The effects of exercise training on elderly persons with cognitive impairment and dementia: A meta-analysis1

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META-ANALYSIS

The Effects of Exercise Training on Elderly Persons With Cognitive Impairment and Dementia: A Meta-Analysis

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ABSTRACT. Heyn P, Abreu BC, Ottenbacher KJ. The effects of exercise training on elderly persons with cognitive impairment and dementia: a meta-analysis. Arch Phys Med Rehabil 2004;85:1694-704.

Objective: To determine by meta-analysis whether physical exercises are beneficial for people with dementia and related cognitive impairments.

Data Sources: Published articles and nonpublished manuscripts from 1970 to 2003 were identified by using electronic and manual searches. Key search words included *exercise, rehabilitation, activities of daily living, dementia, Alzheimer's disease, aged*, and *geriatrics*.

Study Selection: Reviewed studies were limited to randomized trials evaluating exercise in persons 65 years of age or older with cognitive impairment. Studies included quantitative results (means, standard deviations, *t* tests, F tests) for physical fitness, physical functioning, cognition, or behavior outcomes.

Data Extraction: One reviewer extracted data on study characteristics and findings. Selected articles were evaluated for methodologic quality by 2 raters.

Data Synthesis: A total of 2020 subjects participated in the 30 trials that met the inclusion criteria. Summary effects were computed using a fixed effects (Hedge's g_i) model. Significant summary effect sizes (ES) were found for strength (ES=.75; 95% confidence interval [CI], .58–.92), physical fitness (ES=.69; 95% CI, .58–.80), functional performance (ES=.59; 95% CI, .43–.76), cognitive performance (ES=.57; 95% CI, 0.43–1.17), and behavior (ES=.54; 95% CI, .36–.72). The overall mean ES between exercise and nonexercise groups for all outcomes was .62 (95% CI, .55–.70).

Conclusions: Exercise training increases fitness, physical function, cognitive function, and positive behavior in people with dementia and related cognitive impairments.

Key Words: Alzheimer disease; Dementia; Exercise; Meta-Analysis; Rehabilitation.

THE INCIDENCE OF DEMENTIA increases with age and it presents a major public health problem[1] that impacts people's ability to maintain occupational and social function.[2] Patients can live up to 20 years with advancing dementia, with Alzheimer's disease being the most prevalent and devastating form.[3] Exercise has multiple positive effects in older adults, including those with disabilities.[4-9] More precisely, exercise prevents and reduces the risk of developing secondary conditions that arise from functional decline and physical disuse.[9,10]

Regular exercise that focuses on functional fitness, such as walking, has been associated with significant reductions in the levels of dependence and disability in older adults.[11,12] The relations among physical fitness levels, specifically aerobic fitness, cognition, and physical health in older adults, is well established.[13-22] There is also empirical support for exercise improving physical fitness,[23-30] behavior,[23,31-34] cognition,[35-40] communication,[24,30,41] and functioning[26,34,42-44] in older people with cognitive impairments.[45]

Cross-sectional and longitudinal data have demonstrated that physically active people have a lower risk of developing Alzheimer's disease and related cognitive disorders when compared with sedentary people.[46-51] Aerobic fitness training appears to have an association with reduced brain tissue loss in aging humans.[46] A recent meta-analysis[45] examined and supported the positive effect of physical fitness training on cognitive function of older adults.

There is a growing body of research suggesting that some risk factors for heart disease and stroke are associated with the development of Alzheimer's disease and related disorders.[52-56] For instance, Kalmijn et al[57] and Sparks[58] have reported that hyperlipidemia is a risk factor for dementia. Countries that have high dietary fat consumption also tend to have a higher prevalence of dementia.[54] These findings have led to the hypothesis that physical activity strategies designed to prevent and manage cardiovascular disease might also be effective in the prevention and management of dementia. If confirmed, the research would be similar to that conducted in the 1970s and 1980s that positively linked changes in lifestyle to the prevention of cardiovascular disease and related conditions, such as diabetes and hypertension.[59-62]

