The effect of exercise intervention on cognitive performance in persons at risk of, or with, dementia: A systematic review and meta-analysis

Nicole C.L. Hess[1], Gudrun Dieberg[1], James R. McFarlane[1], Neil A. Smart[1*]

1 School of Science and Technology, University of New England, Armidale, Australia

Abstract

Background: The aim of this study was to examine the benefits of exercise on the neurocognitive performance of individuals with dementia.

Methods: We conducted a systematic search of PubMed, the Cumulative Index to Nursing and Allied Health Literature, and the Cochrane Central Register of Controlled Trials (1966–2014) using the concepts of dementia, cognitive impairment, cognitive function, and exercise.

Results: Fourteen randomized controlled trials were included, providing data from 1056 individuals. We found that exercise provided significant improvements in the following assessments: mini mental state examination, mean difference (MD) 1.17 (95% confidence interval [CI] 0.75–1.59, $P < 0.00001$); Alzheimer's Disease Assessment Scale, MD −1.41 (95% CI −2.48–−0.34, $P = 0.01$); Clinical Dementia Rating scale, MD −0.37 (95% CI −0.57–−0.16, $P = 0.0004$); similarities subscale of Wechsler Adult Intelligence Scale Revised, MD 2.21 (95% CI 0.75–3.67, $P = 0.003$); arithmetic subscale of Wechsler Adult Intelligence Scale Revised, MD 1.11 (95% CI 0.03–2.20, $P = 0.04$); Amsterdam Dementia Screening Test 6 picture recognition, MD −2.30 (95% CI −3.59–−1.01, $P = 0.0005$); and clock drawing test, MD 0.75 (95% CI 0.45–1.05, $P < 0.00001$).

Conclusions: Physical activity may improve neurocognitive function in people with cognitive impairments.

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* Email: nsmart2@une.edu.au

Introduction

Ranging across a spectrum from mild cognitive impairment (MCI) to Alzheimer's disease (AD), one of the greatest health threats facing the elderly today is cognitive decline [1]. Whilst dementia is not considered part of the normal aging process, age does appear to be the principle risk factor, with the majority of people aged 65 years or older at the time of AD diagnosis [2,3]. The incidence of AD doubles every five years thereafter [2]. After the age of 85 years, the likelihood of being diagnosed with AD is more than one in three [2], and most cases of dementia are diagnosed in this age category [4]. The social and economic costs associated with dementia in the western world are forecast to reach epidemic proportions [1].

Severe, selective cortical atrophy in regions of the brain such as the temporal, medial temporal, limbic, frontal, and prefrontal cortices is one of the hallmarks of neurodegenerative and age-related dementia [5,6].

The functional and cognitive attributes affected by the deterioration of these brain structures include learning, memory, attention, motivation, executive function, motor function, global cognition, and

activities during daily living [5,7]. MCI, which is often a prelude to dementia [8,9], is also associated with disproportionate atrophy in the medial temporal and temporal cortices [6,7]. The severity and extent of dementia-related atrophy increase as a function of time, destroying cognitive and functional abilities at each stage. This damage is irreversible and devastating to both the individual sufferers and their families or carers. Currently, there is no cure for dementia; therefore, it is paramount that researchers identify behavioral interventions that can prevent, attenuate, or impede the progression or genesis of this condition.

While not fully understood, several mechanisms have been identified that underlie the neurocognitive benefits of physical activity. These include the promotion of neurogenesis, angiogenesis, synaptogenesis, neurotrophin production [10], and the mitigation of vascular risk factors that promote increased cerebral perfusion. The three processes of neurogenesis, angiogenesis, and synaptogenesis are also integral in neurorepair processes [11].

Physical activity stimulates the upregulation of several neurotrophic agents: brain-derived neurotrophic factor, which plays an integral role in the nurturance, survival, and plasticity of neurons within the central nervous system and modulates neuritic outgrowth and synaptic function [12,13]; insulin-like growth factor, which promotes the growth and differentiation of cells and is widely expressed in the human brain [14]; and vascular endothelial growth factor, an angiogenic growth factor that generates new blood vessels and promotes increased collateral circulation [11].

