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REVIEW ARTICLE

The effectiveness of long-term physical rehabilitation to improve balance and locomotion in older people with Parkinson's disease: A systematic review

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ABSTRACT

Walking and balance alterations are critical to address in older adults living with Parkinson's Disease (PD). These alterations negatively impact activities of daily life, decrease the quality of life and increase the risk of falls. Objective: Analyse the effectiveness of different long-term exercise interventions to improve walking and balance parameters in people aged over 60 years with PD. Methods: Experimental studies from the last 10 years collected from 5 databases (PEDro, PubMed, WOS and EBSCO) were analysed. PEDro scale was used to analyse the quality of the studies, and the result shown in the studies was contrasted with the minimal detectable change (MDC). Results: From 413 studies, a total of 7 RCTs and 2 pilot studies were included in the analysis. The range of age was 65.8 ± 10.7 and 73.59 ± 7.93 years. The duration of the disease was 5 to 15 years. The methodological quality ranged from "*good*" to "*excellent*". Conclusions: More significant clinical effect in PD population was obtained after interventions that included: high-intensity strength training, progressive increase of resistance, aerobic exercise, and walking and balance training.
Keywords: Parkinson's disease, Exercise therapy, Rehabilitation, Elderly, Gait.

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INTRODUCTION

Parkinson's disease (PD) is a chronic neurodegenerative disease. PD is characterized by loss of neurons in the Substantia Nigra pars compacta (SNc) and decreased dopamine levels in the entire nervous system. Four clinical signs can appear during the progression of PD: bradykinesia, tremor, rigidity and weak postural control.

Ageing is an essential factor in developing PD. Between 1995 and 2015, the number of PD cases rose to 6 million globally. People living with PD are expected to double, reaching 12 million cases by 2040. PD is a neurodegenerative disease with a prominent increase in the number of cases, surpassing Alzheimer's disease. Consequently, the increase in the number of patients contributes to an increasing disease burden on the healthcare system of a country.

People living with PD experience alterations in walking and maintaining balance. These alterations can lead to difficulty performing daily activities, decreased quality of life, and increased risk of falling. In addition, an increased risk of falling can generate fear of walking in some patients. Gazibara et al. 2015, showed after a 20-year follow-up that 81% of the participants with PD had at least one fall in that period. Of the 81% that suffered a fall, 23% had a fracture from the fall.

The execution or planning of multiple tasks can worsen the ability to walk and balance in people with PD. For example, talking or counting backwards while walking can decrease walking velocity in people with PD. Moreover, in the advanced stages of PD, some people develop a "*freeze of gait*", in which the body stops movement in the middle of the walk. Freeze of gait can happen at the beginning of the walk, while walking on narrow paths, turning, or while executing a second task.

Levodopa is one of the main pharmacological treatments for PD. Levodopa's primary purpose is to increase or replace the dopamine in the central nervous system, helping improve the clinical symptoms of PD. In addition to pharmacological treatment, people living with PD often receive exercise-based treatment to improve or maintain physical capacities. The goal of exercise interventions is to improve balance, strength, coordination, walking and postural control capacities. Nevertheless, the effectiveness of exercise interventions needs to be researched.

Together with exercise interventions, new approaches have arisen to solve the rehabilitation problem of people with PD. These approaches include music therapy, yoga, virtual reality, Tai chi and dance. Despite this, owing to the progressive nature of PD, pharmacological treatment seems to be the most effective and lost-lasting approach. However, people can exhibit walking and balance alterations even with proper doses of Levodopa. The objective of this systematic review is to evaluate the long term effectiveness of exercise-based interventions in improving walking and balance in people living with PD over the age of 60 years.

METHODS

This review follows the standards of PRISMA declaration for standards and transparent systematics reviews (Page et al., 2021).

Eligibility criteria

Papers between the years 2012 and 2022 with English as the main language. The inclusion and exclusion criteria are listed in Table 1.

Table 1. Study eligibility criteria.

	Inclusion criteria	**Exclusion criteria**
P Population	People≥ 60 years old of any gender. PD diagnosis is classified on the HY Scale in stages 1 to 3.	People in advanced stages of PD (stages 4 and 5). People with a diagnosis of PD and other neurological diseases. Included within the same intervention group were people aged 59 or less.
I Intervention	Physical therapy longer than 12 weeks (physiotherapy, physical/therapeutic exercise or other related treatment). Prescription of the intervention in terms of dosage (e.g. frequency, intensity, time, modality). Exercise therapy including the main intervention and other complementary interventions.	There are no details of the intervention procedure. The intervention includes surgical or other treatments not related to exercise.
C Comparison	Inclusion of a passive control group that was intervened by educational sessions or a control group without intervention. An active control group with rehabilitation interventions that do not alter their routine treatment.	Randomised group, without any kind of intervention.
O Outcome	The protocol of the study includes the evaluation of balance and walking with clinical tools commonly used in people with PD (e.g. UPDRS, Berg's Scale, TUG, etc.)	The protocol does not include the evaluation of balance and walking.
D Design	Experimental studies or clinical trials, with or without randomisation.	Systematic reviews, pilot studies, descriptive studies, case and series reports, conference proceedings, and not concluded studies.