Persons with cognitive disorders as a consequence of cognitive decline often need long-term care that leads to institutionalization. Nursing homes and most institutional settings generally lack proper environmental stimulation and physical activity opportunities.[11,63-66]

Despite the growing evidence on the benefits of exercise for the health and functioning of older adults with cognitive disorders, the available literature lacks clinical evidence that supports recommendations for exercise guidelines and testing in older persons with dementia and related cognitive impairments.[67] One possible reason for the absence is the lack of a research consensus. Studies on exercise and Alzheimer's disease or related dementia often include small sample sizes and report inconsistent positive findings. No meta-analytic review has been conducted on the impact exercise has on combined physical, social, and cognitive outcomes in persons with de-

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mentia. Previous quantitative reviews[11,68-70] focused on young persons, included older adults with multiple health conditions, or excluded older adults with cognitive impairments. None of these reviews focused on the older adult with Alzheimer's disease or related dementia. The purpose of the present study was to synthesize the available evidence on the effects of exercise training for cognitively impaired older adults. The findings should be useful in establishing guidelines and recommendations for exercise training in older adults with Alzheimer's disease and dementia.

METHODS

Data Sources

Computer-aided searches[71] were conducted using the following databases: PubMed, MEDLINE, Ageline, CINAHL, PsycLIT, PsycINFO, Sport Discuss (SIRC/CDC), Cochrane Register, PEDro, Educational Resources Information Center, and Dissertation Abstracts International. An extensive manual search and cross-referencing from review and original articles were also performed. Articles not written in English were excluded.

The key words used in the search of computerized databases included *physical activity*, *physical therapy*, *exercise*, *fitness*, *rehabilitation*, *aerobic*, *strength*, *flexibility*, *functional performance*, *activities of daily living*, *behavior*, and *cognition*. These key words were combined with the following words: *aged*, *aging*, *older*, *elderly*, *adult*, *nursing home residents*, *geriatric*, *psychiatric*, *mental*, *dementia*, *Alzheimer's disease*, *cognitive impairment*, *memory impairment*, *mild cognitive impairment*, and *organic brain disorder*.

Study Selection

Criteria for inclusion. The inclusion criteria were (1) randomized trials that included a nonintervention control or comparison group or control or comparison period; (2) subjects older than 65 years; (3) studies that reported a baseline Mini-Mental Status Examination (MMSE) score of less than 26, or subjects diagnosed by a physician as having some degree of cognitive impairment or preexisting diagnosis of dementia reported by the original author; (4) any exercise program or form of rehabilitative exercises, physical activity, fitness, or recreational therapy; (5) studies that reported means, standard deviations (SDs), *t* test or F test, and n values; (6) a minimum of 5 subjects in each group[68,70]; (7) at least 1 dependent variable from one of the following categories: health-related physical fitness (cardiovascular, strength, flexibility, body mass index [BMI]), functional, cognitive, and behavioral; and (8) journal articles, master's theses, and doctoral dissertations published in English and indexed between January 1970 and October 2003.

Criteria for exclusion. Studies were excluded if they did not contain enough statistical information to compute an effect size (ES), or the outcomes did not involve physical fitness or function, behavior, or cognitive function. Studies that were based on qualitative designs or narrative case reports, or involved 5 or fewer subjects were also excluded.

Critical Review

The methodologic quality of the study was assessed by 2 reviewers independently (PH, BCA) using a standardized abstraction form adapted from the Delphi List[72] and The PEDro Scale.[73] The form included information on sampling method, measurement, intervention, interpretation of results, and reporting of biases and limitations. It also included a grade for internal validity, external validity, and level of evidence generated. Assessment scores were 1 for yes, 0 for no, or unclear. The range of possible scores was 0 to 25. High-quality studies were defined as those with a score of 24 or greater; medium quality, 20 to 23 points; low quality, 17 to 19 points; and poor quality, 16 or fewer points. Most of the studies (80%) received a quality score of 20 points or higher with an overall mean quality score of 20.6. The scoring system was based on other reviews that used a similar critical review method to classify the quality of studies.[72-74]