Physical activity that targets cardiovascular fitness (peak VO_2) may offer neuroprotective benefits and attenuate the neuronal structural and functional changes that are associated with MCI and dementia [15-17]. Evidence from animal models has demonstrated that aerobic exercise can increase neurogenesis, angiogenesis, learning, and memory in rats [18,19] and inhibit the progression of Alzheimer's-related neuropathology in mice [20]. The current literature reports that exercise, taken up in midlife by healthy adults, increases cognitive functioning in various domains and reduces the likelihood of developing dementia later in life [21]. Recently, a growing number of randomized controlled trials have focused on the impact of physical activity on the neurocognitive performance of individuals at risk of, and living with, dementia. The literature offers

mild support for exercise as an attenuating or stabilizing intervention for certain cognitive domains [22].

Unfortunately, it is difficult to draw meaningful comparisons about the efficacy of physical activity from the current literature because inconsistencies exist across the studies, in terms of the intervention, neurocognitive outcome measure, statistical reporting method, and disease severity and associated levels of care. For example, a 2008 systematic review from van Uffelen et al. investigated the effects of physical activity on neurocognitive outcomes in individuals diagnosed with MCI or AD, but it only included studies up until early 2008 [23]. A 2011 systematic review on the effects of exercise on cognitive decline was conducted, but the participants were non-demented people [24]. In 2013, Breher et al. conducted a systematic review on exercise training effects on cognition, but data pooling was not performed [25]. The 2013 updated Cochrane review by Forbes et al. assessed changes in cognition, activities of daily living, behavior, depression, and mortality [26]. However, the cognition data were generated and pooled from several different tests of cognition, and a standard mean difference (% change) was used to adjust for the different scoring scales [26].

The lack of recent in-depth publications in this area necessitates a clinical update. Therefore, we conducted a systematic review and meta-analysis that included all published randomized controlled trials up to June 1, 2014. The primary aim was to quantify the expected neurocognitive benefits of physical activity on individuals with cognitive decline and/or dementia. We have taken the unique approach of separately analyzing the different tests of cognitive function.

Methods

Search strategy

Potential studies were identified by conducting a systematic search of PubMed from 1966–2014 (www.ncbi.nlm.nih.gov/pubmed; the search strategy is included in Suppl. Data). The Cumulative Index to Nursing and Allied Health Literature and the Cochrane Central Register of Controlled Trials were also searched (1966–2014). The search strategy included the key concepts of AD, dementia, MCI, exercise training, and physical activity as an intervention. These were combined with a sensitive

search strategy to identify randomized controlled trials. We also scrutinized the reference lists from the papers found for new references. All identified papers were assessed independently by two reviewers (NS and NH). The search of published papers was conducted up until June 1, 2014.

Inclusions

Randomized controlled trials of physical activity intervention in people with MCI or dementia were included. There were no language restrictions.

Exclusions

Animal studies, studies involving healthy individuals, studies that did not have the desired outcome measures, studies that included participants who were non-demented or without cognitive impairment in any allocation group, review papers, and non-randomized controlled trials were excluded. Several authors were contacted to provide missing data or to clarify whether the data was duplicated in multiple publications by the same author or research group; four authors failed to provide the requested information. Incomplete data or data from an already included study were excluded. Studies using interventions other than physical activity were also excluded, e.g., music, handicrafts.

Studies included in the review

Our initial search identified 269 manuscripts, and examination of the latest editions of relevant journals yielded a further 12 manuscripts. Out of the total 281 studies, six were excluded at first inspection as duplicates, 188 were removed after reading the titles or abstracts, and 52 studies were not trials of exercise therapy in cognitively impaired or demented adults. Of the remaining 35 studies, four were not randomized controlled trials, four studies used healthy controls, and 13 studies failed to report the outcome data in a format that allowed meta-analysis. When the authors were contacted, they did not provide the information requested, leaving 14 studies for our analysis (see the consort statement in Suppl. Data).

Data analysis

The data relating to cognitively impaired patients undertaking physical activity versus sedentary

controls were reviewed and archived in a database. All of the data from cognitive performance tools were pooled. Only the analyses that demonstrated a statistically significant post-intervention change and included more than one study are reported in the results section. Egger plots of the significant analyses can be found in Suppl. Fig. 1-8.