Abbreviations: P = Population, I = Intervention, C = Comparison, O = Outcome and D = Desing. PD = Parkinson's disease, HY = Hoehn y Yahr, UPDRS = Unified Parkinson's Disease Rating Scale, TUG = Time Up and Go.

Information sources

The search for articles was performed in electronic databases like EBSCO (MEDLINE, Rehabilitation & Sports Medicine Source, SPORT Discus), Physiotherapy Evidence Database (PEDro), PubMed and Web of Science (WoS) that were available in the Universidad de Los Lagos electronic system. If an article was not available in the system, the researcher asked via email for the paper's authors.

Search strategy

The Medical Subject Heading (MESH) terms related to PD, rehabilitation, balance and walking were used to search for articles. Other related terms were used to increase the accuracy of the search. These terms are listed in Table 2. Boolean operators like AND and OR were also used. The complete strategy is listed below.

Table 2. Controlled and not controlled terms used to develop the search of articles.

	MESH Terms	**Optional terms**
Patient/Population	Parkinson Disease, Parkinsonian Disorders, Aged, Frail Elderly	Parkinson, Parkinsonism, Parkinson's disease Older adults, elderly, seniors, geriatrics
Intervention	Rehabilitation Medicine, Exercise Intervention, Physical Therapy	Exercise Program
Outcomes	Gait, Walking, Locomotion, Postural Balance	Ambulation

- EBSCO: AB (Parkinson Disease OR Parkinsonian Disorders OR Parkinson OR Parkinsonism OR Parkinson's disease) AND AB (Rehabilitation Medicine OR Exercise Intervention OR Physical Therapy) AND TX (Gait OR Walking Locomotion OR Postural Balance OR Ambulation.
- PEDro: Parkinson Disease, Parkinsonian Disorders.
- PubMed: (((Parkinson Disease [Title/Abstract] OR Parkinsonian Disorders[Title/Abstract] OR Parkinson[Title/Abstract] OR Parkinsonism[Title/Abstract] OR Parkinson's disease[Title/Abstract]) AND (Aged[Title/Abstract] OR Frail Elderly[Title/Abstract] OR Older adults[Title/Abstract] OR elderly seniors[Title/Abstract] OR geriatrics[Title/Abstract])) AND (Rehabilitation Medicine[Title/Abstract] OR Exercise Intervention [Title/Abstract] OR Physical Therapy[Title/Abstract] OR Exercise Program[Title/Abstract])) AND (Gait[Title/Abstract] OR Walking[Title/Abstract] OR Locomotion[Title/Abstract] OR Postural Balance[Title/Abstract] OR Ambulation[Title/Abstract]).
- WOS: Parkinson Disease OR Parkinsonian Disorders OR Parkinson OR Parkinsonism OR Parkinson's disease (Abstract) and Aged OR Frail Elderly OR Older adults OR elderly OR seniors OR geriatrics (Abstract) and Rehabilitation Medicine OR Exercise Intervention OR Physical Therapy OR Exercise Program (Abstract) and Gait OR Walking OR Locomotion OR Postural Balance OR Ambulation (Abstract).

The process of article selection

Four researchers (S.V, J.S, M.R, N.V) developed an independent search of articles in a specific electronic database (each in one database). After the obtention of articles, each researcher swapped their database with another researcher and searched articles again. The previous step was implemented to ensure the obtention of the same results. An extra step was carried out if there were articles that generated doubt or conflict among the researchers. A fifth researcher was in charge of deciding on these articles. The fifth researcher (N.F) is experienced in the field.

Data collection

The principal outcome was obtained from the result of each of the articles previously selected. The change in balance and walking were evaluated in a pre and post-intervention state. The results of the papers were based on a clinical scale or tool: Unified Parkinson's Disease Scale (UPDRS), 10-metre walk test (10MWT), Berg Balance Scale (BBS), the Activities-specific Balance Confidence (ABC) Scale, forward and backwards functional reach (FBFR), Romberg Test (RT), Sharpened Romberg Test (SRT), the Six-Minute Walk Test (6MWT), the Timed "*Up & Go*" Test (TUG), and other similar tests were used by the authors of the selected papers.

