplegia; c) employed a physical activity or physical exercise program in the home environment, with or without professional supervision. Any strategy for the implementation of physical exercises or physical activities performed at home, with supervision by health professionals and establishment of minimum characteristics to the activities/exercises, such as type, frequency, volume and intensity, was considered an intervention program; d) described interventions with duration of four weeks or more; and e) investigated some effect (pre and post, with or without a control group) on morphological, motor neuron, functional and quality of life variables of the people submitted to the intervention period at home, considering their implications to the individuals' general health. On the other hand, the following studies were excluded from this review: a) case studies or original studies with small sample sizes (n < 4 participants); b) studies whose intervention was carried out both at home and at laboratories, parks or gyms. Control conditions were considered any type of activity/therapy different from the one being tested in the referred study. Articles describing studies without control groups were also included. Similarly, studies with different designs were also included in this review, like randomized clinical trials, controlled clinical trials, pragmatic clinical trials, experimental studies and quasi-experiments.

The articles' titles and abstracts were digitalized and duplicated articles or articles outside the scope of this study were excluded. The studies were included if they had been published or were in press before the date of the search. The full versions of the studies were recovered and analyzed according to the exclusion criteria presented above. The extraction of the main pieces of information of each article followed the criteria established by the PICO strategy. Data referring to study design, sample size, participants demography (type of injury, age and sex), characteristics of the intervention and of its control (duration, frequency and intensity), outcome measures of the analyses and statistical results, type of intervention and its progression over time were extracted and analyzed. One researcher was responsible for searching and extracting the studies' data and another one, more experienced, was in charge of supervision, confirming the results and consulting references and the "grey literature". In the case of conflicts of information, divergences would be solved by a third evaluator, who coordinated the entire research.

The studies were evaluated concerning risk of bias by means of specific evaluation criteria (Table 1) based on the study carried out by Saw et al.[25]. The scale is composed of six items that assess characteristics of intervention protocols with exercises. Scores were attributed depending on how well each criterion was met. The maximum score was 10 (low risk of bias). Studies whose score in the bias evaluation was 5 or less were considered poor and their contribution to the results was weighed. This tool has been used in previous review studies and in the context of physical activity adapted to people with disability[25,26].

Due to the heterogeneity of the studies, specifically the heterogeneity of the outcome measures used in the investigations included in this review, we did not conduct a meta-analysis. Thus, the articles were analyzed by means of a narrative synthesis that emphasized the main characteristics of individuals, interventions and their main findings, as well as limitations and practical implications that could be associated with the methods of intervention with home-based physical activities for people with spinal cord injury.

Table 1 – Evaluation criteria of the risk of bias.

	Criteria	Definition	Score		
			0	1	2
A	Peer reviewed	Study published in a peer-reviewed scientific journal	No	Yes	-
B	Number of participants	Number of participants included in the study	<5	6-30	>31
C	Characteristics of participants	Age, sex, time since injury, sports modality, frequency/level of training, etc.	No	Partially	Yes
D	Division into groups	Study presents a control group or groups with other disabilities for comparison of outcomes	No	Yes	-
E	Experimental design	Study's procedure/ experimental design is presented and replicable	No	Partially	Yes
F	Physical exercise indicators	Information about intensity, volume, frequency and modality of the physical exercise is presented and described in the study	No	Partially	Yes