Statistical analysis

Meta-analyses were completed for the continuous data by calculating the change in the means and standard deviations of the outcome measures because we did not want to assume that all allocation groups were matched at baseline. Changes in the post-intervention means were calculated by subtracting the baseline from the post-intervention values. Changes in the standard deviations of the post-intervention outcomes were calculated using RevMan 5.0 (Nordic Cochrane Centre Denmark). The data were required to have: (i) a 95% confidence interval [CI] for the pre-post intervention change for each group, or when this was unavailable, (ii) actual P-values for the pre-post intervention change for each group, or if only the level of statistical significance was available, (iii) we used default P-values, e.g., $P < 0.05$ became $P = 0.049$, $P < 0.01$ became $P = 0.0099$, and $P =$ not significant became $P = 0.05$. A random effects inverse variance was used with the effects measure of the mean difference. Heterogeneity was quantified using Cochrane's Q test (I^2). Egger plots were made to assess the risk of publication bias (see Suppl. Data). The study quality was assessed using a modified PEDro score (out of a maximum score of 9) because blinding was difficult in the intervention studies. We used a 5% level of significance and 95% CI; all figures were produced using RevMan 5.

Results

Our analyses included data from 14 studies, totaling 1056 participants. The included studies provided data on 548 elderly men and women, with varying severities of cognitive impairment or AD, who participated in physical activity and 508 elderly men and women control participants, with varying severities of cognitive impairment or AD. One study reported on participants with severe AD [27], and two studies reported on participants with a range of severe-to-mild AD [28,29]. Three reports included

participants with moderate-to-mild dementia [30-32], three studies reported on individuals with amnestic MCI and mild dementia [33-35], and one study reported on participants with a range of moderate-to-mild cognitive impairment and mild dementia [36]. One study reported on individuals with a range of moderate-to-mild cognitive impairment [37], another study reported on participants with MCI and mild dementia [38], and two reported on individuals with MCI only [39,40].

The study durations ranged from 6 weeks to 12 months, and the type of physical activity program varied between studies. The physical activities included walking, varied intensity aerobic training, strength training, flexibility training, postural balance training, and Tai Chi. In most studies, these activities were thoroughly monitored using either qualified instructors, exercise therapists, or physiotherapists; however, one trial also encouraged home-based participation, and another was an exclusively home-based exercise intervention. The physical training sessions were conducted 2–4 times per week, and each lasted from 30–60 minutes per session. The control groups varied in nature across all of the studies: six were of a sedentary nature, two included social visits, two included recreational activities such as handicrafts and cards, and one group participated in stretching and toning exercises. Details of the included studies can found in Suppl. Table 1. A list of excluded studies [32,41-60] can be also found in Suppl. Table 2. Using a modified PEDro scale (out of 9) to assess the quality of the studies, one study scored 5, five studies scored 6, five studies scored 7, and three studies scored 8 (Suppl. Table 3).

Mini mental state examination (MMSE)

Our analysis revealed that physical activity was associated with significant improvements in MMSE scores compared to the control groups; the mean difference (MD) was 1.17 (95% CI 0.75–1.59, $P < 0.00001$; Fig. 1). A sensitivity analysis (removing the Lam and Suzuki studies) reduced the heterogeneity while retaining the statistical significance, MD 2.28 (95% CI 1.68–2.88, $P < 0.00001$; Supp. Sub-Analysis 1).

Cognitive subscale of the Alzheimer's Disease Assessment Scale (ADAS-cog)

We found that physical activity was associated with significant improvements in ADAS-cog performance compared to the control groups; MD −1.41 (95% CI −2.48–−0.34, $P = 0.01$; Fig. 2).

Clinical Dementia Rating scale (CDR) - sum of boxes

The data from the CDR showed that physical activity was associated with significantly improved scores compared to the sedentary control groups; MD −0.37 (95% CI −0.57–−0.16, $P = 0.0004$; Fig. 3). Of the two studies analyzed, one study reported a significant improvement in CDR scores in the intervention group compared to a significant decline in scores in the control group, while the other study reported a marginal improvement in CDR scores in the intervention group compared to a marginal decline in scores in the control group.

