REVIEW

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Strength training protocols in hemiparetic individuals post stroke: a systematic review

Protocolos de treinamento de força em hemiparéticos após acidente vascular cerebral: revisão sistemática

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Abstract

Introduction: Hemiparesis is one of the main sequels of stroke. Evidence suggests that muscle strength exercises are important in rehabilitation programs for hemiparetic patients, but wide variation in previously studied protocols makes the most suitable choice difficult in clinical practice. **Objective:** The aim of this study was to investigate strength training protocols for people with hemiparesis after stroke. **Methods:** A systematic review of literature was performed in the PubMed, PEDro (Physiotherapy Evidence Database), SciELO (Scientific Electronic Library Online), and LILACS (Latin American and Caribbean Literature in Health Science) databases. Only controlled clinical studies that contained strength training protocols for hemiparesis after stroke were selected. **Results:** In total, 562 articles were found. Of them, 12 were accepted for the systematic review. Although strength training protocols are effective in hemiparetic patients, we did not found a standard method for strength training. **Conclusion:** This systematic revision highlights the lack of a standard protocol for strength training, considering the following training parameters: volume, intensity, frequency, series, and repetitions. Isotonic exercises are most commonly used.

Keywords: Exercise. Paresis. Muscle Strength. Stroke. Strength training.

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Resumo

Introdução: *A hemiparesia é uma das principais sequelas do Acidente Vascular Cerebral (AVC). Evidências recentes sugerem que o treinamento de força (TF) é um método eficiente para ganho de força na população hemiparética, porém, a grande variação de parâmetros dentre os numerosos protocolos disponíveis tornam difícil a escolha do protocolo mais adequado a ser utilizado na prática clínica.* ***Objetivo:*** *Investigar e analisar os protocolos de treinamento de força (TF) para população hemiparética pós-AVC.* ***Métodos:*** *Foi realizada uma revisão sistemática da literatura, nos bancos de dados PubMed; PEDro (Physioterapyevidencedatabase); SciELO (Scientific Eletronic Library Online); LILACS (Literatura Latino-Americana e Caribe em Ciências da Saúde). Foram selecionados apenas estudos clínicos controlados que trouxessem protocolos de TF em paciente pós-AVC hemiparéticos.* ***Resultados:*** *562 artigos foram encontrados destes, 12 foram incluídos na revisão sistemática. Apesar do TF ser efetivo para pacientes hemiparéticos, não se observa um protocolo padrão para aplicação dessa intervenção na população hemiparética pós AVC.* ***Conclusão:*** *essa revisão sistemática alerta para a falta de padronização dos protocolos em relação ao volume, intensidade, frequência, séries e repetições de treinamento. Os exercícios isotônicos são os mais utilizados.*

Palavras-chaves: *Exercício. Paresia. Força Muscular. AVC. Treinamento de Força.*

Introduction

Stroke is one of the major causes of hospitalization and mortality worldwide. In 2013, there were nearly 25.7 million stroke survivors, 6.5 million deaths from stroke, and 10.3 million new cases of stroke, with a more pronounced increase in the incidence and prevalence of ischemic stroke after the age of 49 and 39 years, respectively, in developed countries [1]. In Brazil, 160,621 hospital admissions for cerebrovascular diseases were registered in 2009. The mortality rate was 0.05%, and almost 35% of the 99,174 deaths occurred among patients who were over 80-years-old [2].

Stroke patients may exhibit sensorimotor deficits that limit the performance of functional activities such as gait, orthostatism, and sit-up [3] tasks. These affect the mobility of patients, limiting their daily activities, society intervention, and the probability of returning to professional activities, leading to reduced quality of life [4]. Paresis is defined as the change in the ability to generate normal levels of muscle strength and manifests in different forms, including paresis of the contralateral body and brain injury (hemiparesis) [5 - 7]. Muscle weakness seems to be one of the factors responsible for functional limitation in individuals with stroke [8].

Physical rehabilitation is the most effective way to reduce motor deficits in stroke patients [4] and many therapies are proposed [9 - 15]. Strength/resistance training (ST) in stroke rehabilitation was rejected for a long time because of it supposedly inducing spasticity [4, 6]. However, it appears to be an essential part of rehabilitation programs in patients with brain injury [4]. In this context, a recent meta-analysis concluded that ST is the most efficient method for gaining strength in the lower limbs in hemiparetic populations [7]. Another systematic review indicates that muscle strengthening exercises can be integrated as a post-stroke rehabilitation strategy to improve upper limb motor deficits [4]. Furthermore, ST produces increased strength, gait velocity, functional outcomes, and quality of life without exacerbating spasticity after stroke [6].