Risk of bias assessment

The PEDro scale (Maher et al., 2003) was used to measure the quality of each article included in this systematic review. An analysis of the quality of the internal validity and the presentation of the statistical

analysis of each research/clinical trial was performed. According to the PEDro scale, the articles that obtain 9-10 points are considered "*excellent quality*", 6-8 points are considered "*good quality*", 4-5 points are considered "*fair*", and under 4 points are considered "*poor quality*". The articles included in this revision obtained 6 or more points. This threshold was implemented to secure the quality of this review.

Synthesis methods

After selecting articles, the characteristics of each article were summarised in a table. Then, in a second table the details of intervention protocol from each article were plotted. The principal details were type of exercise, time, frequency and duration of the exercises in the protocols. Also the results of balance and walking were added. Finally, the post-intervention values of each article were analysed using the Minimal Detectable Change (MDC) published by Steffen and Seney (2008) for people with PD.

RESULTS

Article selection

The database search yielded 413 results. After removing duplicated studies, a total of 316 were obtained. In 53 cases, the full-text article could not be obtained either through emailing the authors or because it was not part of the Universidad de Los Lagos electronic library. Therefore, the exclusion criteria was applied to the remaining 310 studies.

A total of 304 studies were excluded. The main reason for exclusion was the age of people with PD included in the studies (65 studies). Other reasons to exclude: the stage of PD (n = 20), the intervention was not based on exercise (n = 105), review articles (n = 52), less than 12 weeks of intervention (n = 56) and language (n = 2). After applying the exclusion criteria, four extra articles were added to this analysis. The main reason for this inclusion was that these articles suit the inclusion criteria of age and stage of PD. In total, nine articles were included in this research. The process of selection is explained in the PRISMA flow in Figure 1.

Studies characteristics

Across the nine studies, 297 participants with PD diagnoses were included. Seven randomised clinical trials, two articles that were part of the same research split into two parts (Shen et al., 2014 and Shen et al., 2015), and two were pilot studies (Steffen et al., 2012; Wroblewska et al., 2019). The participants of the study were aged between 64.3 ± 8.25 and 73.59 ± 7.93 years in Shen et al. (2014 and 2015) and Santos et al. (2017). The duration of PD ranged between 5.7 ± 4.23 (Dibble et al., 2015) and 11 ± 6.6 years (Martin et al., 2015). The severity of the disease in the HY scale ranged between 1 and 3. Five studies described the medication of the participants. Levodopa was the primary drug (Dibble et al., 2015; Santos et al., 2017; Shen et al., 2014; Shen et al., 2015; WrTheoblewska et al., 2019). Table 3 contains the details of each article.

Synthesis results

Table 4 includes the analysis of the interventions included in this review. The main results are divided into two categories:

- *Characteristics of the intervention:* Five studies used resistance and strength training as interventions (Dibble et al., 2015; Santos et al., 2017; Paul et al., 2014; Shen et al., 2014; Shen et al., 2015). In five studies, walk training was included in their protocols (Shen et al., 2014; Shen et al., 2015; Shulman et al., 2012; Steffen et al., 2012; Wroblewska et al., 2019). One study used home-based telematic training (Martin et al., 2015). The time of the intervention ranged from 12 weeks (Dibble et al., 2015; Santos et al., 2017; Paul et al., 2014; Shen et al., 2014; Shen et al., 2015; Wroblewska et

al., 2019) up to 10 months (Steffen et al., 2012). The frequency of intervention was two times per week, the sessions lasted 30 to 50 minutes on average, but the more common was interventions of more than 60 minutes.

– *The effects of the intervention on walking and balance parameters.* For the evaluation of walk and balance, most of the studies used TUG, UPDRS, 6MWT, 10MWT and the ABC scale. Three studies used the motor scale of the UPDRS to measure changes after the intervention (Dibble et al., 2015; Santos et al., 2017; Steffen et al., 2012), and one study used the mental scale of UPDRS (Steffen et al., 2012). Unfortunately, only one of the three previously mentioned studies achieved positive clinical change in the MDC results (Santos et al., 2017).