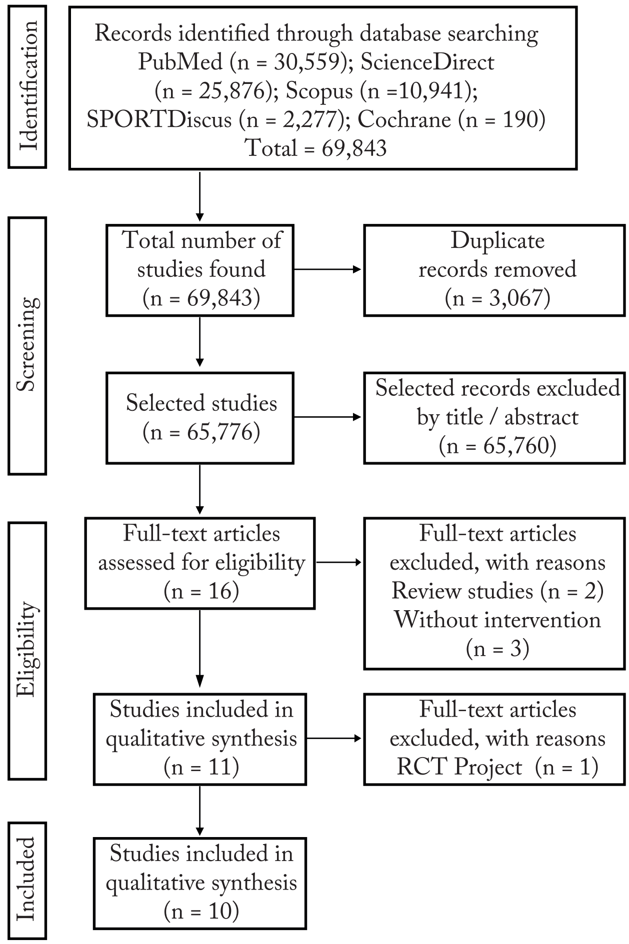

Figure 1 – Flowchart of the search of the included articles according to the PRISMA recommendations.

Results

The entire search strategy, the design and treatment of the results found by means of databases are shown in the flowchart presented in Figure 1. After applying the inclusion/exclusion criteria, 10 studies complied with the presuppositions of the present investigation. Analyzing the general characteristics of the included studies, we found ages that varied from 18 to 74 years and durations that ranged from 8 to 96 weeks. Analyzing the types of intervention proposed in the studies, it was possible to see three large groups of methods/ therapies. In an arbitrary way and considering the characteristics of the equipment used in the interventions, we can group the studies in the following way: a) exercises combined with functional electrical stimulation (n = 4 studies); b) exercises with locomotion assistive devices without functional electrical stimulation (n = 5); and c) stretching/strengthening exercises without electrical and electronic devices (n = 1). Considering the possible outcome variables to be analyzed, we found four areas of study that evaluate the effects of interventions with home-based exercises on the motor neuron (n = 4), morphological (n = 2), functional (n = 5) and quality of life (n = 5) dimensions.

Table 2 presents, according to the PICO strategy, information related to sample of subjects, type (level) of injury, participants' ages and sexes, the type of intervention and its duration. Considering the 10 studies included in the present review after the application of the inclusion criteria, we found that a total of 153 individuals were submitted to home-based interventions: 25 women (16.3%) and 128 men (83.7%). Regarding subjects' type of injury, 118 individuals (78.5%) were classified as paraplegic (injuries in the thoracic, lumbar and sacral areas) and only 33 subjects (21.5%) were classified as tetraplegic. In two studies, 4 subjects suffering from similar pathologies not characterized as a traumatic injury were added to the paraplegic group.

When we analyzed the final scores in the evaluation of the studies' methodological quality, we observed that none of the investigations obtained the maximum score (10 points) nor were classified as having a high risk of bias (scores lower than 4 points), as their scores ranged between 5 to 8 points. The lowest scores were related to studies using the electrical stimulation technique[14,27–29] and those using gait simulators[30], robotic gloves as aids for activities of daily living[31], and virtual reality devices[32]. On the other hand, the studies conducted through

Table 2 – Characteristics of participants with spinal cord injury treated with home-based physical training.