However, the authors of this study, as well as the others [6], observed a large variation in training parameters/protocols in studies that performed ST in hemiparetic patients, making it difficult to choose these parameters in clinical practice. Thus, the current study aimed at investigating and analyzing the ST parameters/protocols for post-stroke hemiparetic patients.

Methods

Inclusion/exclusion criteria

Study types

Controlled experimental randomized clinical trial studies were considered. Studies with case series/

case report design, bibliographic reviews, and uncontrolled experimental studies were excluded. Furthermore, conference abstracts as well as studies falling outside the methodology investigated in this review were disregarded.

Type of participants

Study samples should include stroke patients of both genders and with no age and time of diagnosis restrictions. The classification of tonus (hypotonia or hypertonia) exhibited by study patients was not considered. Studies including patients with other neurological pathologies associated with stroke were excluded.

Type of intervention

The type of training accepted in this review included protocols that used, for instance, equipment (leg press, extender, flexor, high pulley, adductors, and hip abductors) and free weights aimed at strengthening the upper and lower limbs. Training protocols included isokinetic, isotonic (eccentric and concentric), and isometric exercises.

Type of outcome measured

Primary outcome: intervention protocols that include the description of exercises with weights, volume, intensity, and frequency of training.

Search methods

Data sources

The search for articles was performed between August 1 and September 30, 2016 in the following electronic databases: MEDLINE, PubMed, LILACS (*Latin American and Caribbean Literature in Health Science*), Cochrane, SciELO (*Scientific Electronic Library Online*), Manual Search, and PEDro (*Physiotherapy Evidence Database*). Studies published before September 2016, were considered.

Period and language

No date and language restrictions.

Search Keywords

Keywords are described in Table 1.

Table 1 - Search strategies for retrieving articles

DATABASE	KEYWORDS
SciELO	(acidente vascular encefálico OR paresia OR acidente vascular cerebral OR AVC) AND (exercício OR treinamento OR força)
PubMed	(stroke OR hemipar*) AND (“strength training” OR “resistance training”)
LILACS	(Stroke OR Paresis) AND (exercise OR resistance training)
Cochrane	(stroke OR cerebrovascular accident OR paresis) AND (exercise OR resistance training OR strength training)
PEDro	“stroke” “resistance training”

Note: PEDro (Physiotherapy eEvidence Ddatabase); SciELO (Scientific Electronic Library Online); LILACS (Latin American and Caribbean Literature in Health Science).

Data Collection and Analysis

Study selection

After exclusion of duplicates, two reviewers (D.B and M.T.R) evaluated the titles and abstracts of the identified references based on the inclusion and exclusion criteria; in a case of a conflict, a third reviewer was consulted (V.S.H). Clearly irrelevant references were excluded. In the second phase, the reviewers assessed the full text and selected the references based on the same inclusion and exclusion criteria.

Data collection process

The same reviewers read the articles and collected the data according to a previously prepared table (see *collected items*).

Collected items

The items extracted from each study were: author/year, population and experimental groups, exercise types, frequency, volume, intensity of the training, outcomes evaluated by the authors of the studies, and the results.

Quality assessment of the included studies

The evaluation of the methodological quality of included studies was performed according to the PEDro scale [16 - 19].

Results

Selection of studies

Figure 1 represents a flowchart of search methods for identification and selection of studies. A total of 562 articles were found in the databases, of which 515 were excluded based on the title and abstract. Full text reading of the remaining studies led to the exclusion of another 35 articles, which did not meet the inclusion criteria, because they were not controlled studies, omitted the training protocols, or included another type of protocol combined with ST. A total of 12 articles were included in this review.