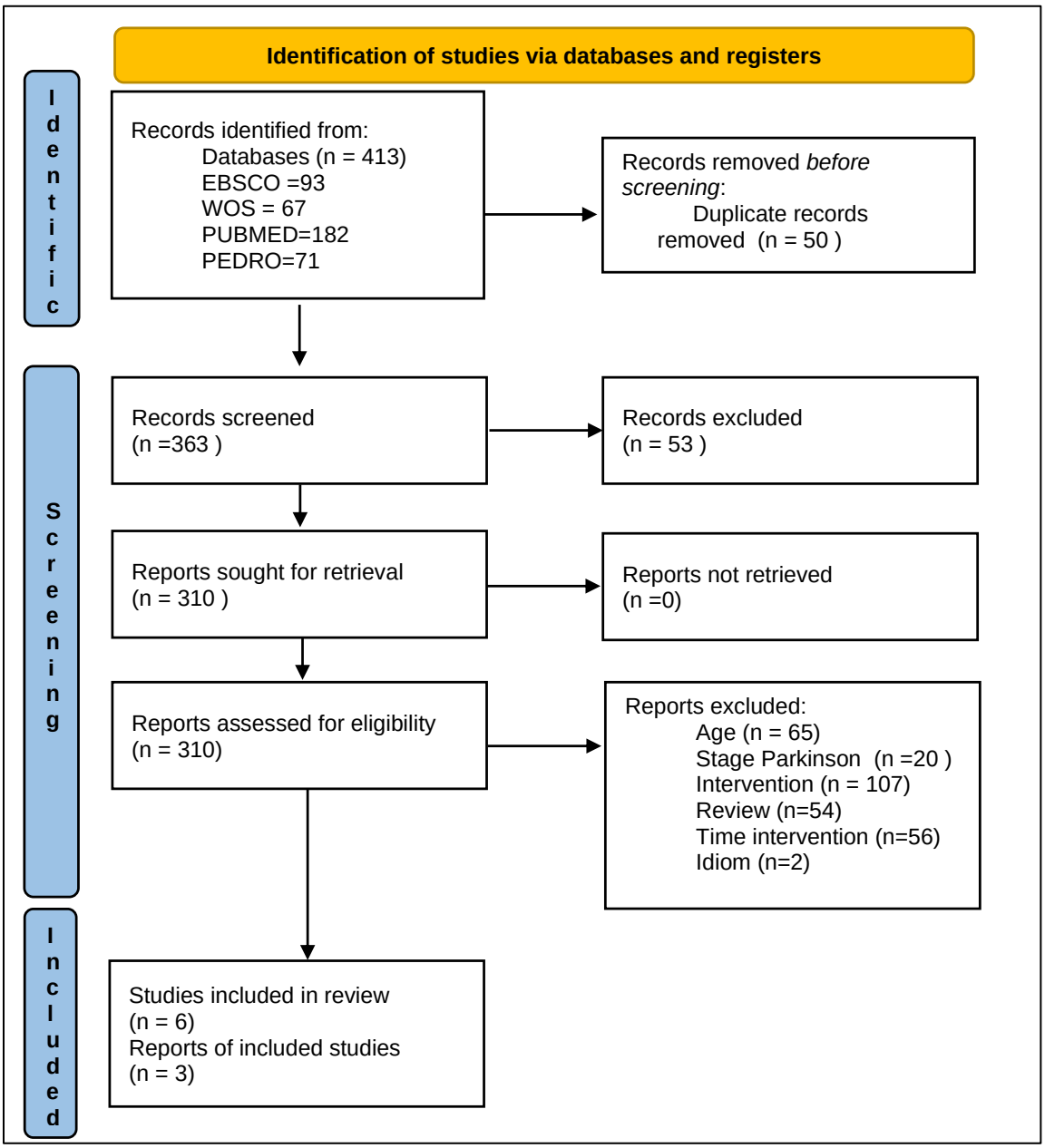

Figure 1. PRISMA flow diagram.

Table 3. Characteristics of the research and population included in this systematic review.