Studies (Authors)	Sample (n)	Type of disability (site of injury-level)	Sex	Age (years)	EMQ
Gorgey et al.[28]	5	Spinal cord injury (C5-L2) PP: n = 4; TP: n = 1	M = 5	18-50	5.00
Kern et al.[14]	25	Spinal cord injury (T5-L1) PP: n = 20; TP: n = 5	M = 20 F = 5	20-55	6.00
Kern et al.[27]				20-55	6.00
Dolbow et al.[29]	17	Spinal cord injury (C4-T11) PP: n = 6; TP: n = 11	M = 15 F = 2	22-64	6.00
Villiger et al.[32]	12	Spinal cord injury (C4-L3) PP: n = 6; TP: n = 6	ND	41-74	7.00
Van Straaten et al.[19]	16	Spinal cord injury (C6-T8) PP: n = 15; TP: n = 1	M = 13 F = 3	18-65	8.00
Osuagwu et al.[31]	15	Spinal cord injury (C2-C5) PP: n = 11; TP: n = 4	M = 11 F = 4	33-60	6.00
Nightingale et al.[33]	21	Spinal cord injury (< T4 and below) PP: n = 21	ND	18-65	8.00
Rupp et al.[30]	25	Spinal cord injury (ND) PP: n = 20; TP: n = 5	M = 14 F = 11	ND	6.00
Ballaz et al.[35]	17	Spinal cord injury (T3-T12) PP: n = 15; SLD: n = 2	ND	35-62	8.00

n = number of subjects; EMQ = evaluation of methodological quality; ND = non-declared; M = male; F = female; PP = paraplegia; TP = tetraplegia; SLD (Strümpell-Lorrain disease) = neurodegenerative disease, genetically and clinically heterogeneous, characterized by progressive hyperreflexia and spasticity of the lower limbs.

the performance of strengthening/stretching activities[19] and using passive cycling[33] obtained better scores, showing greater accessibility for the targeted public.

Table 3 presents information on the studies' design and main outcomes and Table 4 presents the progression of the proposed interventions. It is possible to see that the frequency of exercises varied from 2 to 7 days a week, and the volume of sessions ranged from 4 to 48 sessions lasting 30 minutes to 4 hours. Analyzing the interventions' expected outcomes, we found that the majority of the studies focus on neuromuscular issues, like the function and morphology of the stimulated muscle groups. The rest of the investigations approached effects on quality of life, cardiovascular and hemodynamic responses to the exercise, specific motor capacities, self-efficacy and adherence to the program of exercises. It is important to mention that only one investigation[30] presented adverse effects related to the emergence of a pressure sore on the big toe, caused by a home-based program of exercises. This negative effect was the only one in a total of 800 days of intervention. Generally speaking, the interventions focused on strength and muscle size gains in the lower limbs affected by the paralysis, hemodynamic responses to the training protocols, intervention adherence parameters, locomotion motor functional outcome variables and activities of daily living, and aspects related to quality of life.

Discussion

This review aimed to present the scientific literature about effects of home-based programs of exercises and physical activities, to indicate the main intervention areas on which the programs concentrate, and to show the most frequent benefits of home exercises in individuals with SCI. Our findings show studies conducted with assistive and electronic devices, most of which present positive results regarding neuromuscular aspects and those related to health and quality of life. Only one study out of 10 was carried out with the use of resistance bands to improve the muscle and joint function of people with SCI, focusing on the shoulder joint.

Due to the heterogeneity of the selected studies and the small number of controlled and randomized trials, we decided to summarize the outcomes of the interventions according to the type/mode of exercise that was used. It is important to mention that the heterogeneity can derive from the search method that we used, which did not include, as a comparing criterion, the type of intervention employed in the studies. Therefore, the studies were divided into three sessions, discussed below: a) exercises combined with electrical stimulation therapies; b) therapies using assistive technologies, virtual reality and cycle ergometers; and c) exercises using resistance bands targeted at the shoulder joint.

Table 3 – Characteristics of the interventions and analyzed variables related to general health.