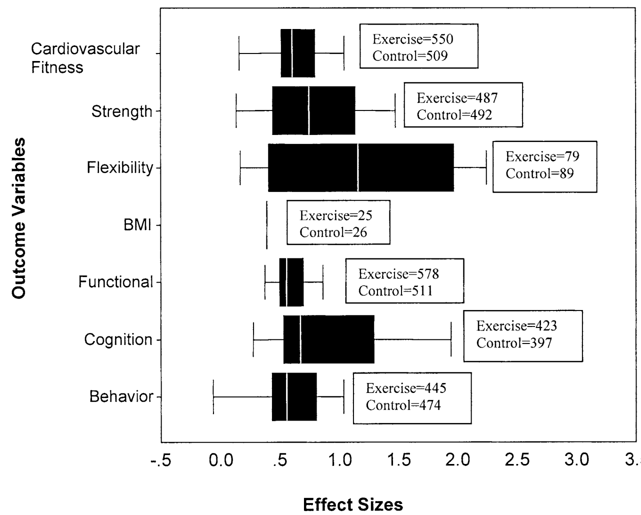


Fig 1. Exercise training outcome variables and ES values.

Data Extraction

The original search yielded more than 300 articles. There was, however, overlap among the articles. To ensure comprehensive coverage, the ancestry search approach was used.[75] The procedure for including studies in the final sample included reading each article in the sample to assess the presence of the inclusion criteria. After exclusion, a total of 30 trials were eligible for analysis.

ES Calculation

The quantitative method of review proposed by Glass[76] involves an estimation of a population ES, obtained from ES values generated from individual studies. Individual ES values were aggregated to a summary effect size (SES). To decide whether an SES was statistically significant, a fixed effects model was used.[77] The SES is the weighted mean of the unbiased individual ES values, calculated according to the fixed effects model. Most studies reported sufficient statistics to calculate the standardized mean difference. Using Hedge's g_i,[77] each individual study ES was calculated by dividing the difference between the experimental and control groups by the estimated pooled standard deviation (SD_i) of the baseline outcome measure in the treatment and control groups.

For each outcome, we reported Hedge's g_i and the 95% confidence interval (CI). In studies where 1 or more exercise programs (eg, programs including socialization or adjunctive therapy) were compared with conventional treatment, we chose the intervention that focused the most on sustained and effortful physical activity (ie, walking, cycling, weights training).

