Exercise and cognitive performance in older adults: a systematic review

Exercício físico e desempenho cognitivo em idosos: revisão sistemática

Alexsander V. Guimarães[1]; Saulo V. Rocha[1,2]; Aline R. Barbosa[3]

ABSTRACT

Objective: The purpose of present study was to conduct a systematic review of reports on the effect of exercise on the cognitive performance of older adults without cognitive impairment. **Methods:** Reports published between January 2008 and October 2013 in PubMed/Medline, SPORTDiscus, Scopus, PsycINFO, SciELO, and LILACS, containing the terms *exercise*, *and physical activity* combined with *cognition, cognitive performance*, *cognitive function*, *and elderly* were reviewed. The search strategy was limited to randomized controlled clinical studies, describing specifically the intensity, duration, and frequency of exercises. **Results:** Five hundred and sixty two reports were identified, of which 83 were subjected to abstract reading, 36 for complete reading, and nine met the inclusion criteria. The results indicate that aerobic (> 30 min, three times a week, minimum of 12 weeks) or resistance (minimum once a week for 12 weeks) exercises imparted positive effects on the cognitive performance among the elderly. **Conclusion:** Aerobic and resistance exercises are non-drug approaches that can improve cognitive performance in the older adults.

Keywords: Aging. Cognition. Physical Activity. Older Adults.

Introduction

Human aging is a deleterious, progressive, multifactorial, and heterogeneous process. This process does not follow the same chronological age in all systems; their various characteristics are influenced by survival bias, gender differences, and historical events in different birth cohorts.[1]

Similarly, cognitive ageing may be the result of behavioural contexts throughout life, alterations in the neural structures, and somatic events such as non-neurological diseases and sensorimotor alterations.[2] It is possible to verify marked individual differences in cognitive performances related to health status, mood, mental stress, educational level, and physical activity.[3,4]

Cognitive alterations do not occur at the same time, and the intensity of decline for all cognitive abilities does not necessarily result in dementia. However, the degeneration of cognitive functions

1. Doutorandos em Educação Física. Programa de Pós-Graduação em Educação Física - Universidade Federal de Santa Catarina (UFSC), Florianópolis, Brasil.
2. Professor Mestre do Departamento de Saúde - Universidade Estadual do Sudoeste da Bahia (UESB) - Campus de Jequié, Jequié, Brasil.
3. Professora Doutora do Centro de Desportos – Programa de Pós Graduação em Educação Física. Universidade Federal de Santa Catarina (UFSC), Florianópolis, Brasil.

Correspondência:
Alexsander Vieira Guimarães.
Núcleo de Pesquisa em Atividade Física e Saúde.
Universidade Federal de Santa Catarina - Centro de Desportos. Campus Universitário - Trindade -
CEP 88040-970. - Florianópolis/SC – Brasil.

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(e.g., perception, attention, memory, language, and executive functions) may compromise the autonomy, quality of life, and independence of the elderly.[2-5] In addition, the care associated with mental health demands costlier and longer-term health services.[6]

Maintenance of cognitive functions is a prerequisite for the independence, quality of life, and health of the elderly. Some events and risk factors may increase the vulnerability of cognitive function over time. In the elderly, the cardiovascular risk factors and diabetes are associated with two leading causes of dementia, namely Alzheimer's disease and vascular dementia.[7]

Some studies[8-14] suggest that regular physical activity and/or exercise[15] can impart neurological benefits and protective effects on the brain, improve cognitive performance, and contribute to the prevention and reduction of cognitive decline. Research studies involving animal models highlight the effectiveness of exercise as a mediator of increased neuronal survival and resistance to brain injury by improving cerebral vascularisation, stimulating neurogenesis[16], and optimizing the oxidative process of proteins.[17] In human models, participation in exercise programs has contributed to the increased perfusion of the frontal areas of the brain and an increase in the volume of the hippocampus.[9,18]

Previous studies have suggested that physical exercise causes significant changes in cognition and, therefore, may serve as a non-drug, low cost, affordable alternative treatment against cognitive decline. These alterations are related to increased memory, attention, the ability to manage multiple tasks, plan future events, and switching between tasks (executive function).[19-21]

Based on these findings, the objective of this study was to conduct a systematic review of the effects of exercise on the cognitive performance of older adults without cognitive impairment.