Characteristics of the research			Study population					
Author	**Year**	**Design**	**Participants in the study**	**Experimental group (EG)**	**Control group (CG)**	**H&Y stage (mean)**	**Pharmacological treatment**	**Years with PD (mean ± SD)**
Dibble et al.	2015	RCT	n = 41; 25 men and 16 women, average age: 68.4 ± 12.99 years old	n = 20; 11 men and 9 women, average age = 66.00 ± 14.78	***Active control: concentric training*** n = 21; 14 men y 7 women; average age 70.71 ± 9.19	I,II,III y IV average age: 2	Carbidopa/ Levodopa	EG: 8 ± 4.48 CG:5.70 ± 4.23
Martin et al.	2015	RCT	n = 21; 13 men, 8 women; average age=72 ± 5.3 years old	***Immediate start group*** n = 12; 7 men and 5 women; 72 ± 5.1 years old ***Late start group*** n = 9; 6 men and 3 women; 72± 5.8 years old		2.8 ± 0.6	Stable medication, name of the drug not informed	11 ± 6.6
Santos et al.	2017	RCT	n = 28, 15 men, 13 women, average age = 73.59 ± 7.93 years old. ***Active group with exercise practice 3 times per week.***	n = 13; 5 men and 8 women; average age = 73.38 ± 8.81years old	***Active control: usual exercises*** n = 10 men, 5 women, average age 73.80 ± 7.05 years old	EG = 1.92 ± 0.49 CG = 1.86 ± 0.35	Levodopa	GE: 10.84 ± 4.09 GC: 10.46 ± 4.01
Paul et al.	2014	RCT	n = 40; 25 men and 15 women; average age: 66.3 ± 6.5 years old	n = 20, 13 men and 7 women; average = 68.1 ± 5.6 years old	***Active control: Low-intensity exercises*** n = 20, 12 men and 8 women; average age = 64.5 ± 7.6 years old	EG = 2 ± 0.7 CG =1.9 ± 0.9	Does not report information	GE: 7.8 ± 5.2 GC: 7.8 ± 5.9
Shen et al.	2014	RCT	n = 45.35 men and 10 women: average age = 64.3 ± 8.25 years old	***Balance training group*** n = 22, 13 men and 9 women; average age = 63.3 ± 8.0 years	***Strength training control group*** n = 23, 12 men and 11 women; average age = 65.3 ± 8.5 years old	EG 2.4 ± 0.5 CG 2.5 ± 0.5	Levodopa	GE: 8.1 ± 4.3 GC: 6.6 ± 4.0
Shen et al.	2015	RCT						
Shulman et al.	2012	RCT	n = 67; 50 men, 17 women; average age 65.8 ± 10.7 years old	***High-intensity training group*** n = 23; 16 men and 7 women; average age = 66.1 ± 9.7 years old ***Low-intensity training group*** n = 22; n = 22; 16 men and 6 women; average age = 65.8 ± 11.5 years old	***Active control: resistance training and stretches*** n = 22; 18 men and 4 women y average age = 65.3 ± 11.3 years old	I, II III 2 (n = 53) 2.5 (n = 4) 3 (n = 10)	Stable medication, name of the drug not informed	6.2 ± 3.8
Steffen et al.	2012	Pilot Study	n = 15; 12 men; 3 women; average age = 72 ± 8 years old.		Does not apply	3 ± 1	Does not report information	6.0 ± 5
Wroblewska et al.	2019	Pilot Study	n = 40; 17 men and 23 women; average age: 69.8 ± 7.3 years old	n = 20; 8 men and 12 women; average age = 72.1 ± 7.5 years old	***Passive control*** n = 20; 9 men and 11 women; average age = 67.6 ± 6.6 years old	2.5	Levodopa, Ropinirole y and other drugs against PD	6.0 ± 1.2

Abbreviations: RCT = Randomised clinical trial; EG = Experimental group; CG = Control group; SD = Standard deviation.

Table 4. Characteristics of the interventions and effect on gait and ambulation parameters reported in the investigations (*continue on the next page*).