	Effect Name	Citation	Effect	Lower	Upper	*P*	NTotal	N1	N2
	Cardio Fit	Alessi et al[23]	.63	-.43	1.69	.09	29	15	14
	Cardio Fit	Alessi et al[23]	.72	-.35	1.79	.06	29	15	14
	Cardio Fit	Alessi et al[88]	.51	-.16	1.18	.04	65	33	32
	Flexibility	Buettner[31]	2.20	.98	3.42	.00	34	18	16
	Strength	Buettner[31]	1.33	.28	2.38	.00	34	18	16
	Strength	Chandler et al[81]	.45	-.09	.98	.03	100	50	50
	Cardio Fit	Clark et al[14]	.15	-1.04	1.35	.71	23	10	13
	Strength	Fiatarone et al[26]	.67	-.10	1.44	.02	51	25	26
	Strength	Fiatarone et al[26]	.71	-.07	1.48	.01	51	25	26
	Strength	Fiatarone et al[26]	1.12	.31	1.93	.00	51	25	26
	Cardio Fit	Fiatarone et al[26]	.57	-.20	1.34	.04	51	25	26
	Body Comp	Fiatarone et al[26]	.39	-.36	1.15	.16	51	25	26
	Strength	Fiatarone et al[26]	.93	.13	1.72	.00	51	25	26
	Cardio Fit	Lazowski et al[83]	.05	-.61	.71	.84	65	35	30
	Flexibility	Lazowski et al[83]	.64	-.21	1.48	.04	44	25	19
	Strength	Lazowski et al[83]	1.18	.41	1.95	.00	57	29	28
	Strength	Lazowski et al[83]	1.12	.35	1.90	.00	56	29	27
	Strength	Lazowski et al[83]	.43	-.27	1.14	.10	59	31	28
	Strength	MacRae et al[86]	.27	-.75	1.29	.45	31	19	12
	Cardio Fit	MacRae et al[86]	.86	-.21	1.92	.02	31	19	12
	Cardio Fit	MacRae et al[86]	.78	-.28	1.84	.04	31	19	12
	Flexibility	McMurdo and Rennie[38]	1.66	.64	2.68	.00	41	15	26
	Flexibility	McMurdo and Johnstone[34]	.17	-.61	.94	.56	49	21	28
	Strength	McMurdo and Rennie[89]	.74	.05	1.43	.00	65	36	29
	Strength	McMurdo and Rennie[38]	.82	-.09	1.74	.01	41	15	26
	Strength	McMurdo and Johnstone[34]	.14	-.64	.91	.63	49	21	28
	Strength	Meuleman et al[90]	1.46	.66	2.26	.00	58	26	32
	Cardio Fit	Morris et al[29]	.62	.28	.96	.00	248	124	124
	Cardio Fit	Nowalk et al[82]	.60	.07	1.12	.00	110	67	43
	Cardio Fit	Pomeroy et al[84]	.55	-.06	1.17	.02	78	41	37
	Strength	Schnelle et al[91]	.45	-.19	1.08	.06	72	35	37
	Strength	Schnelle et al[92]	.87	.35	1.40	.00	111	57	54
	Cardio Fit	Schnelle et al[91]	1.30	.61	1.99	.00	72	35	37
	Cardio Fit	Schnelle et al[91]	.59	-.33	1.51	.08	37	20	17
	Cardio Fit	Schnelle et al[91]	1.27	.24	2.30	.00	35	15	20
	Cardio Fit	Schnelle et al[93]	.49	-.12	1.11	.03	76	36	40
	Cardio Fit	Stamford et al[85]	.66	-.82	2.15	.17	17	9	8
	Cardio Fit	Stamford et al[85]	1.00	-.55	2.54	.05	17	9	8
	Cardio Fit	Tappen et al[30]	.49	-.33	1.31	.10	45	23	22
	Strength	Worm[94]	.63	-.19	1.44	.04	46	22	24
Fixed	**Combined (40)**		**.69**	**.58**	**.80**	**.00**	**2261**	**1142**	**1119**

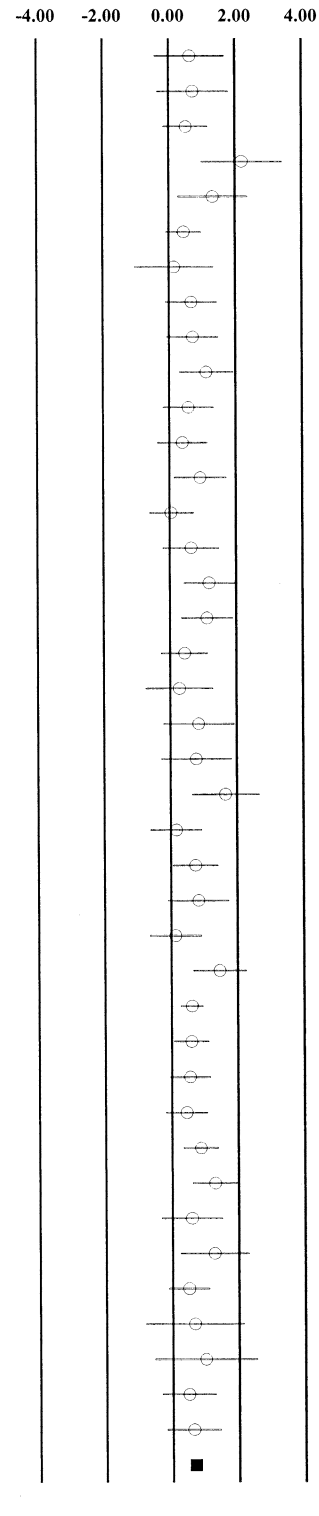
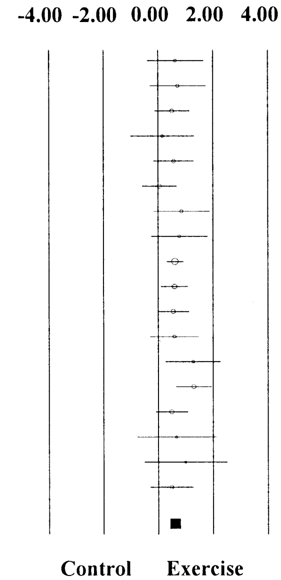