Methods

Eligibility criteria of the studies

Studies published between January 2008 and October 2013 that investigated the benefits of exercise on cognitive performance in elderly individuals without cognitive impairment. Two previous systematic reviews[30,31] reports on similar topics have previously been published, one with studies published up to 2005 and the other up to 2009. However, not all inclusion criteria were the same, and so the period was chosen between 2008 and 2013 in the present study.

We searched the following databases: PubMed (Medline), SPORTDiscus, Scopus, PsycINFO, SciELO, and LILACS, using the following keywords: *exercise*, *cognition*, *elderly*, previously consulted in the Health Sciences Descriptors (DeCS) and Medical Subject Headings (MESH). The terms *exercise* AND *physical activity* were combined with *cognition* OR *performance cognitive* OR *cognitive function* AND *elderly*. The search strategy was restricted to randomized controlled clinical studies.

The defined inclusion criteria were as follows: a) individuals aged e" 60 years; b) studies published between January 2008 and October 2013; c) interventions involving physical exercise programs, with descriptions of the planning, intensity, frequency, and duration of activities; d) studies that used cognitive performance as an outcome; e) articles published in English and/or Portuguese; and f) randomized controlled clinical studies. The exclusion criteria were as follows: 1) studies in elderly patients with cognitive impairments, neurological, and/or psychiatric disorders; 2) studies that did not examine the effects of exercise on cognitive function; and 3) review and/or systematic review articles.

Two researchers, who independently reviewed potentially relevant studies, conducted the selection process on the studies. The process of the literature search and the strategy for the selection of studies is presented in Figure 1. First, potentially relevant articles were searched for in each database, a subset were then selected for abstract reading, and a further subset were subsequently selected for full reading. Nine articles were selected considering the study objectives and the adopted inclusion/exclusion criteria.

Results

The characteristics of the previous studies examined in the current study are shown in Table 1. The number of participants in the studies ranged from 24 to 230 individuals. The intervention period ranged from 12 to 52 weeks, and the weekly frequency of exercise ranged between one to five times per week.

The studies also differed in the form of assessment of cognitive performance. Different cognitive tests were identified: "*Auditory Verbal Learning Test",*