Study	Training protocol	Duration (weeks)	Frequency (days per week)	Session volume (min)	Main outcomes			
					Motor neuron variables	Morphological variables	Quality of life variables	Functional variables
Gorgey et al.[28]	Functional electrical stimulation	8 weeks	2x per week	16 sessions x 30 minutes	NA	TL: MCSA: Knee extensors (↑13-18%) Hip adductor (↑13%) Knee flexor (↑3%) CL: No significant differences	NA	NA
Kern et al.[14]	Functional electrical stimulation	96 weeks	ND x ±30 minutes	ND x ±30 minutes	Force output (↑1187%)	MCSA of quadriceps (↑35%) Mean diameter of muscle fibers (↑75%)	NA	NA
Kern et al.[27]	Functional electrical stimulation	96 weeks	ND x ±30 minutes	ND x ±30 minutes	NA	Muscle bulk (↑26%) Myofiber size (↑94%)	NA	NA
Dolbow et al.[29]	Cycling with the aid of functional electrical stimulation	16 weeks	2x per week	24 sessions x 40 ± 60 minutes	NA	NA	Program adherence (62.9-71.6%) Associated variables: Sex, age, history of exercise and no pain when exercising	NA
Villiger et al.[32]	Functional activities for lower limbs	4 weeks	2x per week	30-45 min	Lower limb muscle strength (↑ 2.5)	NA	Global perception change ↑	Time up and go (follow-up) (↓1s) Lower limb functional mobility Balance during functional activities (↑ 1.8)
Van Straaten et al.[19]	Stretching exercises for the shoulders	12 weeks	3x per week	36 sessions x ND	Isometric strength: lower trapezius ¾ glenohumeral rotators ¾ glenohumeral abductors ¾	NA	NA	Shoulder pain ↑ Shoulder limitations ↑ Shoulder discomfort ↑ Muscle impulse (trapezius) ↑
Osuagwu et al.[31]	Use of robotic gloves in activities of daily living	12 weeks	7x per week	4 sessions x 4 hours	Palmar grasp ↑ Thumb muscle hypertonia ↑	NA	NA	Tasks of the TRI-HFT test ↑
Nightingale et al.[33]	Moderate intensity arm-crank exercises	6 weeks	4x per week	24 sessions x 44 minutes	NA	NA	EXPG: Health-related quality of life↑ Exercise self-efficacy↑ CG: No significant differences	NA

Study	Training protocol	Duration (weeks)	Frequency (days per week)	Session volume (min)	Main outcomes			
					Motor neuron variables	Morphological variables	Quality of life variables	Functional variables
Rupp et al.[30]	Testing of the MoreGait prototype in robotic gait rehabilitation therapy	8 weeks	4x to 6x per week	32 ± 48 sessions x 30 ± 45 minutes	NA	NA	Reduction in the incidence of adverse events ↑	Walking ability ↑
Ballaz et al.[35]	Passive cycling	6 weeks	6x per week	36 sessions x 30 minutes	NA	NA	NA	EXPG: Hemodynamic response to acute exercise ↑ Hemodynamic values at rest ¾ Mean blood flow velocity ¾ CG: No significant differences

↑ = increase/improvement; ↓ = reduction/worsening; ¾ = maintenance; ND = non-declared; NA = not analyzed; TRI-HFT = Toronto Rehabilitation Institute hand function test; MCSA = muscle cross-sectional area; TL = trained limb; CL = control limb; EXPG = experimental group; CG = control group.

Table 4 – Characteristics of each home-based intervention and its respective progression (control group x experimental group) for people with spinal cord injury.

Study	Characteristics of activities/Duration		Progression	
	Experimental group	Control group	Experimental group	Control group
Gorgey et al.[28]	With subjects sitting in their wheelchairs, a unilateral training of one knee extensor (right or left) muscle group was performed using ankle weights. Each participant performed 3 sets of 10 repetitions. Each exercise training session was conducted for at least 30 min with 2–3 min of resting between each set and 5 s between each repetition.	The untrained knee extensor served as a control.	ND	ND
Villiger et al.[32]	Virtual representations of the feet and legs were controlled through sensor nodes attached to the subjects' lower limbs. All the participants' level of injury allowed a minimal voluntary movement of the feet. Participants were trained at home over a period of 4 weeks, with 16–20 sessions of 30–45 minutes each.	NCG	ND	NCG
Van Straaten et al.[19]	A 12-week home-based program with exercises for the rotator cuff and scapular stabilization exercises was provided for each participant. The program included a high dose of 3 sets of 30 repetitions, 3 times per week, and regular supervision of the physiotherapist by videoconference.	NCG	ND	NCG
Osuagwu et al.[31]	Participants were asked to perform a study-defined set of tasks in which they used the glove each day to grasp and release a softball 30 times repeatedly, eat a meal with a fork or spoon, write their name and address and perform activities of daily living.	NCG	ND	NCG
Nightingale et al.[33]	Participants completed 4 moderate-intensity (60%-65% peak oxygen uptake) arm-crank exercise sessions per week for 6 weeks.	Participants assigned to the control group were asked to maintain their habitual physical activity behavior.	ND	ND