Authors/ Quality	Characteristics of the intervention		Outcomes	Results of the intervention		
	Modality	Duration		UPDRS (points)	Balance and walking	MCD Results
Dibble et al.(2015) PEDro: 9/10	EG = Resistance exercises with negative eccentric work (RENEW) ACG = General strength exercises	60 minutes, 12 weeks, 2 times per week	UPDRS, FGA y TM6m	**Motor** EG-RENEW: pre = 15.05 ± 7.78 post = 12.7 ± 9.30* ACG: pre = 15.43 ± 8.62 and post =13.14 ± 9.88* *p < .05	**FGA (points)** : EG-RENEW pre = 2210 ± 6.77 y post = 23.75 ± 7.00* ; GCA: pre = 21.14 ± 8.27 y post = 21.90 ± 7.89* **6MWT (m/s) :** EG -RENEW: pre = 558.07 ± 182.49 and post: 583.70 ± 181.61* ; ACG: pre = 485.99 ± 158.95 and post = 506.09 ± 192.41* p < .05	**UPDRS** (points) EG- RENEW = ↑2.35(unachieved) ACG = ↓2.29 (unachieved) TM6m (m) EG-RENEW = ↑25.63 (unachieved) ACG = ↑20.1 (unachieved)
Martin et al. (2015) PEDro: 7/10	Cued Up! Exercise program and home-base education to avoid Freeze of gait using auditory cues	30 a 60 min, fomenting the practice of exercise everyday	New freeze of gait questionnaire and weekly self-report of falls.	Not applied	**New freeze of gait questionnaire (points)*:*** Immediate start group: pre = 15.7 ± 6.3 and post = 14.8 ± 5.0; Late start group: pre = 16.9 ± 4.1 and post = 16 ± 7.7 **Weekly self-report of falls**. Each participant falls at least 2 times during the study. A mean value of 1.22 falls per week. No statistically significant differences between groups.	Does not apply
Paul et al. (2014) PEDro: 9/10	Strength training using equipment with variable pneumatic resistance	45 min, 2 times per week, 12 weeks of training	Muscle strength, 10 MWT (prefer velocity and fast), TUG, reactions, maximal balance, monopodial test and New freeze of gait questionnaire	Not applied	**10 MWT velocity choose by participant(m/s) :** EG: pre = 1.27 ± 0.17 and post = 1.34 ± 0.22; CG: pre = 1.17 ± 0.31 and post = 1.24 ± 0.38. **10 MWT fast velocity (m/s) :** EG: pre = 1.77 ± 0.25 and post = 1.81 ± 0.31 **;** CG: pre = 1.67 ± 0.39 and post = 1.70 ± 0.44 **TUG (cm) :** EG: pre = 9.7 ± 2.3 and post = 8.3 ± 2.4 ; CG: pre = 9.5 ± 2.8 and post = 8.6 ± 4.3 **Reaction (cm):** EG: pre = 37.0 ± 9.5 and post = 35.2 ± 6.2; CG: pre = 34.3 ± 11.0 and post = 37.5 ± 12.9 **Balance maximal range (cm)** EG: pre = 16.7 ± 5.0 and post = 18.4 ± 4.7 ; CG: pre = 14.4 ± 7.2 and post = 15.1 ± 6.0 **Monopodial test (s) :** EG: pre = 12.9 ± 7.2 and post = 16.1 ± 10.3 ; CG: pre = 20.6 ± 17.3 and post = 21.0 ± 17.2 **New freeze of gait questionnaire (puntos)** : EG: pre = 6.0 ± 8.8 and post = 5.8 ± 7.8; CG: pre = 8.0 ± 10.0 and post: 7.4 ± 10.0	**10 MWT chosen velocity** (m/s) EG: 0.07 (unachieved) CG: 0.07 (unachieved) **10 MWT fast velocity** (m/s) EG: 0.04 (unachieved) CG: 0.03 (unachieved) **TUG** (s) EG: 1.4 (unachieved) CG: 0.9 (unachieved)
Santos et al. (2017) PEDro: 9/10	Progressive resistance training	16 training sessions in 8 weeks. 60 a 70 min, 2 times per week of supervised training. Then, 4 weeks of training without supervision	Anthropometric and neuromuscular function evaluations, 10 MWT, FOG-Q,UPDRS, PDQ-39 and Borg Scale	**Motor** EG: pre = 7.61 ± 5.28 and post = 7.07.± 4.59 CG: pre = 7.30 ± 4.53 and post = 8.8 ± 5.74	**FOG-Q (puntos):** GE: pre = 3.84 ± 3.15 y post: 3.46 ± 3.07; GC: pre = 3.61 ± 3.12 y post: 3.26 ± 1.98 **PDQ-39 (puntos)**: GE: pre = 11.16 ± 7.39 y post± 4.58 ± 4.37* ; GC: pre = 5.98 ± 5.06 y post = 10.60 ± 4.38 **10 MWT (chosen velocity) (m/s)**: EG: pre = 0.87 ± 0.15 and post =0.85 ± 0.12 ; CG: pre: 0.84 ± 0.12 and post: 0.98 ± 0.13 **10 MWT (fast velocity) (m/s):** EG**:** pre = 1.20 ± 0.13 and post = 1.53 ± 0.21; CG: pre = 1.37 ± 0.14 and post: 1.24 ± 0.23 *p < .05	**ΔUPDRS Motor (points)** EG:↓0.54 (unachieved) CG: ↓0.35 (unachieved) **Δ 10 MWT chosen velocity (m/s):** EG: ↓0.2 (unachieved) CG: ↓0.14 (unachieved) **Δ10 MWT fast velocity(m/s):** EG: ↓0.33 (achieved) CG :↓0.13 (unachieved)

Symbology: Δ = variation; ↑ increase or improve and ↓ decrease or reduction. Abbreviation: ABC = Activities-specific Balance Confidence questionnaire ; FGA = Functional Gait Assessment; FOG-Q = Freezing of Gait Questionnaire; EG = Experimental group; CG = Control group and ACG = Active control group; PDQ-39 = Parkinson's Disease Questionnaire; MDC = Minimal Detectable Change; MMSE = Mini-Mental State Examination; 6MWT = 6 minutes walking test; TUG = Timed up and go; UPDRS = Unified Parkinson's Disease Rating; 10MWT = 10 metres walking test.

Table 4. Characteristics of the interventions and effect on gait and ambulation parameters reported in the investigations (*continued*).

