REVIEW ARTICLE

The practice of physical exercise in the context of cognitive compromise and neuro-muscular interactions in the care of the elderly

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ABSTRACT

Objective: to investigate the influence of physical exercise in the context of cognitive compromise of the elderly, and the exercise programmes of greater impact in the motor response and neuromuscular adaptations. **Method:** a systematic review was developed in the Pubmed/MEDLINE, Scopus, LILACS, SPORTDiscus and Embase databases. The PRISMA 2020 checklist and bias risk analysis were applied using the Cochrane handbook scale for the systematic review of interventions (Version 5.1.0). Domains in table 8.5.d. **Results:** 21 studies were included in the qualitative analysis. The regular practice of physical exercise causes a series of positive neuromuscular adaptations in the elderly. These adaptations are related to increases in muscle mass, strength and power, favouring cognitive and motor capacity. The change in lifestyle of the elderly has a significant impact, and 30% of the ageing process is considered natural and caused by sensory, mental and physical factors and a loss of self-control, but 70% depends absolutely on the individual lifestyle. **Conclusion:** The present study suggests a programme composed of combined strength, resistance and aerobic exercises. Such exercises cause increases in neurotrophic, vascular and growth factors, as well as promoting cognitive, mood and quality of life improvements during ageing. Thus, the implementation of an exercise programme involving plyometrics and greater intensities of resistance training (equal or greater to 60% of 1-MR) and an adequate and progressive volume (equal or greater to three 30-40-minute sessions per week), appears to promise improved cognitive and psychomotor outcomes in old age.

Keywords: Exercise, Cognitive dysfunction, Intervention studies, Disease prevention.

INTRODUCTION

The passing of the years causes a normal decline in the performance and activity of human beings in their sensory-motor and cognitive tasks[1]. Amongst other possible causes, studies have revealed various results and inter-occurrences related to trophic alterations and possible neurodegenerative diseases such as Alzheimer's disease (AD), Parkinson's disease (PD) and the alterations that reduce cognitive capacity on ageing[2].

Another factor is the impact caused by postmodern management technology, since the accumulated tasks become significant problems for the aged, causing stress situations and making the performance of the aged even more difficult[3]. Ageing appears to cause diverse complications, including cognitive, neuropathological, perception, physical and motor changes[2]. However, the factors related to cognitive and sensory-motor ageing indicate a strong association with independent functional traits[4]. With increase in age, human behaviour is characterized by increasing needs in a context of reduced resources. This is a consistent affirmation, considering that motor behaviour and sensory aspects require absolute cognitive control to prevent cognitive and neuromotor compromise.

The practice of physical exercise is recommended throughout the whole of an individual's life, however, due to the decline in their physical and cognitive capacities, it is preponderantly important for the ageing public to obtain gains by adhering to training programmes[5,6]. Thus, multicomponent training is strongly indicated by the American College of Sport Medicine for the ageing population, and due to this, much

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research is carried out within this model[6,7], whilst others have signalled direct benefit from resistance training for this population[8]. While some researchers have suggested the systematic practice of running[4], others value an increase in daily physical activity[9].

Amongst the ageing male population, studies have shown significant differences with the practice of exercises, amongst others, improving the mobility and muscle strength of the lower limbs of both sexes of elderly individuals[10,11]. Currently, one can verify the effects of exercise programmes for the elderly by using more robust analyses such as magnetic resonance (MR)[12]. Thus, there appears to be an exponential increase in the search by the aged and for the aged for exercise programmes that can increase both the quality of life and performance of this population.

It is worth mentioning the variables that should be taken into consideration, such as aspects of mobility and muscle strength components, which are fundamental factors for the ageing female population, especially considering the complexity of variables that are altered by age, such as hormones, and physiological and psychological irregularities[7,10].

Some of these are strongly highlighted in the literature, such as knee and back pains[9,13]. With a view to investigating the main variables and inter-occurrences that compromise ageing, the objective of this study was to investigate the influence of physical exercise on cognitive behaviour in the elderly, and the exercise programmes of greater impact in the motor response and neuromuscular adaptations.

METHODS

Carry out a systematic literature review with a literary search source by way of a flow diagram based on the PRISMA checklist (2020)[14].

Eligibility criteria

The studies for inclusion in the qualitative synthesis should have been carried out between 2017 and 2023 in Portuguese, English or Spanish. Inclusion criteria: for a qualitative analysis only randomized clinical trial studies (RCTS) can be included. Review and observational studies cannot be included in a qualitative analysis but, if extremely relevant, could be included just to elucidate and/or ratify specific information included in the text. The same procedure used in methodologic surveys was adopted, containing scientific literature search strategies. Exclusion criteria: this study did not include personal opinions, laboratory results, editorials, comments, letters, booklets or newspaper articles, and did not consider congress abstracts. The same occurred when the techniques were not related to the cognitive, degenerative and neuromuscular outcomes in samples of elderly individuals.

Concerning the subjects of interest, these should contemplate all the cognitive and physiological aspects of the motor abilities during ageing, and also the physical activity programmes that resulted in greater impacts on the neuromuscular results and the systematic statistical values already established scientifically.

Sources of information

The descriptors in the Science of Health of the Virtual Library in Health *Lilacs* (DeCS) were used to obtain the keywords for use in the databases *Scopus*, *PubMed/MEDLINE*, Latin-American and Caribbean Science in Health Literature (LILACS), SPORTDiscus and Embase.