Wechsler Adult Intelligence scale revised (WAIS-R) - similarities subscale

Physical activity was associated with a significant improvement in performance on the similarities subscale of the WAIS-R compared to a marginal decline in the control group. The absolute change in score between the intervention and control groups was significant; MD 2.21 (95% CI 0.75–3.67, $P = 0.003$; Fig. 4).

Wechsler Adult Intelligence scale revised (WAIS-R) - arithmetic subscale

On the arithmetic subscale of the WAIS-R, physical activity was associated with a significant improvement in performance compared to a marginal decline in the control group. The absolute change in score between the groups was significant; MD 1.11 (95% CI 0.03–2.20, $P = 0.04$; Fig. 5).

Amsterdam Dementia Screening Test (ADS 6) - picture recognition

ADS 6 (picture recognition) was significantly improved with physical activity versus the control groups; MD −2.30 (95% CI −3.59–−1.01, $P = 0.0005$; Fig. 6).
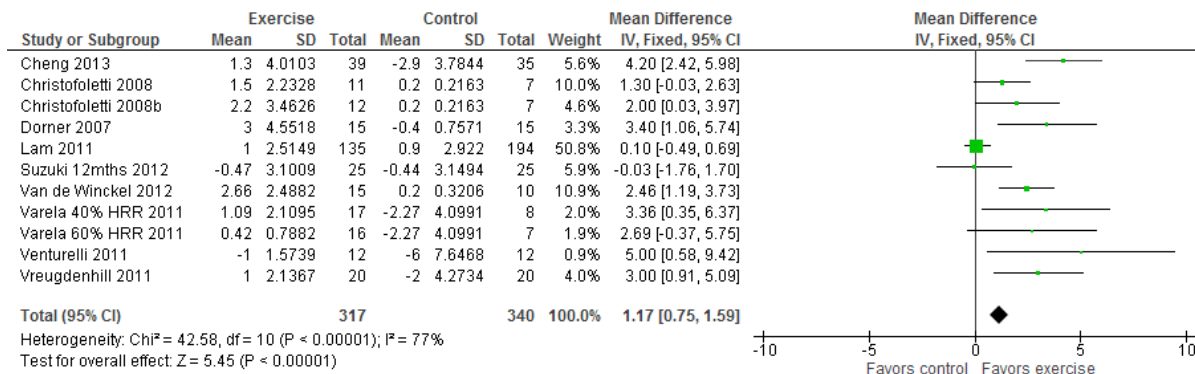
Study or Subgroup	Exercise Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Cheng 2013	1.3	4.0103	39	-2.9	3.7844	35	5.6%	4.20 [2.42, 5.98]
Christofoletti 2008	1.5	2.2328	11	0.2	0.2163	7	10.0%	1.30 [-0.03, 2.63]
Christofoletti 2008b	2.2	3.4626	12	0.2	0.2163	7	4.6%	2.00 [0.03, 3.97]
Dorner 2007	3	4.5518	15	-0.4	0.7571	15	3.3%	3.40 [1.06, 5.74]
Lam 2011	1	2.5149	135	0.9	2.922	194	50.8%	0.10 [-0.49, 0.69]
Suzuki 12mths 2012	-0.47	3.1009	25	-0.44	3.1494	25	5.9%	-0.03 [-1.76, 1.70]
Van de Winckel 2012	2.66	2.4882	15	0.2	0.3206	10	10.9%	2.46 [1.19, 3.73]
Varela 40% HRR 2011	1.09	2.1095	17	-2.27	4.0991	8	2.0%	3.36 [0.35, 6.37]
Varela 60% HRR 2011	0.42	0.7882	16	-2.27	4.0991	7	1.9%	2.69 [-0.37, 5.75]
Venturelli 2011	-1	1.5739	12	-6	7.6468	12	0.9%	5.00 [0.58, 9.42]
Vreugdenhill 2011	1	2.1367	20	-2	4.2734	20	4.0%	3.00 [0.91, 5.09]
Total (95% CI)			**317**			**340**	**100.0%**	**1.17 [0.75, 1.59]**