Study	Characteristics of activities/Duration		Progression	
	Experimental group	Control group	Experimental group	Control group
Rupp et al.[30]	During the 8-week therapy period, individuals were trained with the MoreGait device (a rehabilitation robot that simulates stationary gait at home) for 30–45 minutes per day, 4 to 6 days per week. Users were instructed to set step frequency at a comfortable level to avoid fatigue during each session. Subjects underwent a 30-minute training period to familiarize themselves with the device. To help isolate the effect of the training device, participants were instructed not to modify their regular physical therapy, unsupervised training program, or antispastic medication during the study period.	NCG	ND	NCG
Dolbow et al.[29]	Cycle parameters were individualized depending on the amount of current needed to perform the cycling activity and depending on the comfort of the participants. Cycling parameters ranged among participants as follows: current amplitude, 70 to 140 mA; pulse width, 250 to 400 Hz; and frequency, 33 Hz. Speed was advanced between 30 and 50 rpm, with an initial resistance of 0.5 Nm. Resistance was set on automatic so that the RT300 cycle would vary the resistance to allow the set speed. Participants and helpers were provided training concerning the placement of electrodes.	NCG	Cycling duration was increased over the 16-week period until a goal of between 40 and 60 minutes of continuous active functional electrical stimulation cycling was attained.	NCG
Kern et al.[14]	Subjects were initially treated with biphasic stimulation impulses of very long duration (120-150 ms, 60-75 ms per phase) and high intensity (up to ± 80 V and up to ± 250 mA) (training program 1). Subsequently, they were submitted to progressions in the stimulation parameters of the training protocol according to subjects' improvement.	NCG	After the first period, the routine daily training consisted of combined twitch and tetanic stimulation patterns (training programs 2, 3, and 4) in consecutive sessions lasting up to 30 minutes for each group of muscles (gluteus, thigh, and lower leg muscles on both sides).	NCG
Kern et al.[27]	Electrical stimulation in the home environment in the quadriceps muscle during 24 months (2 years), with different stimulations from a protocol. The bulk of thigh muscle was estimated by transverse computer tomography (CT) scan and force measurements. Needle biopsies of vastus lateralis were harvested before and after 2 years of functional electrical stimulation.	NCG	During the first 6 months, 3 minutes with 1–2 minute pause; from 6 to 12 months, 20-40 repetitions with 1-2 minute pause; from 12 to 24 months, 20-40 repetitions with 1 minute pause (standing, stepping-in-place and walking); Phase 1, weeks 0–4 = 120–150 ms ID / 400 ms IP; 4 second SD / 2 second SP (3-4 6 3 minutes with 1-2 minute pause; 5 days / week); Phase 2, weeks 2-6 = 70–100 ms ID / 400 ms IP; 5 second SD / 2 second SP (4-5 6 3 minutes with 1-2 minute pause; 5 days / week); Phase 3, weeks 4-12 = 36-50 ms ID / 10 ms IP; 2 second SD / 2 second SP (4-6 6 20–40 repetitions 1–2 minute pause); Phase 4, weeks 8–24 = 36 ms ID / 10 ms IP; continuous stimulation (5 days / week. Standing, stepping-in-place and walking; 4-6 6 20–40 repetitions [1–5 min] 1 minute pause; 5 days / week).	NCG
Ballaz et al.[35]	Participants from the experimental group performed passive cycling exercises at home 6 times weekly for a total of 36 sessions. Except for this training, participants from this group did not change their habit of daily living. The cycle trainer dimensions were adjusted for each person to ensure the greatest range of motion while ensuring the comfort of the participant.	Participants from the control group did not change their habit of daily living.	The duration of the session and the pedaling rate were increased regularly during the first week to reach 30 minutes at 40 revolutions per minute at the beginning of the second week of the training period.	From this group, 2 persons continued to follow a weekly physical therapy session as they had for many years. All other participants had no regular physical therapy.