Research strategy

The search for descriptors was carried out on January 28th, 2023, and the data collection between February 02nd and 15th, 2023. The research terms included a combination of medical titles and terms. The descriptors in the Science of Health of the Virtual Library in Health Lilacs (DeCS) were used to obtain the following keywords: *Exercise, Cognitive Dysfunction, Intervention Studies* and *Disease Prevention* together with the Boolean operators “AND” and “OR” to find studies that best corresponded to the subject in question. The

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same search strategy was used for all the sites corresponding to the data bases:

"Exercise" OR "Cognitive Dysfunction" OR "Intervention Studies" OR "Disease Prevention"; Cognitive Aging" OR "Intervention Studies" OR "Disease Prevention" OR "Exercise"; Intervention Studies" OR "Disease Prevention" OR "Exercise" OR " Cognitive Dysfunction"; "Disease Prevention" OR "Exercise" OR" Cognitive Dysfunction" OR "Intervention Studies"; "Exercise" AND "Cognitive Dysfunction" AND "Intervention Studies" AND "Disease Prevention"; "Cognitive Dysfunction" AND "Intervention Studies" AND "Disease Prevention" AND "Exercise"; Intervention Studies" AND "Disease Prevention" AND "Exercise" AND " Cognitive Dysfunction"; "Disease Prevention" AND "Exercise" AND" Cognitive Dysfunction" AND "Intervention Studies".

The search for eligible studies was aided by the strategy PICO[15], mediated by the question: "Which physical activity programme best favours the cognitive and motor inter-occurrences in the elderly?" Thus, for the population of interest, elderly individuals were included; for intervention, strategies with physical activity programmes for the elderly were adopted; the different studies evaluated were compared (control) with the established strategies; the results were the outcomes containing statistical and systematic data. To make it clearer, a table was prepared showing the general characteristics of the studies and another showing the respective strategies used.

Selection process

This research followed the directives of the flow diagram based on the checklist PRISMA – 2020[14]. A protocol involving an evaluation report was developed. Experimental studies carried out between 2017 and 2023 were recommended and other studies with their year of publication were not analysed and scored. It should be mentioned that although there was no limit on the year of inclusion, the pre-established protocol favoured more recent studies and those with greater scientific evidence, advocating the internal validity of the research and guidelines of the Medical Centre based on evidence (Oxford, United Kingdom) (www.cebm.net), which is similar to the guidelines of the Murad et al.[16] pyramid. In the first stage of collection the reference manager EndNote X9.1[17] was used.

Collection process and data list

As from the initial selection, added the chosen bases and the criteria, a selection process of reference for systematic reviews was applied, following the steps: identification of repeated works; reading of the descriptors; reading of the titles; reading of the abstracts; and methodologic analysis. Studies that did not present the aspects related to the proposed outcomes were excluded.

The studies should contain the physiological aspects and types of techniques and methods used by the researchers, and the results should contain clarified systematic data. Similarly, the investigation concerning the internal validity of the studies should identify the methodologic strategies containing the criteria, restrictions, pairings and stratifications. The collection process was organised as follows: The complete texts of potentially eligible articles were conferred independently by three authors (J.M.M., C.M.O., J.C.A.B) based on the inclusion and exclusion criteria. Disagreements were solved by way of a discussion based on the consensus between two of the reviewers, and if necessary, a fourth reviewer (I.B.N) was requested to give a final opinion. The authors provided the following information: year, population information (mean age, proportion of the sexes, sample size, period of treatment), study design, instrument model used to measure the evaluation of the exercise programmes, and the principal findings of these studies concerning neural and/or neuromuscular adaptations. To eliminate doubts, the reviewers used the pre-established protocol.

After verifying the criteria again and acquired the list of articles to be used, the selected studies were reorganised in topics contemplating two pertinent subjects for a discussion inter-related with the main study objective:

- Physical activity for the improvement of cognitive outcomes and the relationships

of the neurotrophic factor (BDNF) with neuroplasticity during ageing.
- Motor, health and neuromuscular responses to the exercise programmes.

Assessment of the bias risk in the selected studies

Two authors (S.F. and K.M.S.) were commissioned to carry out an analysis of the experimental studies according to the guidelines of the "Cochrane handbook for systematic reviews of interventions (Version 5.1.0)[18]. A third author (I.B.N.) evaluated and defined any disagreement. The Cochrane Handbook was adapted to check bias as follows: a determined study was considered satisfactory and of possible allocation when it reached "≥4" domains on table 8.5.d (*handbook-5-1.cochrane*) with a low bias level. It should be mentioned that to be selected, a determined study should preferably present a low bias risk in domains six and seven, that is, a greater low risk level in four or more domains if contemplating the sixth and seventh domains. A study reaching a "low bias risk" in only one, two or three domains "≤3" was considered unsatisfactory for this research.

RESULTS

Selection of studies

A total of 6,449 articles were identified as related to the subject of interest in the data bases selected for the search of articles. After removing 3,607 duplicated articles, 2,842 articles remained for assessment in Portuguese, English and Spanish. A comprehensive analysis of the titles and abstracts eliminated 2,439 articles, resulting in 403 scientific articles. Subsequently, an assessment based on the PICO question excluded 371 articles. In the second step, the 32 remaining articles were read in their entirety and 11 excluded for the following factors: seven studies presented little detail in the methods section, three studies presented results concerning physical exercise and cognitive deficit that were not well clarified in terms of statistical data, and one article evaluated a different outcome. The flow diagram in Figure 1 shows the process used for identification, inclusion and exclusion in greater detail.