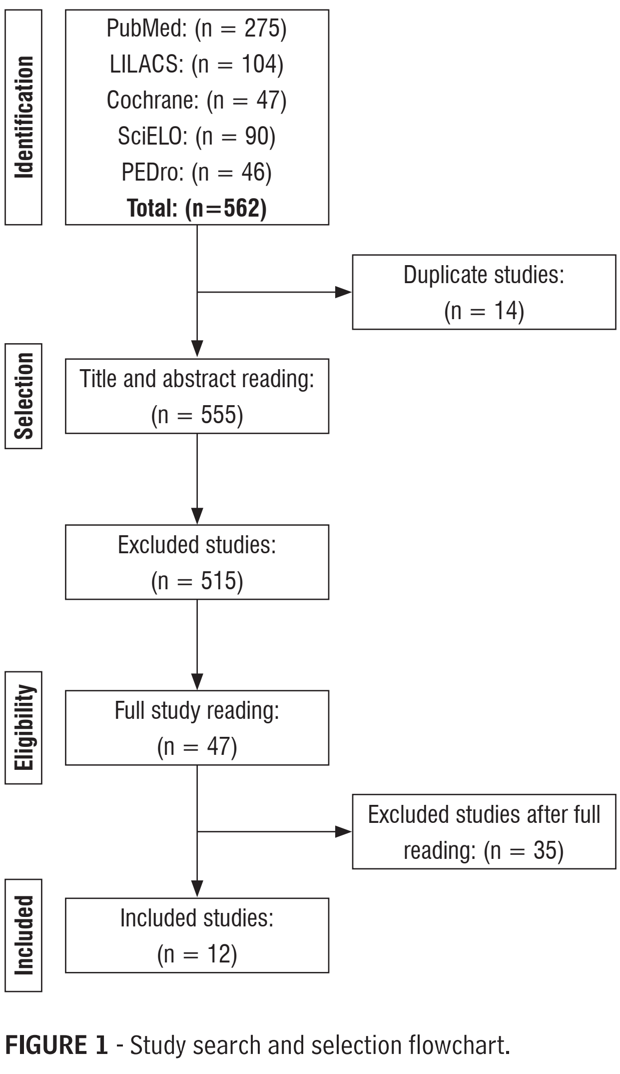

FIGURE 1 - Study search and selection flowchart.

Characterization of the studies

The characteristics of the included studies are presented in Table 2. The studies found that ST is a valid therapy for strength gain in hemiparetic patients. The considered studies involved a total of 371 patients, who were allocated to different intervention groups and controls: control (e.g., range of motion exercises, flexibility exercises, maintenance of daily routines), *sham* control, aerobic exercises, and task oriented training.

All studies (12/12; 100%) included ST of the lower limbs, while a single study included ST of the upper limbs. With respect to the muscle groups exercised, those with greater incidence were the knee extensors, plantiflexors, and dorsiflexors. Regarding the exercises used, knee extension and/or flexion (8/12; ~ 66%), leg press (6/12; 50%), and ankle flexion and/or extension (6/12; 50%) were the most studied. Regarding the number of sessions per week, only two out of 12 (17%) studies involved five weekly sessions; the other studies involved two or three sessions per week. Concerning duration, six (50%) studies covered a period between 10 to 12 weeks, four (~ 33%) studies involved six weeks, and two (~ 17%) studies were less than six weeks long.

Regarding the intensity of ST, the mean intensity used was between 70% and 80% of a maximal repetition (1MR). This review also included two studies that analyzed the differences between the benefits associated with eccentric and concentric ST, using maximum repetitions as intensity grading; the remaining studies involved isotonic exercises.

The studies considered in this review exhibit a great variety of outcomes and evaluation tools. Examples include: dynamometry, timed up and go, six-minute walk test, stair climbing test, sit and stand up test, isokinetic strength, walking speed, FC Peak and peak VO_2, 1MR, quality of life, balance, scales used to monitor perception of effort, electromyography (EMG), and force platform. All studies reported beneficial results associated with ST regarding different outcomes.