Fig 2. Physical fitness outcomes (no. of effects=40). Abbreviations: Comp, composition; Fit, fitness; N1, experimental; N2, control.

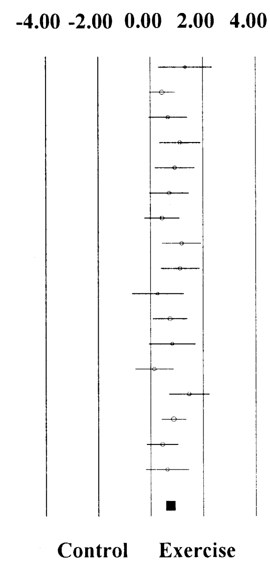
A

	Citation	Effect	Lower	Upper	P	N Total
	Alessi et al[23]	.63	-.43	1.69	.09	29
	Alessi et al[23]	.72	-.35	1.79	.06	29
	Alessi et al[88]	.51	-.16	1.18	.04	65
	Clark et al[14]	.15	-1.04	1.35	.71	23
	Fiatarone et al[26]	.57	-.20	1.34	.04	51
	Lazowski et al[83]	.05	-.61	.71	.84	65
	MacRae et al[86]	.86	-.21	1.92	.02	31
	MacRae et al[86]	.78	-.28	1.84	.04	31
	Morris et al[29]	.62	.28	.96	.00	248
	Nowalk et al[82]	.60	.07	1.12	.00	110
	Pomeroy et al[84]	.55	-.06	1.17	.02	78
	Schnelle et al[91]	.59	-.33	1.51	.08	37
	Schnelle et al[91]	1.27	.24	2.30	.00	35
	Schnelle et al[91]	1.30	.61	1.99	.00	72
	Schnelle et al[93]	.49	-.12	1.11	.03	76
	Stamford et al[85]	.66	-.82	2.15	.17	17
	Stamford et al[85]	1.00	-.55	2.54	.05	17
	Tappen et al[30]	.49	-.33	1.31	.10	45
Fixed	**Combined (18)**	**.62**	**.45**	**.78**	**.00**	**1059**



B

	Citation	Effect	Lower	Upper	P	N Total
	Buettner[31]	1.33	.28	2.38	.00	34
	Chandler et al[81]	.45	-.09	.98	.03	100
	Fiatarone et al[26]	.67	-.10	1.44	.02	51
	Fiatarone et al[26]	1.12	.31	1.93	.00	51
	Fiatarone et al[26]	.93	.13	1.72	.00	51
	Fiatarone et al[26]	.71	-.07	1.48	.01	51
	Lazowski et al[83]	.43	-.27	1.14	.10	59
	Lazowski et al[83]	1.18	.41	1.95	.00	57
	Lazowski et al[83]	1.12	.35	1.90	.00	56
	MacRae et al[86]	.27	-.75	1.29	.45	31
	McMurdo and Rennie[89]	.74	.05	1.43	.00	65
	McMurdo and Rennie[38]	.82	-.09	1.74	.01	41
	McMurdo and Johnstone[34]	.14	-.64	.91	.63	49
	Meuleman et al[90]	1.46	.66	2.26	.00	58
	Schnelle et al[92]	.87	.35	1.40	.00	111
	Schnelle et al[91]	.45	-.19	1.08	.06	72
	Worm et al[94]	.63	-.23	1.48	.04	46
Fixed	**Combined (17)**	**.75**	**.58**	**.93**	**.00**	**979**