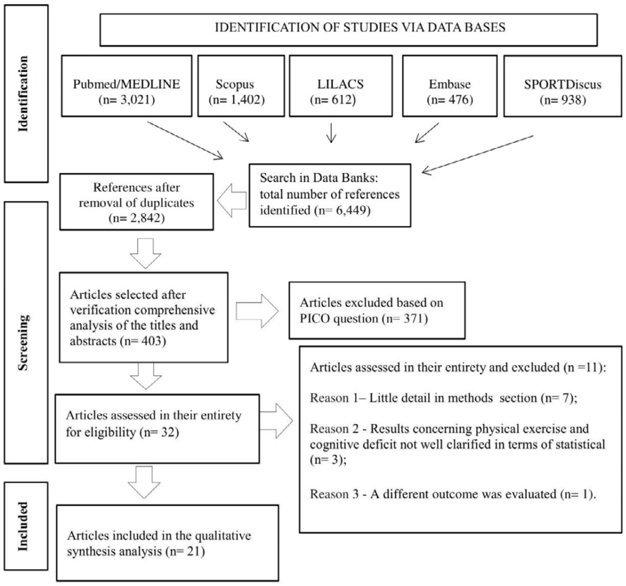

Figure 1: Identification of the studies obtained via data bases and registers (flow diagram following the guidelines of PRISMA-2020)

Source: verification list adapted from Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj. n71. For more information, visit: http://www.prisma-statement.org/

General characteristics of the studies included in the qualitative synthesis

Twenty-one (21) randomized controlled experimental studies were eligible and included in the qualitative synthesis. The studies were published between 2017 and 2023 and were carried out according to the pre-established inclusion criteria. The studies were developed in the following countries: four (19.04%) in Spain, three (14.3%) in Holland, two (9.5%) in Iran, two (9.5%) in Japan, two (9.5%) in Sweden, two (9.5%) in South Korea, one (4.7%) in the United States of America (USA), one (4.7%) in China, one (4.7%) in the United Kingdom, one (4.7%) in Australia, one (4.7%) in Belgium and one (4.7%) in Saudi Arabia. (Frame 1).

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First author/Year/ Country	Sample/ gender/ type of study	Treatment period	GE/GC
Otsuka et al.[12] / 2022 / Japan	Elderly (n = 50) / M & F / RCES	24 weeks	EG1 (n = 17); EG2 (n = 16); CG (n = 17)
Seo et al.[13]/ 2021 / South Korea	Elderly (n = 22) / F / RCES	16 weeks	EG (n = 12); CG (n = 10)
Imaoka et al.[20]/ 2019/ Japan	Elderly (n= 67) without cognitive dysfunction / M & F / RCES	90 days/ 1x week (45min)	EG (n=36); EG+Nut (n=31)
Bossers et al.[21] / 2015 / Holland	Elderly (n=109) / M & F / RCES	9 weeks/ 36 sessions (30min)	Combined G (n= 37); Aerobic G (n= 36); Social G (n=36)
Yu et al.[22]/ 2021/ USA	Elderly (n=96) with Alzheimer/ M & F/ RCES	6 months/ 3x week (20 to 50 min)	EG (n=64); CG (n=32)
Toots et al.[23]/ 2017/ Sweden	Elderly (186) with dementia/ M & F/ RCES	4 months/ 40 sessions (45 min)	ExG (n=93); CG (n=93)
Lamb et al.[24]/ 2018/ United Kingdom	Elderly (494) with dementia/ M & F/ RCES	4 months/ 2x week (60 to 90 min)	ExG (n=329); CG (n=165)
Arazi et al.[30] / 2021 / Iran	Elderly (n=30) / M / RCES	2 visits with interval of 48hours. (45 min).	SG= Strength group (n=10) RG= Resistance group (n=10) GC= Control group (n=10).
Nilsson et al.[31] / 2020 / Sweden	Elderly (n=97) / M & F / RCES	12 weeks (35 min).	FE+COG (n=25); COG+FE (n=24) FE (n=27); COG (n=21).
Liao et al.[32] /2021 / China	Elderly (n=46) / M & F / RCES	12 weeks (60 min 3x/week).	EXER= exergame (n=25); CPE= combined physical exercise (n=21).
Koevoets et al.[38] / 2022 / Holland	Patients with breast cancer exposed to chemotherapy (n=181) / F / RCES	6 months (4 hours/ week).	IG (n=91); CG (n=90).
Izquierdo-Alventosa et al.[42]/ 2020 / Spain	Women with fibromyalgia (n=32) / F / RCES	8 weeks (60 min, 2x/ week).	PEG = physical exercise group (n=16); CG = control group (n=16).
Marcos-Pardo el al.[45]/ 2019 / Spain	Elderly (n = 45) / M & F / RCES	12 weeks	EG (n = 24); CG (n = 21)
Sadeghi et al.[46] / 2021 / Iran	Elderly (n = 58) / M / RCES	8 weeks	EG1 (n = 14); EG2 (n = 15) EG3 (n = 14); CG (n = 15)
Kim et al.[47]/ 2022 / South Korea	Elderly with back pain (n = 20) / M & F / RCES	8 weeks	EG (n = 10); CG (n = 10)
Van Roie et al.[48] / 2020 / Belgium	Elderly (n = 36) / M / RCES	12 weeks	EG1 (n = 11); EG2 (n = 11) CG (n = 14)
Rodriguez-Lopez et al.[49] / 2022 / Spain	Elderly (n = 42) / M & F / RCES	12 weeks	EG1 (n = 15); EG2 (n = 14) EG3 (n = 13)
Sanudo et al.[51] / 2022 / Spain	Elderly (n = 36) / M & F / RCES	6 weeks	EG (n = 18); CG (n = 18)
Conlon et al.[52] / 2017 / Australia	Elderly (n = 33) / M & F / RCES	22 weeks	EG1 (n = 10); EG2 (n = 13) CG (n = 10)
Galle et.al.[55]/ 2023/ Holland	Elderly (n= 102) / M/F / RCES	9 months	G.COACH(Analysed)(n=69); CG (Analysed)(n= 33)
Nambi et al.[58]/ 2022 / Saudi Arabia	Elderly (n = 76) / M / RCES	8 weeks	EG1 (n = 38); EG2 (n = 38)