Heterogeneity: Chi² = 42.58, df = 10 (P < 0.00001); I² = 77%
Test for overall effect: Z = 5.45 (P < 0.00001)

Figure 1. Change in MMSE: physical activity versus control

Study or Subgroup	Exercise Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Lam 2011	-1.9	6.5606	135	-1.3	5.4181	194	63.2%	-0.60 [-1.94, 0.74]
Lautenschlager 2008	-0.87	4.4507	48	1.29	5.0534	52	32.9%	-2.16 [-4.02, -0.30]
Vreugdenhill 2011	-4.2	8.9741	20	4	8.5467	20	3.9%	-8.20 [-13.63, -2.77]
Total (95% CI)			**203**			**266**	**100.0%**	**-1.41 [-2.48, -0.34]**

Heterogeneity: Chi² = 8.02, df = 2 (P = 0.02); I² = 75%
Test for overall effect: Z = 2.58 (P = 0.010)
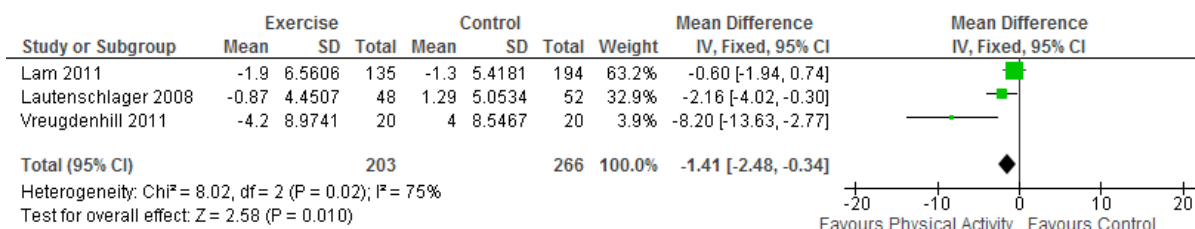
Figure 2. Change in ADAS-Cog: physical activity versus control

Study or Subgroup	Exercise Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Lam 2011	-0.2	0.6907	135	0.2	1.4124	194	76.7%	-0.40 [-0.63, -0.17]
Lautenschlager 2008	-0.24	1.0663	48	0.01	1.0663	52	23.3%	-0.25 [-0.67, 0.17]
Total (95% CI)			**183**			**246**	**100.0%**	**-0.37 [-0.57, -0.16]**

Heterogeneity: Chi² = 0.38, df = 1 (P = 0.54); I² = 0%
Test for overall effect: Z = 3.55 (P = 0.0004)
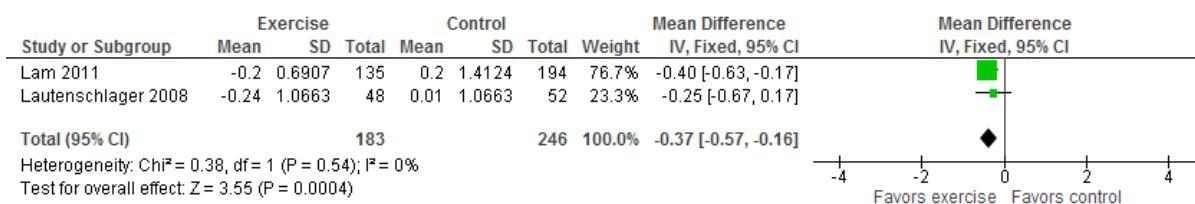
Figure 3. Change in CDR-sum of boxes: physical activity versus control

Study or Subgroup	Exercise Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Brown (FR) 2012	1.4	3.5929	26	-0.1	3.2803	17	49.1%	1.50 [-0.58, 3.58]
Brown (GE) 2012	2.8	5.4866	66	-0.1	3.2803	17	50.9%	2.90 [0.85, 4.95]
Total (95% CI)			**92**			**34**	**100.0%**	**2.21 [0.75, 3.67]**