ND = non-declared; NCG = no control group; ID = electrical impulse duration; IP = impulse intensity; SP = stimulation pause; MoreGait device = a special seat combined with an inclined backrest, a pneumatically driven gait orthosis for each side to assist movements of both legs in the sagittal plane and a dedicated mechanical foot stimulation unit.

Exercises combined with electrical stimulation therapies

Four investigations were carried out with this type of device. Gorgey et al.[28] investigated the feasibility and initial efficacy of telehealth communication in conjunction with muscle resistance training with the aid of surface neuromuscular electrical stimulation in five men with complete spinal cord injury. The knee extensor muscle cross-sectional area increased by 13% ($p = 0.002$) and 18% ($p = 0.0002$), with no changes in the contralateral controlled limb. The muscular areas of the knee flexor and adductor muscles increased by 3% ($p = 0.02$) and 13% ($p = 0.0001$), respectively. The muscular areas of thigh and knee intramuscular fat decreased significantly in the trained limb by 14% ($p = 0.01$) and 36% ($p = 0.0005$), respectively, with no changes in the controlled limb.

Similarly, Dolbow et al.[29], by means of a functional electrical stimulation cycling program, found exercise adherence rates for evaluation periods 1 and 2 of 71.7% and 62.9%, respectively. Age, history of exercise, and no pain when exercising were determined to have significant impact on exercise adherence rates. The authors concluded that exercise adherence rates were well above the reported 35% in the healthy population, which provides evidence for the feasibility of a home-based functional electrical stimulation lower extremity cycling program.

Two studies conducted by the same research group in two different periods with the same intervention found important benefits for muscle characteristics. Kern et al.[14] found a 35% cross-sectional increase in area of the quadriceps muscle (from 28.2 ± 8.1 to 38.1 ± 12.7 cm^2), a 75% increase in mean diameter of muscle fibers (from 16.6 ± 14.3 to 29.1 ± 23.3 mm), and improvements in the structural organization of contractile material. In addition, the authors found a 1187% increase in force output during electrical stimulation (from 0.8 ± 1.3 to 10.3 ± 8.1 Nm).

It is important to mention that the recovery of quadriceps force was sufficient to allow 25% of the subjects to perform stand-up exercises with the assistance of electrical stimulation. The results show that home-based therapy of denervated muscle is an effective home therapy that results in rescue of muscle mass and tetanic contractility. In another investigation[27], the authors found that daily training induced: (a) very similar increases in muscle excitability and contractility in right and left legs; (b) feasibility to elicit tetanic contractions by means of stimulation with about ten times improvement of muscle force; (c) 26% increase in muscle bulk, improving appearance of limbs and muscle cushioning; and (d) myofiber size increase (> 94%). None of the subjects that performed 1 year daily training (20 people) worsened their functional class, while 20% (4/20) improved to functional class 4, that is, the ability to stand.

In short, electrical stimulation has been effective in home-based exercise programs. Even though significant improvements have been observed in different morphological and functional variables of the trained muscles, it is necessary to obtain further information on the indicators to prescribe this type of method and on the intensity of electrical stimulation dosage. It seems that the method can effectively produce beneficial tetanic effects in the majority of the investigated subjects, both in morphology and in muscle function. Some of these findings reiterate the importance of maintaining good levels of muscle strength in this population, especially when we consider activities of daily living like body weight transfers and support[3].