Table 2 - Characterization of the studies according to the analyzed outcomes

Author (year)	Groups	Type of Exercise	Training Volume	Intensity	Frequency	Outcome	Result Conclusion
1. Mi-Joung Lee, et al [20] Year: 2008	ATG n = 13 STG n = 13 ATG + ST n = 14 GC n = 12	Knee extension and flexion and plantar flexion (pneumatic resistance); adductors and abductors (free weights) and dorsiflexion (isometric training).	12 weeks	50% of 1 MR After 2nd week 80% of 1MR	2 × per week	Strength (dynamometry and stair climbing test) and cardiorespiratory fitness (peak FC and peak VO2 max)	Training improved the VO2 max, climbing stairs performance, and strength of individuals with stroke.
2. Michelle M. Ouellette, et al [21] Year: 2004	GC n = 21 STG n = 21	Leg press (bilateral), knee extension, plantar flexion, and dorsiflexion.	12 weeks	3 sets of 8-10 repetitions 70% of 1 MR Adjusted after 15 days by a new MR test	3× per week	6mWT, stair climbing and TSL test and gait speed	ST improved strength in the paretic and non-paretic lower end after stroke and reduced functional limitations and disabilities.
3. Rodrigo Fernandez Gonzalo et al [22] Year: 2016	GC: n = 16 STG n = 16	Leg press unilateral (paretic member) with emphasis in eccentric contraction.	12 weeks	4 sets of 7 MR	2 × per week Recovery period of at least 48 h between sessions	Strength (load cell; TUG) and balance (Berg scale)	Muscle power, gait performance, and balance increased in the STG.
4. David J. Clark, et al [23] Year: 2013	STG eccentric n =18 STG concentric n =17	Knee extension and flexion; hip abduction, plantar flexion, and dorsiflexion; and a multistage task involving the hip, knee, and ankle.	5 weeks	3-4 sets of 10 repetitions	3 × per week	Strength (isokinetic dynamometry)	The results of this study support the hypothesis that eccentric exercise is more effective than concentric exercise for neuromuscular activation in patients post-stroke.
5. Ulla-Britt Flansbjer, et al. [5] Year: 2008	STG n =15 GC n = 9	Knee extension and flexion.	10 weeks	2 series of 6-8 repetitions plus 2 sets with maximum repetitions 80% 1 MR Adjusted every 2 weeks (4x during the training period)	2× per week	Strength (isokinetic dynamometry) and TUG	The strength of the paretic limb significantly increased in the STG.
6. Severinsen K, et al. [24] Year:2014	ATG n = 13 STG n = 14 GC n = 16	Knee extension, leg press, hip extension flexion; dorsiflexion and plantar flexion.	12 weeks	3 series of 8-12 repetitions 70% - 80% of 1 MR	3 × per week	6mWT; 10mWT; V02 peak and strength (dynamometry)	Muscle strength increased after ST and was preserved after one follow-up.

(To be continued)

(Conclusion)

Table 2 - Characterization of the studies according to the analyzed outcomes

Author (year)	Groups	Type of Exercise	Training Volume	Intensity	Frequency	Outcome	Result Conclusion
7. Felipe José Aidar et al. [25] Year: 2016	STG n = 11 GC n = 13	Bench press, horizontal leg press, development, abdominal exercise, high pulley, and lunge squat.	12 weeks	3 sets of 8-10 repetitions with the same intensity of 3-5 (according to the OMNI scale)	3 × per week	Strength (1MR)	The results indicated an improvement in strength measures in the STG (post-stroke patients).
8. Sung Min Son, et al. [26] Year: 2014	STG n = 14 GC n = 14	Leg press	6 weeks	3 sets of 8-10 repetitions 70% of 1 MR (loads adjusted weekly)	5 × per week	TUG, dynamic balance, and Berg scale	Significant evolution of the STG in the anteroposterior and mid-lateral oscillation distance tests, Berg scale, and TUG relative to the GC.
9.Sami S. Alabdulwahab, et al. [27] Year:2015	STG n = 10 Group Training. Guided Tasks n = 13	STG: isotonic exercises for hip flexors and extensors; knee flexors and extensors; dorsiflexors and plantar flexors. Group Training. Guided Tasks: walk with anklet with 5% of the body weight.	4 weeks	3 series of 10-15 MR	3 × per week	Scales (Cadence, SGS, FGS, WBAL e SIS)	Significant improvements are present in all evaluated aspects of both STG and training of oriented tasks. The results of the latter are more pronounced.
10. Na Kyung Lee, et al. [28] Year: 2013	STG n = 14 GC n = 14	Leg press	6 weeks	3 series of 8-10 repetitions 70% of 1MR Intensity adjusted weekly through the 1 MR test.	5 × per week	Temporal and spatial parameters of gait (electric walkway system)	Increased gait speed and pacing length were present in the STG compared to pre-intervention values in the CG.
11. C. Maria Kim, et al. [29] Year: 2002	STG n = 10 GC n = 10	Hip flexion; knee extension and flexion, dorsiflexion, and plantar flexion.	6 weeks 18 sessions	3 sets of 10 concentric maximum repetitions	3 × per week	Strength (isokinetic dynamometry), walking performance (e.g. gait velocity), and health-related quality of life	Although both groups exhibited enhanced strength after intervention, a tendency of strength improvement in the STG was observed relative to the GC.
12. Margareta Engardt,et al. [30] Year: 1995	STG concentric n = 10 STG eccentric n = 10	Knee extension and flexion (concentric and eccentric)	6 weeks	Growing series from 1 to 15 with 10 repetitions	2 × per week	Strength (isokinetic dynamometry), EMG, weight distribution in sit and lift movements (strength platforms), and gait speed	The extensor strength of the knee increased in both groups. Regarding the strength of the healthy limb, an increase was observed only during eccentric exercise.