Frame 1: General characteristics of the randomised controlled experimental studies selected in the qualitative synthesis

Abbreviations: M - male, F - female, CG – control group, EG – experimental group, RCES – randomised controlled experimental study, CG – control group, G.COACH –motivational interview technique, EG – experimental group, IG –intervention group, ExG – exercise group, GEx+Nut – exercise group + nutrition, NRCT – non-randomised clinical trial, SG -strength group, RG – resistance group, CG – control group, PE+COG – physical exercise + cognitive training group, COG+PE – cognitive training + physical exercise group, PE – physical exercise, COG –cognitive training group, EXER – exergame, CPE – combined physical exercise, PEG – physical exercise group, FM – fibromyalgia, QL – quality of life, BDNF – Brain derived neurotrophic factor. USA – United States of America.

Table 2 describes the 21 intervention programmes and the variables related to the results of the scientific research studies.

Absolute sum of the data in relation to the number of research studies and scores obtained

With respect to the scores on the scale using the Cochrane Handbook tool, two (2) experimental studies showed a low risk of bias in 6 domains, which was the most significant proportion of a low risk of bias; five (5) research studies reached a low risk of bias in 5 domains and sixteen (16) studies reached a low risk of bias in 4 domains (Table 1).

DISCUSSION

Physical activity for the improvement of cognitive outcomes and the relationship of BDNF with neuroplasticity during ageing

First author/Year	Intervention and Variable outcomes
Otsuka et al.[12] / 2022	Resistance training programme with focus on the lower limbs, loads of 40% (EG2) and 60% (EG1) of 1-MR, 40 minutes duration, 3 times a week. Outcomes: Cross-sectional area (magnetic resonance), lean mass, electrical properties of thighs (bioimpedance) and hand grip strength (hand dynamometry)
Seo et al.[13]/ 2021	Resistance training programme with weights for large muscle groups and elastic bands for small groups. Outcomes: Lean mass, senior fitness test, hand grip strength (hand dynamometry), gait velocity, thigh muscle volume (computerized tomography), knee extension isometric torque peak (isokinetic dynamometry).
Imaoka et al.[20]/ 2019	Multicomponent exercise programme with aerobic exercises and memory training + nutritional supplementation. Outcome variables: Effect of multicomponent exercises on cognitive and physical functions.
Bossers et al.[21] / 2015	Combined exercise programme (aerobic and strength) and aerobic exercises. Outcome variables: Effect of exercise programme on motor and cognitive functions.
Yu et al.[22]/ 2021	Aerobic exercise programme (cycling). Outcome variables: Effect of exercise programme on global cognitive function.
Toots et al.[23]/ 2017	High intensity functional exercise programme or seated attention control activity. Outcome variables: Effect of exercise programme on cognitive function.
Lamb et al.[24]/ 2018	Aerobic and strength exercise programme. Outcome variables: Effect of exercise programme on cognitive function.
Arazi et al.[30] / 2021	Two circuits of resistance exercise, 6 exercises with 10 repetitions at 65-70% of maximum repetition. RG = 30 min running with 65-70% of maximum heart frequency. Outcome variables: strength and resistance interventions are efficient in raising BDNF, IGF-1 and platelets.
Nilsson et al.[31] / 2020	CTG = The adaptive cognitive training programme aimed to update the work memory. PE = 5 minutes of heating-up and 30 minutes of moderate aerobic activity at a heart frequency corresponding to 65-75% of the maximum individual heart frequency of the participants (HFmax), as indicated by the evaluation of physical condition. PE+COG = the participants had a brief pause to drink some water and put on a sweater before starting the cognitive training. COG-PE = the participants used ergometric bicycles and started heating-up as soon as the cognitive training session finished. Outcome variables: acute changes in the peripheric BDNF after physical exercise at an interindividual level. Individuals with greater plasmatic BDNF changes after physical exercise in the pre-test showed greater gains from cognitive training, but only if each cognitive training session was preceded, instead of followed, by physical exercise.
Liao et al.[32] /2021	CPE = resistance and aerobic exercises, Tai Chi and equilibrium exercises, 20 min each, as suggested by the American College of Sports Medicine. EXER - resistance and aerobic exercises, Tai Chi and equilibrium exercises during the exergame, 20 min each, using the Kinect system (Microsoft Corp., Redmond, WA, USA). Outcome variables: exergame and CPE could improve cognitive function. Exergame could be superior to CPE, especially in improving global cognition.