Authors/ Quality	Characteristics of the intervention		Outcomes	Results of the intervention		
	Modality	Duration		UPDRS (points)	Balance and walking	MCD Results
Shen et al. (2014) PEDro: 10/10	EG: Balance and walking training ACG: Strength training of lower limbs	12 weeks, 3 supervised sessions and 5 sessions per week of home-based training	ABC, sit-to-stand of chair and walking characteristics (velocity and steps)	Does not applied post training	**ABC (%)** EG : pre = 75.8 ± 15.1 and post = 80.1 ± 16.5; CG: pre = 70.6 ± 18.3 and post = 73.7 ± 17.9 **10 MWT(cm/s)*:*** EG : pre = 96.5 ± 15.2 and post = 103.6 ± 13.2* ; CG: pre = 97.8 ± 13.6 and post = 106.8 ± 11.1* **Length of steps (cm)** : EG : pre = 109.9 ± 17.9 y post = 124.6 ± 16.5*; CG: pre = 115.7 ± 13.0 and post = 118.8 ± 12.1 *p < .05	**Δ ABC (%)** EG = ↑6.3 (unachieved) CG = ↑2.8 (unachieved) **Δ 10 MWT (m/s)** EG = ↑0.96 (achieved) CG = ↑1.02 (achieved)
Shen et al. (2015) PEDro: 10/10			Number of falls in 12 months. Rate of falls per years and spatio-temporal characteristic of walk		**Number of falls:** EG: pre = 2:20 and post = 6:16 ; ACG: pre = 11:12 and post = 13:10 **Rate of falls:** EG : pre = 0.57 and post = 0.29; ACG: pre = 0.76 y post 1.52 **Latency in postural control:** EG : pre = 130.0 ± 12.0 and post = 8.4±15.8 ; ACG: pre = 132.2 ± 10.3 and post = 3.7 ± 11.6 **Walking velocity:** EG : pre = 96.5 ± 15.2 and post = 10.4±13.9; ACG : pre = 97.8 ± 13.6 and post = 6.7 ± 15.6 **Length of steps:** EG : pre = 109.9 ± 17.9 and post = 13.3 ± 14.8 ACG: pre = 115.7 ± 13.0 and post = 2.6 ± 12.5	**Δ 10 MWT (m/s)** EG = ↑0.86 (achieved) CG = ↑0.91 (achieved)
Shulman et al. (2012) PEDro: 8/10	High-intensity aerobic exercises (HAE) and Low-intensity aerobic exercises (LAE) on treadmill and Resistance exercises and stretches (RE)	36 sessions, 3 times per week for 3 months	UPDRS, MMSE, S&E disability scale	Does not applied post training	**TM6m** HAE: pre = 1374.2 ± 57.4 and post = 1451.2 ± 62.5 LAE: pre = 1446.7 ± 95.2 and post = 1607.7 ± 111.6* RE: pre = 1395.5 ± 75.6 and post = 1502.4 ± 81.6* *p < .05	**Δ6 MWT** (m) HAE = ↑77 (unachieved) LAE = ↑161 (achieved) RE = ↑107 (achieved)
Steffen et al. (2012)	Walking forward and backward. Resistance training	10 months, 2 times per week, 60 minutes	UPDRS, 6MWT, Berg Scale and TUG	**Mental:** pre = 3.2 ± 2.4 and post = 1.6 ± 1.7 **DLA** pre = 14 ± 7 and post = 12 ± 6 **Motor:** pre = 13 ± 5 and post = 12 ± 3 **Total:** pre = 30 ± 13 y post = 26 ± 9	**6 MWT (m)** Pre = 309 ± 123 and post = 370 ± 114 **Berg Scale (points)** Pre = 48 ± 6 and post = 49 ± 6 **TUG (s)** Pre = 16 ± 8 and post = 14±4	**ΔUPDRS (points)** Mental = ↓1.2 (unachieved) DLA = ↓0.8 s (unachieved) Motor = ↓0.14 (unachieved) Total = ↓0.06 (unachieved) Δ6 MWT (m) ↑61 m (unachieved)
Wroblewska et al. (2019)	Nordic walk	12 weeks, 2 times per week	FOG-Q, TUG, provocation test for freezing and movement blocks	Does not applied post training	**FOG-Q (points) :** EG: pre = 12.6 ± 1.4 and post = 7.1 ± 1.7 ; GC: pre = 7.1 ± 1.7 and post = 7.1 ± 1.7 **TUG (s) :** EG: pre = 17.2 ± 1.4 and post = 12.6 ± 1.4; GC: pre = 12.6 ± 1.4 and post = 12.6 ± 1.4	**ΔTUG (s)** EG ↓4.6 s (unachieved) CG = 0 s (unachieved)

Symbology: Δ = variation; ↑ increase or improve and ↓ decrease or reduction. Abbreviation: ABC = Activities-specific Balance Confidence questionnaire ; FGA = Functional Gait Assessment; FOG-Q = Freezing of Gait Questionnaire; EG = Experimental group; CG = Control group and ACG = Active control group; PDQ-39 = Parkinson's Disease Questionnaire; MDC = Minimal Detectable Change; MMSE =Mini-Mental State Examination; 6MWT = 6 minutes walking test; TUG =Timed up and go; UPDRS =; Unified Parkinson's Disease Rating; 10MWT =10 metres walking test.