Note: n (total number of participants); ATG (aerobic training group); STG (strength training group); GC (group control); MR (maximum repetition); ST (strength training); 6mWT (6-minute walk test); TSL (sit and stand up test); TUG (timed up and go); 10mWT (10 meters walk test); OMNI (OMNI resistance exercise scale); SGS (slow gait speed); FGS (fast gait speed); WBAL (weight bearing on affected limb); SIS (stroke impact scale); EMG (electromyography).

Methodological Quality of the Studies

Table 3 (supporting information) represents the evaluation of the methodological quality of the studies, which was performed according to the PEDro scale. The results showed an average score of 5.42 points. There was greater score loss in the studies in item three (allocation omission), item five (participants blinding), item six (therapist blinding), and item nine (intention-to-treat analysis). No study reached the maximum score.

Supporting information

Table 3 – PEDro scale

Author (Year)	1	2	3	4	5	6	7	8	9	10	11	PEDro Score
1. Mi-Joung Lee, et al. (2008)	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	yes	8/10
2.Michelle M. Ouellette, et al. (2002)	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	yes	7/10
3.Rodrigo Fernandez Gonzalo et al. (2016)	Yes	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes	6/10
4. David J. Clark, ScD et al. (2013)	Yes	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes	6/10
5. Ulla-Britt Flansbjer, et al. (2008)	Yes	Yes	No	Yes	No	No	Yes	Yes	No	Yes	Yes	6/10
6.Severinsen K, et al. (2014)	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5/10
7. Felipe José Aidar et al. (2016)	Yes	Yes	No	Yes	No	No	No	No	No	No	Yes	3/10
8. Sung Min Son, et al. (2014)	Yes	Yes	No	Yes	No	No	No	No	No	Yes	No	3/10
9. Sami S. Alabdulwahab, et al. (2015)	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5/10
10. Na Kyung Lee, et al. (2013)	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4/10
11. C. Maria Kim, et al. (2002)	Yes	Yes	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes	7/10
12. Margareta Engardt, et al. (1995)	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5/10
Average (SD) PEDro Score: 5.42(1.56)/10												

Note: Criteria: 1) eligibility; 2) random allocation; 3) allocation omission; 4) baseline comparison; 5) blinding to participants; 6) blinding to therapists; 7) blinding to evaluators; 8) adequate follow-up; 9) intention-to-treat analysis; 10) comparison between groups; 11) estimation of effect and variability.

Discussion

This systematic review aimed at identifying ST protocols in hemiparetic individuals. Twelve controlled clinical trials that tested ST in hemiparetic patients were included. All studies considered in this review showed that ST increased muscle strength in hemiparetic individuals relative to their controls, although no standard protocol was found for this intervention.

The ST program exhibits some variables that form the basis of any method: intensity percentage, volume of exercise (number of sets, repetitions, and exercises), frequency, type of exercises, and training structure [31]. The average load percentage found in this study was 75%. In this context, Kraemer and Ratamess [32] reported that exercises performed with 70-80% of the maximum load induce a change in strength. Nonetheless, different authors report positive results with workloads between 50% and 80% of 1MR and with 40% loads already showing positive results with regards to muscle strength enhancement [33]. This technique of load percentage definition is widely recognized as a reference standard for the evaluation of muscle strength [34]. Although the data resulting from this review showed that there was no defined ST protocol for hemiparetic patients, all the studies used a load percentage within the recommended ideal values for strength gain.

Although it was not one of the factors of analysis of this study, it should be emphasized that all studies selected included hemiparetic patients six and nine months after the cerebrovascular event. This time period is consistent with that of the study by Teixeira et al. [35], which reported an improvement in physical activities after a training period involving bodybuilding strengthening exercises.

In addition, it was observed that the selected articles aimed at studying the lower limbs. Only the study reported by Aidar et al. [25] involved both the upper and lower limbs. Among the most studied exercises are knee extensors and flexors, hip flexors, plantar flexors, and dorsiflexors, while bench press exercises are the most common for the upper limbs. These exercises may contribute to walking in these individuals, since gait training is one of the main goals in functional rehabilitation after stroke [36].