Therapies using assistive technologies, virtual reality and cycle ergometers

Assistive technologies are a set of devices and instruments that emphasize the individual's potential in the rehabilitation process or in their daily routine, and favor their social interaction and reinsertion in society with the best possible quality of life[34]. Five studies were found with similar characteristics. All the studies selected for this topic presented positive results in the health parameters that were evaluated. Ballaz et al.[35] found that, after the planned training, mean blood flow velocity and flow velocity index did not differ significantly in the experimental group compared to the pre-training values. However, in this group, the post-exercise mean blood flow velocity and the flow velocity index are respectively increased and decreased immediately after training ($p < 0.05$) compared with the pre-training values. No changes were noted in the control group.

In addition to lower limb blood flow indicators, adaptations of the cardiovascular system are usually transferred as goals in physical training and rehabilitation programs for people with SCI. Previous studies have shown positive results when programs are conducted in controlled environments[36,37]. Devices like arm ergometers are normally used, or even wheelchair accessible treadmills[36,38].

However, our investigation did not find home adaptations of devices of this type. It seems that the transport and accessibility conditions of homes, even in regions with better socioeconomic conditions, continue to be factors that hinder the implementation of more traditional interventions for this particular public. Another aspect that may be related to implementation difficulties is the lack of commercialized portable devices[18] that stimulate larger body movements (upper limbs and trunk) in people with SCI.

In a similar study that used an arm ergometer, Nightingale et al.[33] found changes in the psychological and physical dimensions, while exercise self-efficacy and global fatigue were significantly different between the two groups (experimental and control), presenting moderate to large effect sizes. Various quality of life outcomes showed likely to very likely positive inferences in favor of the experimental group after the 6-week intervention. Furthermore, changes in exercise self-efficacy were significantly associated with changes in psychological profile and global fatigue.

Three of the studies were conducted with the use of devices developed especially for the stimulation of people with SCI. Rupp et al.[30] tested the feasibility of an unsupervised home-based application of five MoreGait® prototypes (devices for passive stimulation of lower limbs as gait aids). After therapy, 9 of 25 study participants improved with respect to dependency on walking aids. For all individuals, the short-distance walking velocity showed significant improvements compared to baseline, as well as average and maximum speed and endurance estimated with the six-minute walk test.

Osuagwu et al.[31] investigated the therapeutic effect of a hand rehabilitation program using a robotic glove. The training based on activities of daily living demonstrated improvement in hand function at week 6 of the intervention, including improvement in object manipulation and palmar grasp (assessed as the length of the wooden bar that can be held using a pronated palmar grip). A significant improvement in pinch strength, with reduced thumb muscle hypertonia, was also detected. Function improvements were present during the week 12 assessment and also during the follow-up.

Finally, Villiger et al.[32] tested if virtual reality training at home (unsupervised) is feasible with subjects with incomplete SCI. At post-assessment (immediately after treatment), high motivation and positive changes were reported by the subjects. Significant improvements were shown in lower limb muscle strength, balance and functional mobility. At follow-up assessment (2–3 months after treatment), functional mobility remained significantly improved in contrast to the other outcome measures.

Functionality aspects are extremely important to the quality of life of people with SCI. Up to the present date, there has been no consensus regarding the indicators that can best represent the actions of greatest predominance over the functional health of this population. Nowadays, protocols of ability and movement in the subjects' wheelchairs are accepted, and even a set of functional reach movements in different directions is preferable to existing protocols for people with no disability or motion impairment[39–41]. However, we could not find any studies showing the effects of home-based exercise/physical activity programs on some of these parameters.