Heterogeneity: Chi² = 0.88, df = 1 (P = 0.35); I² = 0%
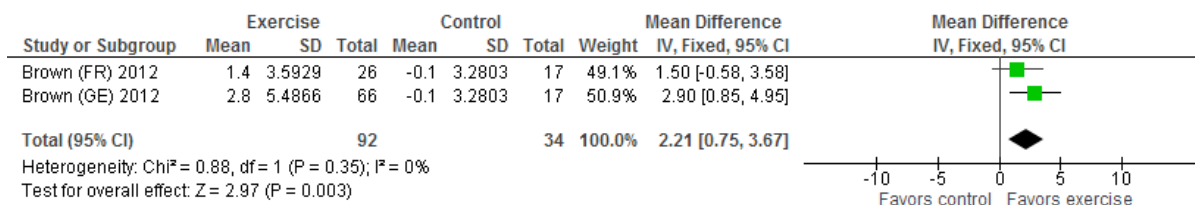Test for overall effect: Z = 2.97 (P = 0.003)

Figure 4. Change in WAIS-R (similarities): physical activity versus control

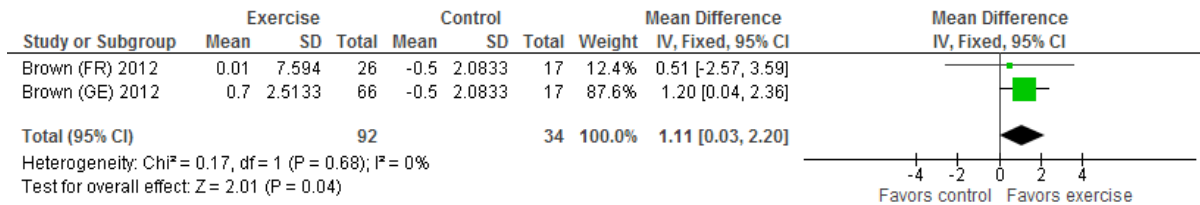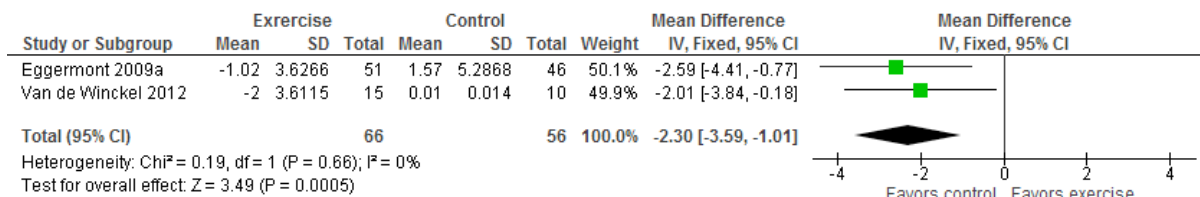*FR = flexibility and relaxation training, GE = general exercise*

Study or Subgroup	Exercise Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Brown (FR) 2012	0.01	7.594	26	-0.5	2.0833	17	12.4%	0.51 [-2.57, 3.59]
Brown (GE) 2012	0.7	2.5133	66	-0.5	2.0833	17	87.6%	1.20 [0.04, 2.36]
Total (95% CI)			92			34	100.0%	1.11 [0.03, 2.20]

Heterogeneity: Chi² = 0.17, df = 1 (P = 0.68); I² = 0%
Test for overall effect: Z = 2.01 (P = 0.04)

Figure 5. Change in WAIS-R (arithmetic): physical activity versus control

FR = flexibility and relaxation training, GE = general exercise

Study or Subgroup	Exercise Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Eggermont 2009a	-1.02	3.6266	51	1.57	5.2868	46	50.1%	-2.59 [-4.41, -0.77]
Van de Winckel 2012	-2	3.6115	15	0.01	0.014	10	49.9%	-2.01 [-3.84, -0.18]
Total (95% CI)			66			56	100.0%	-2.30 [-3.59, -1.01]

Heterogeneity: Chi² = 0.19, df = 1 (P = 0.66); I² = 0%
Test for overall effect: Z = 3.49 (P = 0.0005)