Frame 2: Intervention programmes and the variable outcomes of the studies selected for qualitative analysis

(Continuação)

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First author/Year	Intervention and Variable outcomes
Koevoets et al. [38]/ 2022	Intervention group = aerobic and strength training supervised by a physiotherapist close to the patient's home (2h/week), and motorized walk which could be carried out individually or in a group. Control group = they were requested to maintain their habitual level of physical exercise. A 12-week programme of supervised exercises was offered after conclusion of the study. Outcome variables: exercise improved self-reported cognitive functioning, physical aptitude, fatigue, QL and depression in breast cancer patients with cognitive problems exposed to chemotherapy. The cognitive functioning tested was not affected.
Izquierdo-Alventosa et al.[42] / 2020	PEG = low intensity exercise combining resistance and coordination training, supervised by a physiotherapist with experience in therapeutic exercise. Outcome variables: a low intensity combined exercise programme including resistance and coordination training improved the psychological aspects, pain perception, quality of life and physical condition of women with FM.
Marcos-Pardo et al.[45]/ 2019	Resistance training programme in moderate to high-intensity circuit 3 times a week. Outcome variables: muscle strength (1-MR) and lean muscle (bioimpedance).
Sadeghi et al.[46] / 2021	Equilibrium training (EG1), virtual reality ((EG2) and combined training (EG3), 40 minutes duration, 3 times a week. Outcomes: joint flection toque and knee extension (isokinetic dynamometry), equilibrium (one-leg support test and tandem test) and functional mobility (timed up-and-go test and 10-metre gait test).
Kim et al.[47]/ 2022	Passive stretching and resistance training sessions for the hip muscles (EG) or just passive stretching (CG) 3 times a week. Outcomes: muscle rigidity of quadratus lumborum, gluteus medius and hamstrings (hand myometer), lean mass (bioimpedance), flexibility of lumbopelvic region (sit and reach test) and functional capacity (sit and stand test).
Van Roie et al.[48] / 2020	Plyometric training programme (EG1), resistance training (EG2) or gait (CG), 3 times a week. Outcomes: strength of lower limbs (1-MR leg press), lower limb potential (jumping performance), functional ability (battery of functional tests).
Rodriguez-Lopez et al.[49] / 2022	Unilateral potential training programme using leg press with different loads for each lower limb, twice a week. Outcomes: lower limb strength, potential, work and strength/velocity ratio (linear accelerometry and force platform).
Sanudo et al.[51] / 2022	Training for squatting programme using an iso-inertial device, 2-3 times a week, 4 series of 9 repetitions per session. Outcomes: torque and concentric and eccentric joint extension and flexion of the knee (isokinetic dynamometry).
Conlon et al.[52] / 2017	Resistance training programme with undulating periodicity (EG1), in blocks (EG2) or not periodized (CG). Outcome variables: cross-sectional area of the vastus lateralis and rectus femoris (ultrasound); isometric and isokinetic torque peak (isokinetic dynamometry); speed, strength, power and height of jump (vertical jump with force platform); strength development rate in knee extension (isokinetic dynamometry); muscle activation of the vastus lateralis and rectus femoris (electromyography).
Galle et.al.[55]/ 2023	Step count in elderly with low level of physical activity with respect to strength, balance, aerobic capacity and cognition. The participants were designated for 9 months of counselling about exercises or active control. The analyses of the intention to seek treatment increase the level of physical activity, but have no significant effect on physical aptitude or cognition. Those who increased their physical activity by 35% or more showed significant improvement in their aerobic capacity, gait speed, verbal memory, executive functioning and overall cognition.
Nambi et al.[58]/ 2022	Resistance training programme together with low intensity (EG1) or high intensity (EG2) aerobic training 4 times a week. Outcome variables: hand grip strength (hand dynamometry) and cross-sectional areas of the biceps brachii, quadriceps femoris and triceps surae (magnetic resonance).

Frame 2: *Continuação.*

Abbreviations: M - male, F - female, CG – control group, EG –experimental group, IG – intervention group, RCES – randomized controlled experimental study, SG – strength group, RG – resistance group, CG – control group, PE+COG – physical exercise + cognitive training group, COG+PE – cognitive training + physical exercise group, PE – physical exercise, COG – cognitive training group, EXER – exergame, CPE – combined physical exercise, PEG – physical exercise group. MR – maximum repetition.

In the absence of an absolute method to prevent dementia, a healthy lifestyle involving regular physical activity, cognitive activities and balanced diets should be given priority as an alternative to reduce the risks of this declining cognition condition[19]. In a study carried out with the elderly in Japan, one group carried out aerobic exercises associated with supplementation using soy peptides, while another group just carried out the cognitive exercises. The intervention with multicomponent exercises showed beneficial effects on physiological function and also improved

Table 1

Experimental studies as from an adaptation of the Cochrane handbook scale for systematic reviews of interventions (Version 5.1.0)

Author /year published	Type of study	Cochrane Handbook SO/MS	Relative Frequency (%)
Otsuka et al.[12] / 2022	RCES	4/7	57.1
Seo et al.[13]/ 2021	RCES	4/7	57.1
Imaoka et al.[20]/ 2019	RCES	5/7	71.4
Bossers et al.[21] / 2015	RCES	4/7	57.1
Yu et al.[22]/ 2021	RCES	5/7	71.4
Toots et al.[23]/ 2017	RCES	4/7	57.1
Lamb et al.[24]/ 2018	RCES	5/7	71.4
Arazi et al.[30] / 2021	RCES	4/7	57.1
Nilsson et al.[31] / 2020	RCES	4/7	57.1
Liao et al.[32] /2021	RCES	4/7	57.1
Koevoets et al.[38]/ 2022	RCES	4/7	57.1
Izquierdo-Alventosa et al.[42] / 2020	RCES	4/7	57.1
Marcos-Pardo el al.[45]/ 2019	RCES	4/7	57.1
Sadeghi et al.[46] / 2021	RCES	4/7	57.1
Kim et al.[47]/ 2022	RCES	5/7	71.4
Van Roie et al.[48] / 2020	RCES	6/7	57.1
Rodriguez-Lopez et al.[49] / 2022	RCES	5/7	71.4
Sanudo et al.[51] / 2022	RCES	4/7	57.1
Conlon et al.[52] / 2017	RCES	6/7	85.7
Galle et.al.[55]/ 2023	RCES	4/7	57.1
Nambi et al.[58]/ 2022	RCES	4/7	57.1

Abbreviations: SO: score obtained; MS – maximum score; RF –relative frequency; RCES – randomized controlled experimental study

cognitive function as shown by the scores in the TMT-A test (trail test) with p<0.05[20].