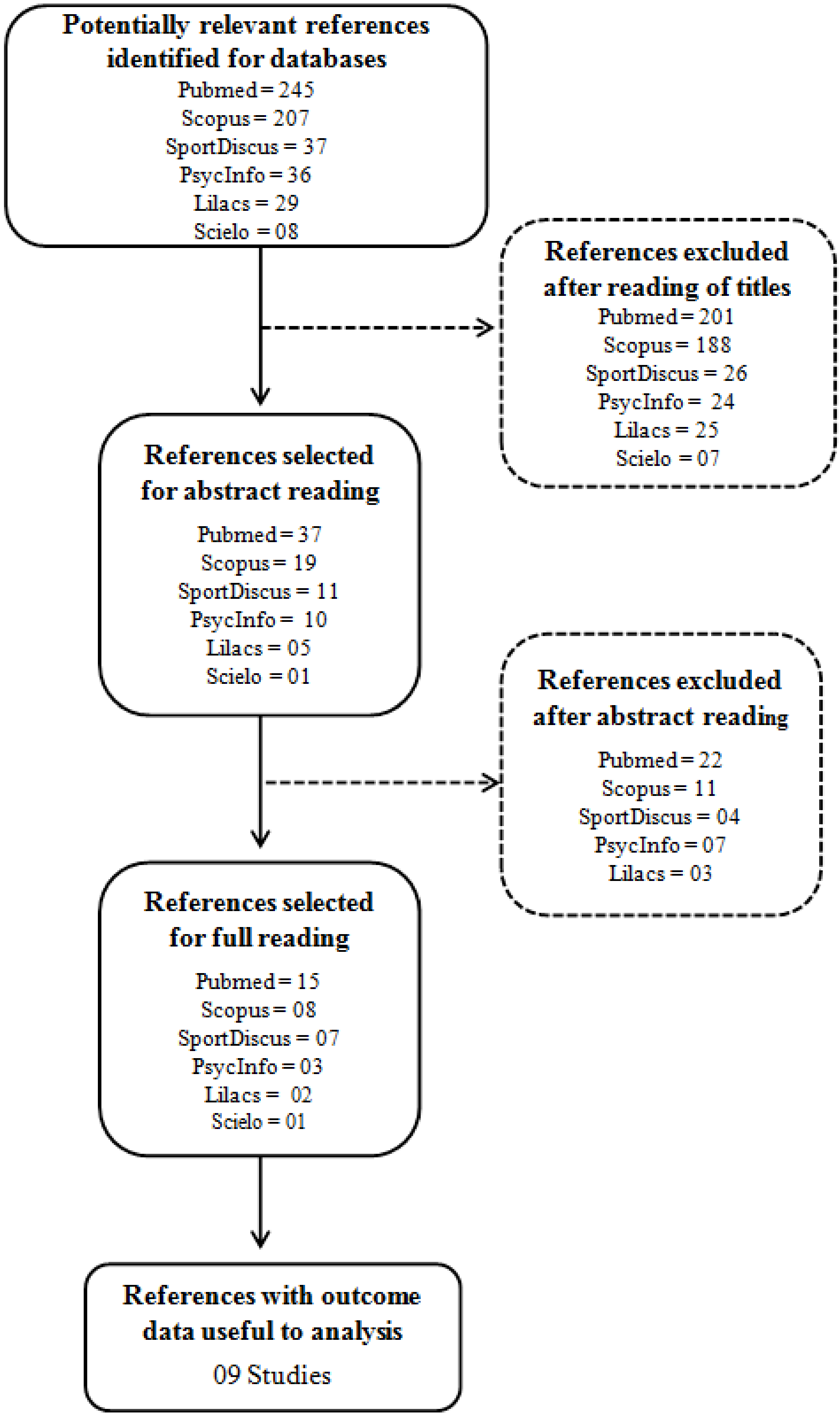

Figure 1. Flow diagram of the literature search.

"Flanker task"; "Free and Cued Selective Reminding Test", "Random number generation task", "Rivermead Behavioural Memory Test", "Stroop Test", "Task-switching test", "*Trail Making Test", "Verbal digits forward and backward" e "Wisconsin card sorting test"*, which involved the assessment of specific cognitive domains such as working and episodic memory, selective attention, executive functions (planning, inhibitory control, and flexibility of thought), information processing speed, and reaction time. The overall assessment of the cognitive status made by the Mini-Mental State Examination (MMSE), heart rate variability (HRV), and magnetic resonance imaging were also used (Table 1).

Of the selected studies, five performed interventions with aerobic exercise[10,22-25] and four with resistance exercise.[26-29]

The study by Albinet et al.[22] compared a controlled intense aerobic exercise program (40-60% of the Heart Rate Reserve - HRR) with stretching exercises, both performed three times a week for 12 weeks, and demonstrated the benefits of aerobic exercise on the executive function and HRV.

Klusmann et al.[24] conducted an aerobic training program combined with strength, flexibility, balance, and coordination exercises in 230 elderly women, three times per week for 24 weeks and compared the findings with that of a group receiving computer classes and another group without any intervention. Cognitive performances were superior in both the intervention groups than in the group without intervention. Subsequently, Evers et al.[23] added other analyses for the same participants and also showed that both interventions imparted positive effects on cognitive performance, especially in working and episodic memory.

Ruscheweyh et al.[10] compared two intervention groups - one employing "nordic walking" with the use of hand-held poles, at an intensity of 50-60% of maximum effort, and another involving gymnastics, including stretching and flexibility exercises, at an intensity of 30-40% of the maximal effort, both held for 50 min, five times per week for 24 weeks - with a control group without exercise. The intervention groups showed better cognitive performances as compared to the group without intervention. Moreover, higher levels of physical activity were positively associated with increases in scores for episodic memory, the volume of grey matter (mainly in the prefrontal cortex), and alterations in the levels of neurotrophic factors.

Liu-Ambrose et al.[28] reported the effect of resistance training in 135 elderly women, where one group trained only once a week and another group twice a week for 52 weeks. The results showed that both groups showed an increase in their selective attention and troubleshooting performances. In another study, Liu-Ambrose et al.[29] showed that resistance exercise, held twice a week, can positively contribute to the functional plasticity of response-inhibitory processes in the cortex.