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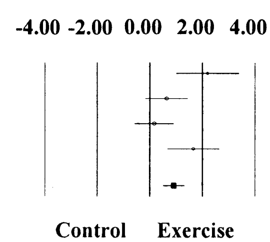
	Citation	Effect	Lower	Upper	P	N Total
	Buettner[31]	2.20	.98	3.42	.00	34
	Lazowski et al[83]	.64	-.21	1.48	.04	44
	McMurdo and Johnstone[34]	.17	-.61	.94	.56	49
	McMurdo and Rennie[38]	1.66	.64	2.68	.00	41
Fixed	**Combined (4)**	**.91**	**.47**	**1.36**	**.00**	**168**



D

	Citation	Effect	Lower	Upper	P	N Total
	Fiatarone et al[26]	.39	-.36	1.15	.16	51
Fixed	**Combined (1)**	**.39**	**-.36**	**1.15**	**.17**	**51**

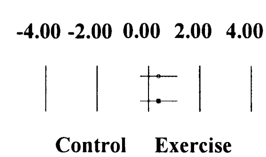
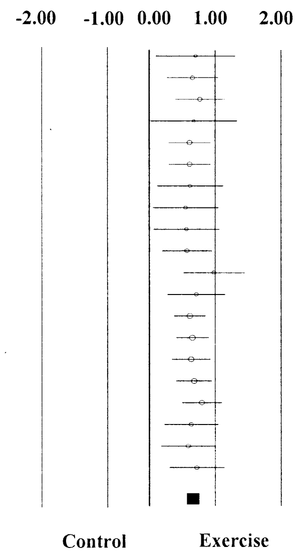


Fig 3. Health-related physical fitness outcomes. (A) Cardiovascular fitness outcomes (no. of effects=18). (B) Strength outcomes (no. of effects=17). (C) Flexibility outcomes (no. of effects=4). (D) BMI outcomes (no. of effects=1).

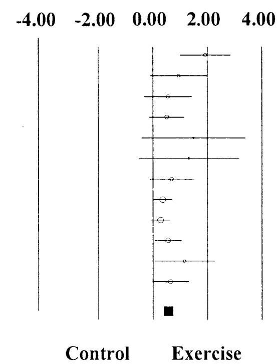
A

	Citation	Effect	Lower	Upper	*P*	N Total
	Clark et al[14]	.67	-.56	1.91	.11	23
	Cott et al[95]	.58	-.22	1.38	.05	49
	Fiatarone et al[26]	.81	.02	1.59	.01	51
	Lazowski et al[83]	.62	-.71	1.95	.17	20
	Lazowski et al[83]	.49	-.18	1.16	.05	65
	Lazowski et al[83]	.49	-.17	1.16	.05	66
	MacRae et al[86]	.51	-.53	1.54	.17	31
	MacRae et al[86]	.37	-.66	1.40	.31	31
	MacRae et al[86]	.40	-.63	1.43	.28	31
	McMurdo and Johnstone[34]	.41	-.37	1.20	.15	49
	McMurdo and Rennie[38]	1.23	.27	2.18	.00	41
	McMurdo and Rennie[38]	.70	-.21	1.60	.03	41
	Nowalk et al[82]	.50	-.02	1.02	.01	110
	Nowalk et al[82]	.58	.05	1.10	.00	110
	Pomeroy et al[84]	.53	-.08	1.14	.02	78
	Schnelle et al[92]	.62	.06	1.19	.00	91
	Schnelle et al[93]	.86	.22	1.50	.00	76
	Tappen[96]	.54	-.31	1.39	.08	42
	Tappen[96]	.44	-.40	1.29	.15	42
	Worm et al[94]	.71	-.16	1.57	.02	46
Fixed	**Combined (20)**	**.59**	**.43**	**.76**	**.00**	**1089**