Only one study reported a positive statistically significant change in the 10MWT (Shen et al., 2014). However, two other studies achieved a clinically positive MDC in the evaluation of 10MWT after the strength training (Santos et al. 2017 y Shen et al. 2015). In addition, one study reported a statistically significant and clinically significant change in the 6MWT in intervened groups with low-intensity aerobic exercise and muscle resistance. In contrast, the high-intensity group of the same research only reported a clinical effect (Shulman et al., 2012). Dibble et al. (2015) inform a statistically positive change in groups training in eccentric and groups training in concentric modality of exercise.

Quality of the evidence

The PEDro scale was applied to 7 of the 9 studies included in this systematic review. Wroblewska et al. (2019) and Steffen et al. (2012) were excluded from the PEDro evaluation because they were pilot studies. The details are in Table 4.

DISCUSSION

This systematic review focused on analysis of the effect of long-term physical therapy and exercise in older people living with PD. Aerobic exercise, endurance exercises, strength training and balance exercises obtained better outcomes. The protocols follow a progression from low to high intensity.

Shein et al. (2015) obtained better MDC walking velocity results in both intervened groups. The balance training group obtained ↑0.86, and the strength training group obtained ↑0.91. Shulman et al. (2012) showed significant changes in 3 intervened groups: High-intensity = ↑77, Low-intensity = ↑161, and stretching and strengthening exercises = ↑107. Santos et al., (2017) report an MDC in the walking velocity of both groups of ↓0.33. The above mentioned articles' all share strength and muscular endurance components in their protocols, all of which progressed from low to high intensity. However, the three articles have differences in the duration of the intervention. Santos et al. (2017) executed 8 weeks of supervised training, followed by 4 weeks of unsupervised training (12 weeks). In contrast, Shen et al. (2015) and Shulman et al. (2013) followed an exclusive supervised program of 12 weeks. Even with the difference in the protocols, all three articles include training based on walking on treadmills or walking or running frontwards and backwards, with strength training focused on lower limbs, using the exercises of flexo-extension of knees and hips.

People living with PD experience changes in their walking characteristics, like an increase in the number of steps, a decrease in the length of steps, more time spent in the stance phase of walking in normal gait or during freezing of gait, asymmetric movement in lower and upper limbs, trunk rigidity and decrease in the range of movement of hips, knees and ankles (Zanardi et al., 2021). All the changes in walking that people with PD experience led to a decrease in walking velocity. Zanardi et al. (2021) shows no improvement in the walking velocity of people with PD; this could be due to comparisons being drawn between PD population and a healthy control group. In contrast, Radder et al. (2020) include 191 clinical trials with an objective to compare conventional physical therapy against new modalities of exercise: Conventional physical therapy, endurance training, treadmill training, strategy training, dance, martial arts, aerobic exercises, hydrotherapy, balance and walking training, double task training, exergaming and Nordic walk. Although, Radder et al. (2021) showed an increase in walking and balance parameters, this review did not discriminate based on age or stage of PD, instead comparing people with PD with themselves, possibly leading to improved results.

The principal limitation of our systematic review is the lesser number of studies that report the effect of long-term exercise interventions in people with PD. Also, the wide variety of scales used to evaluate change in

each study negatively impacted this review. This factor makes it difficult to compare the various studies. Despite these limitations, the quality of the study was high and contributed to enriching this review.

CONCLUSIONS

Based on the results of the present systematic review, it can be concluded that a 12 weeklong intervention (long-term) is superior in improving the walking and balance parameters of people with PD. Specifically, interventions with modalities of high-intensity strength training, progressive endurance training, aerobic exercise and balance and walking exercise most improved the clinical outcomes in people with PD. The common factor in all the studies was the frequency of two times per week, and progressive load, trying to reach maximal repetitions, series and load.

From the literature on exercise and PD, it can be concluded that short-term interventions of 6 weeks of training predominate the field. Therefore, to improve the quality of new studies related to health and sport, it is suggested that new clinical trials related to the field of health and exercise choose interventions of more than 12 weeks in an attempt to produce more literature related to long-term training in people over 60 years old. Additionally, further research could include supervised interventions, starting from the earliest stages of PD (I and II), and include modalities of strength, resistance and balance training with a frequency of a minimum of two times per week. All these recommendations are necessary to secure clinically and statistically significant change. Implementing new research combining conventional exercise with Tai Chi, Ai Chi, music-therapy, and dance is essential for long-term rehabilitation research.

AUTHOR CONTRIBUTIONS

The idea for the article was conceived by Nicole Fritz. The literature search and data extraction was performed by Jaime Silva, Nicolas Velásquez, Matías Rosas Ruiz and Sandra Vargas. The data analysis was carried out by Jaime Silva, Nicolas Velásquez, Matías Rosas Ruiz and Sandra Vargas and Nicole Fritz. Nicole Fritz and Cristian Mansilla critically revised the work. All authors read and approved the final manuscript.

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