Among the studies analyzed in this review, the type of exercise used by ~ 92% of the studies was isotonic. Only two studies [22, 23] aimed at measuring differences between eccentric and concentric contractions. The skeletal muscle system produces less strength in concentric contraction when compared to eccentric contraction in post-stroke patients submitted to ST, and in this context, the eccentric exercise has been shown to be more effective in neural adaptations [23].

The studies included in this review exhibit a great variability of outcomes and evaluation tools. Muscle strength was assessed using dynamometry [20, 23] and functional tests (functional capacity) such as the timed up and go test, which measures the time (seconds) it takes for an individual to stand up from a standard armchair (about 46 cm in height), walk a distance of 3 m, turn around, walk back to the chair, and sit again [37]. Another common functional test was the six-minute walk test, which has been recommended and used in evaluating the results of a cardiorespiratory rehabilitation program. It is a simple and easily performed test for the measurement of functional capacity [38]. Other outcomes, such as climbing stairs, sit-up and stand-up tests, isokinetic strength, walking speed, peak heart rate, oxygen consumption, 1MR, quality of life, dynamic balance, scales used to monitor perception of effort, EMG, and force platform, were also used.

The methodological quality assessment tool, PEDro, was used. A mean of 5.42 points was observed in the studies included in this review. Similar results (5.78 points) were observed in another study, which evaluated 272 stroke studies using the PEDro scale, concluding that the PEDro scale provides a more comprehensive measure of the methodological quality of literature on stroke [19]. The same authors reported that in studies on stroke rehabilitation, double-blinding is usually not possible. Other authors reported that two criteria of the PEDro scale (therapist and patient blinding) are not always possible to be fulfilled during the studies, namely, in studies where the intervention is the exercise [39]. Thus, the maximum score of the study would be eight points.

This study, as well as others [6, 7], found that there is no standard protocol for ST in stroke patients. Pak and Patten [6] recommend parameters for ST. However, unlike this review, that study aimed at determining whether high-intensity ST counteracts muscle weakness without increasing spasticity in post-stroke patients and whether ST is effective in improving functional outcomes compared to traditional rehabilitation programs. Table 4 summarizes the ST protocols of the studies included in this review. Although the use of resistance exercises is commonly accepted as an excellent ST method in healthy muscles, the benefits and risks of resistance exercises in post-stroke patients remains a matter of debate [40]. Despite the restriction of many physiotherapists regarding the use of muscle strengthening techniques, ST has been shown to increase muscle strength, gait velocity, and functional outcomes and to improve quality of life without exacerbation of spasticity in post-stroke patients [6]. Recently, it has been shown that ST appears as the most efficient method for gaining strength in the lower limbs in hemiparetic populations [7].

Table 4 - Summary of the protocols of the included studies on strength training in hemiparetic patients

	Volume/time training (weeks)	Intensity (%MR)*	Frequency (times/week)	Series (number)	Repetitions (number)*
Average (SD)	8.58 (3.31)	75.00 (5.48)	3 (1.04)	3.30 (0.48)	10.50 (1.84)
Median (EP)	8 (0.96)	75 (2.24)	3 (0.30)	3 (0.15)	10 (0.58)
Minimum	4	70	2	3	8
Maximum	12	80	5	4	15
Type of contraction	Predominantly isotonic.				
Muscle groups/proposed exercises:	MMII: knee extensors and flexors, hip flexors, plantar flexors, and dorsiflexors; MMSS: bench press.				
Outcomes/measures	Dynamometry; timed up and go; six-minute walk test; stair climbing test; sit and stand up test; isokinetic strength; walking speed; peak FC; peak VO2; 1MR; quality of life; balance; scales used to monitor perception of effort; EMG; strength platform.				

Note: * the MR maximum load and the maximum number of repetitions were considered. MR (maximum repetition); HR (heart rate); VO2 (oxygen consumption); EMG (electromyography).

Conclusion

Despite the observed benefits of ST in hemiparetic patients, this systematic review highlights the lack of standard protocols regarding volume, intensity, frequency, series, and training repetitions. Isotonic exercises are the most commonly used. Thus, it is suggested that more controlled studies should be designed to define the optimal parameters of ST for hemiparetic individuals, which can be used as a reference for treatment personalization.

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