Forte et al.[26] randomized 42 elderly subjects into two exercise groups; each group performed exercises twice a week for 12 weeks. One group performed resistance training, three sets of eight repetitions, with 60% of 1 repetition maximum (RM) in the initial weeks and 80% in the following. The other group performed balance, coordination, strength, and agility exercises. The results showed that both groups showed positive effects in terms of cognitive performance, especially in the inhibitory function. However, in the study by Kimura et al.[27], which also performed resistance training twice per week for 12 weeks, no significant effects were observed in cognitive performances.

Discussion

This systematic review indicates that both the realization of aerobic physical exercise (held for at least 30 min three times per week for 12 weeks) and resistance exercise (at least once per week for 12 weeks) may have positive effects on the cognitive performances of elderly individuals with no prior cognitive impairment. The exercise was associated with an improvement in executive functions, attention, working memory, and episodic memory.

Two previous systematic reviews[30,31] also showed a relationship between exercise and cognitive performance in elderly individuals without cognitive impairment. The study by Angevaren et al.[30] included 11 studies with interventions that aimed to improve cardiorespiratory fitness and cognitive performance. Tseng et al.[31] reviewed 12 studies, but only six involved elderly individuals with no cognitive impairment.

In our review, five studies used aerobic exercise programs as interventions, which included walking, running, taking steps, and walking with canes, and varied in terms of their intensity, duration, and frequency of exercise.[12,22-25] Two of these studies[23,24] combined aerobic exercises with strength, flexibility, balance, and coordination exercises.

In the study conducted by Albinet et al.[22], the performance of at least 40 min of aerobic exercise reflected an improvement in cognitive performance and heart rate variability (HRV). The exercise program was performed three times per week for 12 weeks, using intensities between 40% and 60% of the heart rate reserve (HRR). HRV has been used as an indicator of autonomous functioning. A low HRV has been associated with a poor regulation of the autonomic nervous system, whereas a high HRV has been associated with better health and preserved cognition. Muscari et al.[25] showed that the performance of aerobic exercise on a treadmill or stationary bicycle for 60 min three days a week for 52 weeks may prevent cognitive decline in elderly individuals without cognitive impairment. However, this study only employed the MMSE, which is a screening tool for dementia and, thus, their approach may have not adequately assessed cognitive functions in the healthy elderly.

With respect to studies using resistance-training[26-29], variations in results were observed. Liu-Ambrose et al.[28] observed a significant increase in cognitive function in elderly individuals who performed exercise for 52 weeks (once or twice/week). In a subsequent study, Liu-Ambrose et al.[29] also showed positive effects in the functional plasticity, selective attention, and conflict resolution of the study participants. The study conducted by Forte et al.[26] showed that resistance training, with circuit of 12 strength exercises alternating muscle groups at 80% 1RM, performed twice per week for 12 weeks, imparted positive effects on cognitive performance, especially in the inhibitory function. Meanwhile, the study of Kimura et al.[26] found no significant effects on cognitive performance in the elderly undergoing resistance exercise. Maybe the reason for this was different training methods which were used, with exercise like leg press, knee extension, hip abduction and rowing and an intensity of 60% of 1 RM.

A number of mechanisms have been suggested to explain the relationship between exercise and cognitive performances, including increased volume of white and grey matter in the prefrontal cortex[8,19], increased plasticity and neural functions[29,32], and increased hippocampal volume, mainly of the anterior part.[9] In addition to increased cerebrovascular circulation and synthesis of several neurotransmitters, the protective effects of exercise on the brain may also reduce the risk of developing neurodegenerative diseases.[33-35]

Although the reports examined in this study showed differences in duration (12-52 weeks), frequency (1-5 times/week), and intensity of activity, the results showed that regular exercise has beneficial effects on the cognitive performance of elderly individuals. However, the tests used to assess cognitive performance and the cognitive domains varied among the reports. The assessment of cognitive performances was aimed to establish a parallel between human brain functions and concepts such as receiving, encoding, storage, repair, and storage of information.[36] The studies included in the current review used these tests. The most frequently evaluated cognitive domain in these studies was the executive function, which is characterized as a set of skills that seamlessly favour the development of behaviours, as well as perform voluntary actions.[36]

Both the process of sample selection and subject allocation in the intervention and control groups were randomly conducted, and only individuals with no cognitive impairment were included. However, the studies by Albinet et al.[22] and Forte et al.[26] included only a small number of participants (24 and 42, respectively), which compromises the external validity of the studies.