Exercises using resistance bands targeted at the shoulder joint

The scientific community is greatly concerned about the discomforts caused by the movement of propulsion in manual wheelchairs, especially on the shoulder joint[42,43]. Only one study[19] tested the effectiveness of a high-dose home telerehabilitation program for people with SCI, determining whether the intervention would reduce pain and increase function. The home exercise program lasted 12 weeks, with exercises for the rotator cuff and scapular stabilization exercises for each participant. The program included a high dose of 3 sets of 30 repetitions, 3 times per week. Pain was reduced and function improved after the intervention. There was a significant main effect for pain and function between three time points. The isometric strength measurements of the serratus anterior and scapular retractors increased after the exercise intervention. Muscle impulse produced by the lower trapezius during a fatigue task also improved. No differences were measured in isometric strength for the lower trapezius, shoulder rotators and abductors, all of them belonging to the glenohumeral joint, between the baseline and 12-week time points. These findings corroborate other studies that have already shown improvements in functionality indicators of the shoulders area in people with SCI[43,44].

Generally speaking, we can note that different home-based exercise programs can promote general health benefits in different dimensions of the physical fitness and functionality of people with SCI, depending on the individual's objective and needs. Home therapies are usually chosen in an attempt to ensure participants' adherence. In periods of confinement such as the one we are currently experiencing, guaranteeing the necessary adaptations of these methods for the SCI group seems to be the best course of action for health maintenance, rehabilitation or even for the physical training of this population, so that they can perform the recommended daily amount of physical activity and exercises[6]. Although only two studies[30,32] investigated the effect of electronic devices, we believe that active video games can help to maintain this population's joint motion. Although the effects of such home-based practices have not been investigated, some research findings reinforce their utilization[20,45,46].

Despite presenting interesting results, the present systematic review has important limitations that must be addressed. The first is the quantity and heterogeneity of the studies that were included in the review, which prevents summarization in the form of a meta-analysis of the interventions' outcomes. Part of this difficulty lies in the very nature of the interventions: the fact that they occur in people's homes denotes particularities pertaining to the disability condition and also to accessibility. Secondly, the scarcity of studies related to the Brazilian population is also cause for concern, due to the distance of the findings in times of social confinement and to the need of establishing conditions for maintaining the rehabilitation of people with spinal cord injury in different regions of Brazil. Finally, the heterogeneity of the studies did not allow us to perform a more accurate assessment concerning the level of evidence of the set of findings pertaining to each study.

Respecting individualities and, especially, the social distancing rules, as well as the disinfection of devices and places of practice, we believe that physical exercise performed at home has a fundamental importance for the maintenance and gradual return to the daily activities of people with SCI, mainly in the muscle and joint aspects. However, data related to immunosuppression and control of other morbidities related to this population, such as autonomic dysreflexia, have not been investigated in home-based exercise programs. Thus, we believe that the same care provided at any time in relation to these morbidities should be constantly maintained. Finally, we recommend that any decisions in this area should be supervised by professionals capable of choosing the best approach to the physical training of this population, specially physiotherapists and physical education professionals.

To conclude, we could ascertain that home-based exercise promotes beneficial effects to the health of people with SCI. When we analyzed the parameters approached in the studies, we found that the muscle (function and morphology), functional, quality of life and neuromuscular parameters of this population are strongly influenced by electrical stimulation techniques, by the use of assistive devices and by simpler interventions like the use of resistance bands for strengthening. From the clinical point of view, we recommend that the strategies used for home training, either through exercise or by increasing the level of physical activity, should be supervised by physical education professionals or by therapists, in face-to-face or remote sessions. The choice of the technique/method must be in accordance with the individuals' need and take into account availability/accessibility to the equipment. If the objectives are related to the neuromuscular or functional dimensions of patients with SCI, we believe that various techniques can be employed, even low-cost ones. Finally, different stimuli can provide benefits for the health of people with spinal cord injury; however, it is necessary to obtain scientific information by means of controlled trials, mainly considering subjects' accessibility conditions, so that their direct and indirect effects are pondered with better methodological quality and, consequently, better levels of evidence.

Conflicts of interest

The authors declare no conflict of interest.

Authors' contribution

Oliveira L, Costa M, Perrier-Melo R, Simim M and Oliveira S participated in the initial conception of the study and in the writing and critical review of the text. Oliveira J was responsible for searching the literature and collecting data.

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