Figure 6. Change in ADS 6 (picture recognition): physical activity versus control

Study or Subgroup	Exercise Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Fixed, 95% CI
Christofoletti 2008	0.6	0.8931	11	-0.5	0.5406	7	20.7%	1.10 [0.44, 1.76]
Christofoletti 2008b	0.1	0.1574	12	-0.5	0.5406	7	54.0%	0.60 [0.19, 1.01]
Stevens 2006	0.125	1.3346	24	-0.6667	0.6316	21	25.4%	0.79 [0.19, 1.39]
Total (95% CI)			47			35	100.0%	0.75 [0.45, 1.05]

Heterogeneity: Chi² = 1.60, df = 2 (P = 0.45); I² = 0%
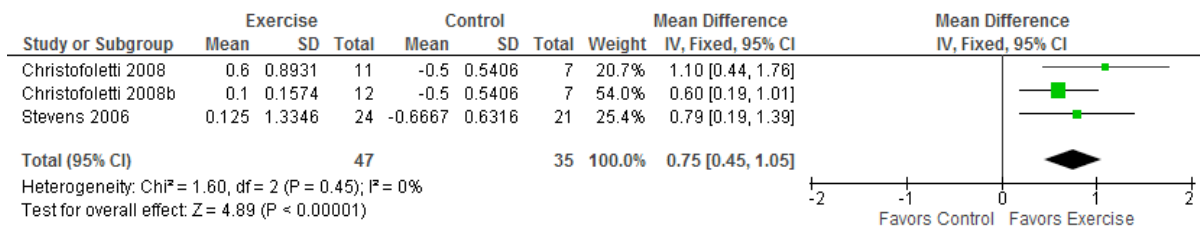Test for overall effect: Z = 4.89 (P < 0.00001)

Figure 7. Change in clock drawing test: physical activity versus control

Clock drawing test (CDT)

While exercise did not significantly improve cognitive performance in relation to clock-drawing, a significant decrease in clock-drawing ability was observed in the control subjects compared to the exercise group; MD 0.75 (95% CI 0.45–1.05, P < 0.00001; Fig. 7).

ADS 6 - drawing alternating sequences

Only one study used the drawing of alternating sequences as a readout. We found that there was a significant improvement in performance in the physical activity versus the control group; MD 1.99 (95% CI 0.16–3.82, P = 0.03).

Rapid Evaluation of Cognitive Function- French version (ERFC)

There was a significant improvement in the physical activity versus the control group in the one study that used the ERFC as its evaluation tool; MD 8.67 (95% CI 4.56–12.78, P < 0.0001).

The following cognitive testing measurements did not report any significant post-intervention differences between the individuals who undertook physical activity and the control subjects: visual span forwards, visual span backwards, verbal fluency (category), verbal fluency (letter), Chinese trail making B, word list delayed recall, digit symbol coding, digit span forwards, digit span backwards, logical memory of

immediate recall (WMS-LM I), logical memory of delayed recall (WMS-LM II), stroop colour word test (SCWT-colour), orientation in time/space, copying figures, ERFC, and free recall subscales.

Study quality

The median study quality score was 7 (Suppl. Table 3).

Egger plots

There was a minimal suggestion of publication bias, which is shown on the Egger Plots in Suppl. Fig. 1-8).

Discussion

To the best of our knowledge, this study is the first meta-analysis that specifically focused on cognitive-related outcomes in elderly individuals diagnosed with MCI, amnestic MCI, and/or dementia or AD. The findings are pertinent because cognitive performance is arguably the most important outcome measure in people with a cognitive impairment. Previous analyses have reviewed the effects of exercise training across a range of functional- and health-related outcomes for mixed populations of healthy-to-demented individuals. Our pooled data analysis showed significant improvements in nine neurocognitive measurement scores in the participants who completed physical activity versus the control groups. With the exception of the MMSE (Fig. 1), our analyses were justified because the heterogeneity between studies was low. We conducted a sensitivity analysis on the MMSE and removed the studies by Lam [34] and Suzuki [33], which appeared to be a major source of heterogeneity for this scale. This strengthened the effect size for this measurement. A significant improvement in the global measures was particularly notable; most of the subscales and narrow outcome measures did not show any significant differences. However, the subscale-type outcomes failed to reveal any measures where the control group performed better than the participants that underwent physical activity: either the non-significant trends favored the exercise group or the outcomes were similar. Our work demonstrates that physical activity has an aggregate benefit, supporting a growing body of literature that posits the therapeutic benefits of physical activity on cognitive performance outcomes [22-24,61-63].