Exercise may represent an important non-drug therapy in the prevention of cognitive decline. However, variations in the frequency, intensity, exercise duration, sample size, and ways to assess cognitive performance are some of the limitations that have been identified by some studies investigating the effects of exercise on cognitive performances.[14,20,21]

Conclusion

This review highlighted the efficacy of both aerobic and resistance exercises in improving cognitive performance in older adults. Therefore, it is important to include the practice of aerobic and resistance exercises in health programs designed for the elderly population. However, it is necessary to conduct studies involving different forms of exercise such as resistance training and mixed programs (aerobic and resistance exercise) to establish the dose-response relationship between exercise and cognitive performance.

Tabela 1. **Characteristics of the inclued studies**.

Author, Year	Participants	Intervention	Measures and focus cognitive as reported by authors	Results
Albinet et al., 2010 [22]	24 older individuals (13 women) Age: 70,7 yearsEducation: 12,1 yearsMMSE: 28,8	G1) Aerobic exercise (walking, circuit-training, step and gradually running): 60 min, 3x/week /12 weeks, 40-60% HRR; G2) Stretching exercise: flexibility, balance, and body consciousness, 60 min, 3x/ week /12 weeks.	*Wisconsin Card Sorting Test*: executive performance; *Heart Rate Variability* (HRV)	Only the aerobic training group increased vagal-mediated HRV parameters and executive performance.
Evers et al., 2011 [23]	229 older women Age: 73,5 yearsEducation: 12 years MMSE: 28,8	G1) Aerobic exercise: 30 min bicycle ergometers or treadmills + 60 min of strength, flexibility, balance and coordination training, 3x/week / 24 weeks; individual control of HRM; G2) Computer course: learning how to operate commom software and hardware, 3x/ sem por 24 sem; CG) Control group: no intervention	*Free and Cued Selective Reminding Test:* episodic and working memory; *Rivermead Behavioural Memory Test:* immediate and delayed recall; *Trail Making Test:* executive function.	Both groups of intervention improved their cognitive performance than control group, especially in episodic and working memory.
Forte et al., 2013 [26]	42 older individualsAge: 69,8 yearsEducation: NRMMSE: NR	G1) Resistance training: circuit of 12 strength exercises alternating muscle groups, 3 sets of 8 repetitions at 60-80% 1RM, 2x/week / 12 weeks; G2) Multicomponent training: prioritizing neuromuscular coordination, balance, agility and cognitive executive control, 60 min, 2x/week / 12 weeks.	*Random number generation task:* executive function (inhibition); *Trail Making Test:* attention, speed, and cognitive flexibility.	Both groups showed positive effects in terms of cognitive performance, especially in the inhibitory function.
Kimura et al., 2010 [27]	119 older individuals (70 women) Age: 74,4 yearsEducation: NRMMSE: 27,9	G1) Resistance training: leg press, knee extension, hip abduction and rowing. First phase, low-intensity with high repetition; second phase 3 sets of 10 repetitions 60% de 1RM, third phase addition balance training; all phases with 2x/week / 12 weeks. G2) Health education program: lectures on health promotion, 90 min 2x/week / 12 weeks.	*Task-switching test:* executive function (reaction time).	There were no training effects identified on cognitive performance.