With the same perspective, a multidomain intervention study (diet, exercise, cognitive training, and monitoring of vascular risks) showed that the risk of cognitive decline increased in the CG as compared to the EG (odds ratio 1·31, CI 95% 1·01–1·71) in the executive functioning and processing speed domains (p=0.04). Also, the effect of the intervention on the secondary cognitive outcomes increased by 150% for both executive functioning (83%; p=0.039) and processing speed in relation to the control group (p=0.029)[20].

In cases where the individual already showed a condition of absence or progressive memory loss (dementia), a combined aerobic and strength training programme was shown to be beneficial, with a significant improvement in motor function on walking resistance (p<0.049), leg muscle strength (p=0.004) and balance (p=0.024); as well as a significant effect on global cognitive function (p<0.001), visual memory (p=0.008) and executive function (p<0.001)[21].

These findings corroborated with another study that verified the benefits of an aerobic exercise intervention (cycling) lasting 6 months, which significantly reduced the declines in global cognition, attention, processing speed and language (p<0.01) as compared to the natural decline caused by dementia[22], thus demonstrating the positive effect of exercise both in reducing risk factors and in decelerating the evolution of dementia[20,21]. Another explanation for the positive motor and cognitive outcomes in combined exercise interventions could be related to a stronger neuromotor stimulus after the strength exercises, since, in addition to demanding that the patient carry out complex cognitive tasks, motor coordination and balance are incorporated into the tasks, activating both specific cerebellar-cortical connections and cognitive and balance functions[21].

As a counterpart, a programme of high intensity functional exercises carried out during 4 months showed no superior effects on global cognition or executive function in elderly individuals with dementia, when compared with an attention

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control activity[23]. The same outcomes were found in a study with individuals showing slight and moderate dementia applying moderate and high intensity aerobic and strength training, where improvements in physical aptitude were found but no alterations in cognitive compromise[24].

Scientific studies have shown that the regular practise of physical exercise benefit diverse aspects of the lives of the elderly, such as improvements in cardiovascular health, muscle strength, functional capacity and the quality of life, and reductions in mortality[25,26,27]. Also physical exercises can contribute to prevent and treat various chronic diseases common in this age range such as diabetes, osteoporosis and neurodegenerative diseases[28,29]. Four studies indicated an increase in BDNF in treatment periods between 15 minutes and 12 weeks of intervention. The exercises applied were: resistance exercises, running, aerobic exercise, Tai Chi and balance exercises[30,31,32,33]. Of the outcomes evaluated, strength and resistance interventions were efficient in increasing the BDNF ($p = 0.003$, $F = 15.642$), IGF-1 ($p = 0.03$, $F = 16.013$) and platelets ($p = 0.001$, $F = 104.989$)[30]. The BDNF is essential for growth, survival and maintenance of the neurons in the central nervous system, and is related to functions such as brain plasticity, learning ability, memory and mood[34].

Hence increasing the BDNF can have positive effects on brain function and the prevention of neurodegenerative diseases[35,36], and practices such as physical exercise and meditation have been associated with an increase in BDNF[34,35,36]. Also physical exercise with a video game (Exergame) and/or combined physical exercises (resistance, aerobic, Tai Chi and balance exercises) can improve cognitive function in the elderly[32]. The results indicate that the exergame may be even better than the use of combined exercises, especially for global cognition, and changes in the cortical grey matter and in the brain blood flow in the cortical grey matter[32]. Amongst other changes, acute changes in peripheral BDNF were noted after the practise of aerobic exercises[31].

It is well known that the regular practise of aerobic exercise by the elderly can improve cardiovascular health, improve pulmonary capacity and promote mental and emotional well-being[37]. However, with respect to its effect on the CNS, individuals showing greater increases in plasmatic BDNF after aerobic exercise in the pre-test appeared to show greater gains in the cognitive training, but only if each cognitive training session was preceded, not followed, by physical exercise.

Another study showed that after 15 minutes of aerobic exercise, alterations were observed in the blood neurotrophin concentrations of the growth factor similar to insulin 1 (IGF-1), the vascular endothelial growth factor (VEGF) and the brain derived neurotrophic factor (Vidoni et al. / 2022)[33]. The increase in VEGF could improve brain blood circulation, benefiting brain health[38], and IGF-1 has been associated with improvements in cognition, mood and quality of life in studies with elderly patients and those with neuropsychiatric disorders. Practices such as physical exercise and a healthy diet have been related to increases in IGF-1[39].

Physical exercise has shown benefit to women submitted to chemotherapy after breast cancer. Studies have shown that exercise can help reduce fatigue, anxiety, depression and the side effects of chemotherapy, such as a loss of muscle mass and osteoporosis[40]. Another study carried out with exercise (resistance and aerobic) improved self-reported cognitive functioning, physical aptitude, fatigue, quality of life and depression in women with breast cancer[41]. Thus the regular practice of aerobic and strength exercises, such as walking, running, swimming, muscle-strengthening and yoga have been recommended as part of the complementary treatment for women with breast cancer submitted to chemotherapy[40].