Cognitive improvements were observed across several neurocognitive domains, including attention (ADS-6 drawing alternative sequences), executive function (CDT and ADS-6 verbal fluency), and fluid intelligence (WAIS-R similarities and arithmetic). We also found improvements in global cognition (MMSE, ADAS-cog, and ERFC) and clinical dementia ratings (CDR). Across all of the studies, the measurements of global cognition were the most robust in terms of detecting significant changes in cognitive performance. For example, of the nine studies that used a global cognitive measurement tool, seven reported significant results, irrespective of the severity of the cognitive impairment of the participants and the physical activity performed. It may be that global tests of cognition are inherently the most sensitive to changes in cognitive performance because they take into account numerous cognitive domains.

Analyses using the WAIS-R (similarities and arithmetic), ADS-6 category fluency, and clock drawing tests all demonstrated sufficient sensitivity to detect changes in executive function between the physical activity and control groups. All three tools showed physical activity improved executive function. While memory performance was reported in four studies, none of these studies observed significant absolute differences between the intervention and control groups. Memory is the cognitive domain most significantly impaired in MCI and in early stages of dementia, whereas executive functions tend to falter in the later stages of AD [6,64].

Recent MRI studies have reported an association between medial temporal deterioration and cardiovascular fitness [17] and an association between increased cardiovascular fitness and reduced brain atrophy in AD [16]. The spectrum of physical training interventions adopted in these trials included Tai Chi, flexibility, relaxation, balancing techniques, and varying intensities of aerobic exercise and strength training. Consequently, not all of the physical activities reported are considered aerobic; despite this, there was still evidence of improvement in certain domains (executive function) of cognitive function. Unfortunately, the notable variation in the modalities of physical intervention prevented speculation regarding which exercise modality was optimal.

Limitations

The relatively small pooled sample size of this analysis may have reduced our ability to detect significant effects. Data pooling from a number of related studies is one method to counteract the pitfalls of small sample sizes; however, this method is most effective when comparable interventions and outcome measures are used across most, if not all, studies. The Cochrane I2 values in our analyses suggest that, except for the MMSE analysis (Fig. 1), all of the studies were appropriate for data pooling. Indeed, removal of the largest studies by Lam et al. and Suzuki et al. reduced the heterogeneity to 0% (Suppl. Sub-Analysis 1). In the current analysis, there was considerable variation between the studies in a number of areas: type and version of neurocognitive testing tool, mode of physical intervention, time period of the intervention, data reporting method, definition of the control group (e.g., sedentary, handicrafts, stretch, or tone), and severity of the cognitive impairment and dementia among the participants. Individuals with MCI may be more inclined to engage in physical activity and at a higher level (i.e., less apathy, which is common in severe dementia). Moreover, the benefit of the intervention may differ depending on the degree of neuronal loss (i.e., individuals with advanced dementia may be too ill to benefit). Finally, there may have been a Hawthorne effect, where the improved clinical trial outcome was simply due to interaction with the participants. More attention and interaction may have influenced their motivation to perform on the tests and influenced the scoring of the global assessments.

Suggestions for future research

While aerobic exercise has been heralded as delivering neuroprotective benefits and attenuating the neuronal, structural, and functional changes associated with dementia and MCI, the results of our analysis suggest that other modes of physical activity may also have the capacity to deliver similar benefits. Because of the considerable variation in physical activity programs, it was not possible to draw any specific conclusions about which physical activity program was optimal. Therefore, future research should use a standardized approach to investigating and comparing the efficacy of different exercise modalities on cognitive performance.

Conclusions

Our analysis lends further support to the suggestion that physical activity may be an effective therapeutic intervention tool for individuals diagnosed with cognitive impairment and dementia.

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