B

	Citation	Effect	Lower	Upper	*P*	N Total
	Cott et al[95]	1.92	.96	2.87	.00	49
	Friedman and Tappen[32]	.94	-.13	2.02	.01	30
	McMurdo and Rennie[38]	.56	-.34	1.45	.09	41
	McMurdo and Rennie[89]	.51	-.16	1.19	.04	65
	Molloy et al[39]	1.49	-.45	3.42	.01	14
	Molloy et al[39]	1.32	-.56	3.20	.02	14
	Molloy et al[97]	.69	-.14	1.52	.02	45
	Mulrow et al[98]	.36	-.03	.75	.02	180
	Mulrow et al[98]	.28	-.11	.67	.06	180
	Nowalk et al[82]	.56	.03	1.08	.00	110
	Powell[17]	1.16	.02	2.29	.00	30
	Schnelle et al[91]	.64	-.05	1.34	.01	62
Fixed	**Combined (12)**	**.57**	**.38**	**.75**	**.00**	**820**



C

	Citation	Effect	Lower	Upper	*P*	N Total
	Alessi et al[23]	1.01	-.09	2.11	.01	29
	Alessi et al[23]	.76	-.31	1.83	.05	29
	Alessi et al[23]	.42	-.24	1.09	.09	65
	Buettner[31]	2.99	1.57	4.40	.00	34
	Gillogly[33]	.44	-.48	1.36	.18	37
	MacRae[86]	.31	-.71	1.33	.39	31
	McMurdo and Johnstone[34]	.44	-.34	1.23	.13	49
	McMurdo and Rennie[38]	.83	-.08	1.75	.01	41
	Powell[17]	-.06	-1.11	.99	.87	30
	Schnelle et al[92]	.56	.12	1.00	.00	147
	Schnelle et al[92]	.56	.12	1.00	.00	147
	Teri et al[99]	.27	-.17	.72	.11	140
	Teri et al[99]	.59	.14	1.04	.00	140
Fixed	**Combined (13)**	**.54**	**.36**	**.72**	**.00**	**919**

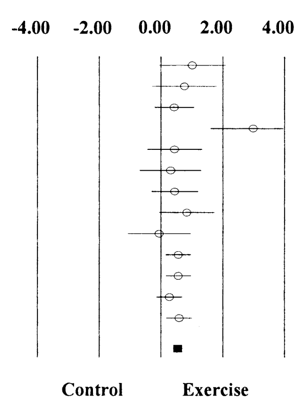


Fig 4. (A) Functional (no. of effects=20); (B) Cognitive (no. of effects=12); and (C) Behavioral outcomes (no. of effects=13).

The ES values were coded such that positive numbers always reflected improvements in performance, and negative numbers reflected deteriorations in performance. Basing decisions on Cohen's "rules-of-thumb" interpretation of ES results,[78] we adopted the following standardized mean difference ES for this study interpretation[79]: small, .20 to .49; medium, .50 to .79; and large, .80 or greater.

Statistical Analysis

The overall approach to ES calculations and moderator variables analyses were conducted using computer programs Excel 2002 software[a] and SPSS software, version 11.0.[b] The ES values were calculated using the statistical program called Effect Size Determination Program.[79] This computer program computes standardized mean difference ES (*d*) and the correlation coefficients (*r*) from summary statistics, such as means and SDs, *t* tests, F tests, and frequencies. Additional analyses were conducted and SES statistics were computed through the Comprehensive meta-analysis software package,[c] using Hedge's formula,[77] as previously described.