With respect to fibromyalgia, a low intensity, 8-week combined exercise programme including resistance training and coordination improved psychological variables, pain perception, quality of life and physical condition[42]. Physical exercise can act positively on the central nervous system, reducing central sensitivity, improving pain regulation and the response to stimuli as well as promoting neuroplasticity, that is, the ability of the brain to adapt and change in response to environmental stimuli[43]. In addition, exercise can improve cognitive function and mood and sleep regulation, both of which are affected in patients with fibromyalgia[43,44].

Motor, health and neuromuscular adaptation responses to an exercise programme

Based on scientific findings, the practice of regular physical exercise can cause positive neuromuscular adaptations in the elderly, such as increases in muscle mass[12,45,46,47], muscle strength[48,49,50], muscle power[48,49,51,52], flexibility[47], rate of strength development[49], drive in the gamma frequency of muscle activation (30-60 Hz)[50], balance[46], functional capacity[13,46,47], decrease in muscle rigidity[47] and an improvement in the electric parameters of the thigh muscle[12]. Hence problems arising from ageing, such as a greater difficulty in carrying out everyday activities, increase in the risk of falls and fractures and a greater dependency on medical care, could be decreased by the practice of physical exercise[53,54,55].

The magnitudes of the increases in muscle mass, strength and power are related to the type, volume and intensity of the exercise and the duration of intervention. In one of the studies which compared 12 weeks of resistance training with intensities of 40 and 80% of the 1-MR, the results indicated a greater effect on muscle strength (1-MR with the leg press exercise) with greater exercise intensities (d of Cohen: 1.29 vs 0.95)[12]. However, under exercise conditions where the total work is equalized, the difference in size of the effect between the conditions tends to be smaller[56]. With respect to the volume of training, the researchers adopted a weekly volume of 3 x 30-40 minute sessions, and it should be mentioned that the concept remains with respect to the dose-dependence effect between the volume of training and muscle mass and strength[57]. Muscle power improved after traditional resistance training interventions[49,51], but when compared with plyometric resistance training intervention, the effects were smaller (mean difference of 10.9% vs 1.2% in the power peak of the vertical jump after the intervention period)[48].

With respect to duration of the intervention, the study with the longest duration carried out 24 weeks of intervention, evaluating muscle mass after 12 and 24 weeks and muscle strength after 4, 8, 12, 16, 20 and 24 weeks[12]. The results indicated that 12 weeks of resistance training were sufficient to significantly increase the cross-sectional area of the quadriceps femoris (mean difference: 2.7 cm^2), and that continuing the training for another 12 weeks resulted in additional increases of 0.8 cm. In the same study, every 4 weeks of resistance training resulted in an increase in muscle strength (1-MR in the leg press exercise) with a Cohen effect size of 0.65 after the first 4 weeks and a total of 1.29 after 24 weeks[12]. Consecutively, after six months of another intervention study, the hand grip strength -3.9 (IC 95% -4.26 to -3.53), kinesiophobia 4.7 (IC 95% 4.24 to 5.15) and quality of life -10.4 (IC 95% -10.81 to -9.9) showed more improvement ($P < 0.001$) with the low intensity aerobic training group than with the high intensity aerobic training group, although for muscle mass, neither of the groups showed any significant difference ($P > 0.05$)[58].

The development of muscle mass, strength and power is important for the elderly, since these adaptations are related to the capacity to carry out everyday activities more easily and with less effort, such as going up and down stairs, sitting down and getting up, picking up objects, carrying objects and walking[56]. Equally important for the improvement in health of the elderly are the increase in flexibility and decrease in muscle rigidity resulting from the practice of physical exercises[47]. These effects can reduce the risk of musculoskeletal injuries in the elderly, since these adaptations allow for a greater amplitude of joint movements and a better response to external stimuli, such as falls and imbalances[53]. Increases in the rate of development of strength and drive in the gamma frequency of muscle activation are also important to maintain the neuromuscular health of the aged[49]. Both these variables indicate a greater efficiency of the neuromuscular system in recruiting and controlling muscle fibres[50].

In 2022 some researchers demonstrated that the use of the squatting exercise twice or three times a week, with 4 series of 9 repetitions, was an adequate way of improving the strength and functional capacity of the aged of both sexes[51]. However, exercise programmes applied to elderly individuals between 70 and 89, reported that their sample of 1,635 elderly individuals presented physical limitations as defined by the criteria of the Short Physical Performance Battery, reporting a score equal or below 9, even when capable of walking 400m. An incidence of

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mobility incapacity was observed in the physical activity group with an energy expenditure in physical activity (PAG) of 30.1% (n=246 elderly individuals) and of 35.5% in the health education group (HEG) (n=290 elderly individuals), but the mobility incapacity was greatly modified after submission to a structured exercise programme[7]. The outcomes demonstrated a reduction in mobility incapacity of 2.6 years in elderly individuals with a risk of incapacity, at the exact moment when searching to verify the effects of comparing physical exercise programmes based on plyometrics for power, strength production, jumping and functional performance based on traditional resistance training (RT) and walking in elderly men. Even having an imminent risk in applying plyometric training to the elderly due to the chance of injury, the results were satisfactory. The data for 1-MR, after application of the protocol, reported greater improvements for RT (25.0 ± 10.0%) and plyometrics (23.0 ± 13.6%) than for walking (2.9 ± 13.7%) ($p < 0.001$)[48].