Klusmann et al., 2010 [24]	230 older womenAge: 73,6 yearsEducation: 12,0 yearsMMSE: 28,8	G1) Aerobic exercise: 30 min bicycle ergometers or treadmills + 60 min of strength, flexibility, balance and coordination training, 3x/week / 24 weeks; individual control of MHR; G2) Computer course: learning how to operate commom software and hardware, 3x/ sem por 24 sem; CG) Control group: no intervention	*Free and Cued Selective Reminding Test:* episodic and working memory; *Rivermead Behavioural Memory Test:* immediate and delayed recall; *Trail Making Test:* executive function; *Stroop Test*: executive function (inhibition).	Both intervention groups exhibited better development of performance than the control group in immediate and delayed recall and working memory.
Liu-Ambrose et al. 2010 [28]	135 older womenAge: 69,6 yearsEducation: -MMSE: 28,6	G1) Resistance training (once-weekly): biceps curls, triceps extension, seated row, latissmus dorsi pull downs, leg press, hamstring curls, and calf raises; 2 sets of 6-8 repetition, 52 weeks, 7RM method; G2) Resistance training (twice-weekly): biceps curls, triceps extension, seated row, latissmus dorsi pull downs, leg press, hamstring curls, and calf raises; 2 sets of 6-8 repetition, 52 weeks, 7RM method; G3) Balance and tone: stretching, balance and relaxation exercises, 2x/week / 52 sem.	*Stroop Test*: selective attention;*Trail Making Tests:* psychomotor speed;*Verbal Digits Forward and Backward:* working memory;*Whole Brain Volume:* Magnetic resonance imaging	Both resistance training groups significantly improved their performance on theStroop Test and demonstrated reductions in whole brain volume compared with the balance and tone group.
Liu-Ambrose et al. 2012 [29]	52 older womenAge: 69,3 yearsEducation: -MMSE: 28,9	G1) Resistance training (once-weekly): biceps curls, triceps extension, seated row, latissmus dorsi pull downs, leg press, hamstring curls, and calf raises; 2 sets of 6-8 repetition, 52 weeks, 7RM method; G2) Resistance training (twice-weekly): biceps curls, triceps extension, seated row, latissmus dorsi pull downs, leg press, hamstring curls, and calf raises; 2 sets of 6-8 repetition, 52 weeks, 7RM method;	*Functional magnetic resonance imaging;* *Flanker task*: selective attention;	Resistance training twice-weekly significantly improved their performance on the flanker task. Showing positive functional changes in hemodynamic activity in regions of cortex.

		G3) Balance and tone: stretching, balance and relaxation exercises, 2x/week / 52 sem.		
Muscari et al., 2010 [25]	120 older individuals (58 women) Age: 69,2 yearsEducation: 6,5 yearsMMSE: 26,9	G1) Aerobic exercise (Cycle ergometer or treadmills) 60 min 3x/week / 52 weeks 70% MHR; CG) Educational materials about suggestions to improve lifestyle.	MMSE: Global assessment of cognitive status.	The control group showed a significant decrease in MMSE score. The intervention group stabilized, suggesting that exercise may reduce the age-dependent cognitive decline.
Ruscheweyh et al., 2011 [12]	62 older individuals (41 women) Age: 60,2 years Education: 12,2 yearsMMSE: 29,3	G1) Nordic walking (walking with hand-held poles): 50 min 5x/week / 24 weeks; 50-60% maximal exertion; G2) Gymnastics: exercise program of stretching, limbering, and toning of upper and lower extremities, 50 min 5x/week / 24 weeks; 30-40% maximal exertion. CG) Control group: no intervention	*Auditory Verbal Learning Test:* episodic memory;*Structural Magnetic Resonance Imaging*	Both intervention groups showed improvement performance in the episodic memory that the GC. But no difference was detected between the two intervention groups.

Note: MMSE: Mini Mental State Examination; HRR: Heart Rate Reserve; MHR: Maximum Heart Rate; RM: Repetition Maximum.

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RESUMO

Objetivo: A proposta do estudo foi realizar uma revisão sistemática de estudos que verificaram o efeito do exercício físico no desempenho cognitivo de indivíduos idosos, sem comprometimento cognitivo. **Métodos**: Foram pesquisados estudos publicados entre janeiro de 2008 e outubro de 2013, nas seguintes bases de dados: Pubmed/Medline, SportDiscus, Scopus, PsycInfo, Scielo, Lilacs, com os termos *exercise, physical activity* combinados com *cognition*, *performance cognitive*, *cognitive function* e *elderly*. A estratégia de pesquisa foi limitada a estudos clínicos controlados randomizados, que descreveram, especialmente, a intensidade, duração e frequência dos exercícios. **Resultados**: Foram encontrados 562 artigos nas bases de dados, 83 foram selecionados para leitura do resumo, 36 para leitura completa e nove estudos preencheram os critérios de inclusão adotados. Os resultados apontam que a realização de exercícios físicos, aeróbios (ao menos 30 minutos, três vezes por semana, mínimo 12 semanas) ou contra resistência (mínimo uma vez por semana, por 12 semanas), podem ter efeitos positivos no desempenho cognitivo de idosos. **Conclusão**: Exercícios aeróbios e contra resistência pode representar uma terapia não medicamentosa que pode melhorar o desempenho cognitivo de idosos.

Palavras-chave: Envelhecimento. Cognição. Atividade Motora. Idosos.

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