A study with elderly individuals submitted to an exercise programme for 5 years reported significant increases ($p<0.005$) over the years. The research showed higher percentages in the second year for the 6-minute gait test (6MG) (7.43%), sit and reach test (SR) (383.33%), reach one's back test (RB) (40.33%), forearm flexion (FF) (13.05%) and the rise and sit test (RS) (12.5%) ($p<0.05$). The 6MG, RS, FF, RB, and SR tests improved between 4.17% and 57.6% during all the training periods, and decreased between 3.21% and 85.31% during all the non-training periods[6]. However, using a multicomponent exercise programme (balance, strengthening and stretching exercises) for 4 weeks, as compared to the control group (no exercises), the data showed improvements in the lower (LL) and upper (UL) limbs of the body for flexibility, dynamic balance and agility, although with no significant effect on aerobic resistance or body composition[6].

The use of Pilates or proprioceptive neuromuscular facilitation (PNF) resulted in an increase in functional aptitude, hand grip strength, gait speed and isometric muscle strength in elderly individuals submitted to a 16-week programme[50]. The muscle growth factors, such as follistatin, showed similar results after 16 weeks of resistance training ($p < 0.05$, 0.81; large). The authors suggested that resistance training with an elastic band, based on the body weight, could be an alternative training method for sarcopenia to minimize adverse effects related to age as a function of muscle quality[13].

Elderly athletes of both sexes were systematically submitted to a running programme to verify the impact of running on postural control and balance. The results showed larger peak torque values for the extensor muscles of the trunk at 60◦/s ($p = 0.046$) and 180◦/s ($p = 0.007$) and a relative mean power during extension of the trunk at 60◦/s ($p = 0.008$) and 180◦/s ($p = 0.004$)[9]. Another important factor for the science of the third age is associated with body weight control, since it is well known that the greater the weight of elderly individuals, the greater the mobility difficulties, apart from prejudicing physiological and hormonal factors and the health in general. Thus the control of body weight (kg) could be important for a healthier life. Based on this idea, a controlled random study investigated the effect of 12 weeks of training using a resistance circuit of moderate to high intensity, comparing EG and CG. The authors reported that the sample of 45 individuals (27 women, 18 men) aged between 65 and 75, showed a decrease in fatty mass and increase in lean mass for both sexes. In addition, significant improvements in functional autonomy were observed ($p<0.005$)[45].

Concerning outcomes associated with power, elderly individuals of both sexes submitted to strength training oriented for strength using heavy loads (HL-PT), resulted in greater improvements for 1-MR and F0 (size of effect (SE) = 0.55-0.68; $p < 0.001$) than those verified after strength training oriented for strength using light loads (LL-PT) (SE = 0.27-0.47; $p \leq 0.001$) (post hoc effect of treatment, $p \leq 0.057$)[49]. However, the SE of the alterations in V0 was higher than in LL-PT when compared to UL-PT (SE = 0.71, $p < 0.001$ vs SE = 0.39, $p < 0.001$), but this difference was not statistically different. Both the strength training interventions caused a moderate increase in Pmax (SE = 0.65-0.69, $p<0.001$). Only LL-PT improved early RFD (that is ≤100 ms) and muscle excitation (SE = 0.36-0.60, $p < 0.05$). An increase in area of the muscle cross section

(CSA) was found with both strength training programmes (SE = 0.13-0.35, p <0.035), whereas the pennation angle only increased for the UL-PT (SE = 0…37, p = 0.004)[49]. Another study with elderly individuals of both sexes showed that combined exercise (CE) is comparable to lumbar stabilization exercises (LSE) as an efficient and well-succeeded intervention exercise to decrease muscle rigidity and the P-VAS scores. Also, CE was shown to be more satisfactory than LSE in developing physical function in elderly people with backache[47].

The present study showed some limitations, such as a reduced number of research studies with physical activity programmes advocating the particularities in the cognitive behaviour of the elderly, and similarly a reduced longitudinal accompaniment of the quality of life of the elderly after entering a new lifestyle. Thus, we would have better parameters to establish new techniques with physical exercises and better prognoses. The limitations related to an analysis of bias were the difficulties of the elected studies in reaching a score in domains 6 and 7 of the Cochrane Handbook scale, since different RCES had difficulties in reaching a score referring to internal validity. The strength of this research was the large number of intervention studies aimed at behaviour and motor improvements in old age.

CONCLUSIONS

The regular practice of physical exercise leads to a series of positive neuromuscular adaptations in the elderly. These adaptations include an increase in muscle mass, strength and power and improvements in flexibility, balance and functional capacity as well as a reduction in muscle rigidity. The present study suggests a programme composed of combined strength, resistance and aerobic exercises. Such exercises promote an increase in BDNF, VEGF and IGF-1, as well as leading to improvements in cognition, mood and quality of life during ageing. Thus, the implementation of an exercise programme involving plyometrics and resistance training with greater intensities (equal or greater to 60% of the 1-MR), and an adequate and progressive volume (equal to or greater than 3 x 30-40 minute sessions per week) appears to be promising in providing better cognitive and psychomotor outcomes in the third age.

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JMM – Substantial contribution to the outline of the data collection and interpretation. **KMS** – Took part in writing of the preliminary version. **JCAB** – Took part in approving the final version; data collection; analysis; and a critical review of the intellectual content. **CMO** – Data collection and organization of the method steps and writing of the results. **SF** – Evaluation of bias; analysis and verification of the qualitative synthesis and contribution to the design of the work and writing of the discussion section. **IBN** – Acceptance of the responsibility for the exactness or integrity of each part of the study and final critical review.

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