Study Characteristics

Intervention characteristics and subjects' levels of cognitive impairment were characteristics of primary interest. Among the categoric intervention characteristics that were coded were

Table 1: Summary ES Values of Exercise Training

Outcome	No. of Effects	ES*	Standard Error	ES 95% CI	P	U3 %†
Health-related physical fitness‡	40	.69	.04	.58–.80	.000	75.8
Cardiovascular	18	.62	.06	.45–.78	.000	73.0
Strength	17	.75	.06	.58–.93	.000	77.8
Flexibility	4	.91	.17	.47–1.36	.010	81.6
Cognitive	12	.57	.07	.38–.75	.000	72.0
Functional	20	.59	.06	.43–.76	.000	72.6
Behavior	13	.54	.07	.36–.72	.000	72.4
Overall ES‖	85	.62	.03	.55–.70	.000	73.0

*An ES of .80 or more, defined as a "large" effect, indicated that the means of the groups are separated by a .80 SD; ES values of .50 and .20, defined as "moderate" and "small," respectively, indicate that the means of the 2 groups are separated by .50 or .20 SDs.
†The percentage of the scores in the lower-meaned group that was exceeded by the average scores in the higher-meaned group.
‡Cardiovascular, strength, flexibility, and BMI.
‖Overall ES (combined cardiovascular, strength, flexibility, BMI, cognitive, functional, behavior effects).

exercise modality, duration, and frequency. When available, MMSE[80] scores also were coded. These training characteristics and outcome measures were chosen a priori as variables that may influence the primary study outcome (ES).

Missing Data

When important information about methods or relevant statistics was missing from a study (ie, sample size, age, exercise mode), that study was dropped from further consideration in the analysis. Fortunately, the selected studies provided most of the information needed for the statistical analysis. Two moderator variables on session duration[81,82] and 8 MMSE scores were not reported by the primary authors[14,17,29,33,38,83-85] (although they reported the sample as having cognitive impairments, dementia or Alzheimer's disease).

RESULTS

The 30 selected trials generated a sample size of 2020 subjects. Treatment and control and comparison groups were composed of 1023 and 997 subjects, respectively. Subjects' mean age ± SD was 80±6.1 years (range, 66–91y). Gender proportions (72% women, 28% men) were identified from the original sample sizes. Twenty-nine studies reported random assignment procedure, and 1 study[86] reported a delayed intervention design with control condition. Only 6 studies reported a blinding procedure; 5 studies presented analyses accounting for patient drop-out during intervention; 2 studies did not describe the exercise session duration; and the reliability and validity of 2 studies' cognitive measures were questionable.

The MMSE scores were reported in 22 studies (75% of the investigations). The scores ranged from 6 to 25 for a scale ranging from 0 to 30 points. The mean MMSE ± SD for the 22 studies was 16.5±7.0, which is classified as a moderate cognitive impairment.[80] Nine studies reported subjects with mild cognitive impairment. Another 9 studies reported subjects with moderate cognitive impairment, and 4 studies reported subjects with severe cognitive impairment. The remaining studies reported subjects' cognitive impairments, such as Alzheimer's disease, dementia, mixed dementia, cognitive disorders, organic brain disease, mentally impaired older adults, cognitively impaired nursing home residents, or geriatric mental patients.

The mean ES ± standard error (SE) for the health-related physical fitness, behavioral, functional, and cognitive performance tasks for the 30 intervention studies was .62±.03, (effects n=85, $P<.0002$). This mean ES was computed from 85 statistical tests included in the 30 reviewed trials. These ES values ranged from −0.06 to 3.06, and showed sufficient heterogeneity ($Q_{84}=138.0$, $P<.000$) to justify further examination. Subgroup analyses were conducted to explore the effect of differences in trial quality. The fixed effects model was used in the analysis of pooled data because it provides a more conservative estimate.

Some experimental reports included multiple dependent measures, which caused the number of ES to be larger than the number of reports. For example, a trial might include measures related to different functional or performance levels, such as measuring lower- and upper-body strength, or left and right grip strength. The average intervention study contained a mean of 2.5 statistical comparisons (number of ES values). Figure 1 displays the ES distributions for each outcome variable and the sample size of each category.

Examination of the estimates for the combined health-related physical fitness components revealed that exercise training had a significant positive effect on the physical performance of 1142 cognitively impaired older adults (ES ± SE, .69±.04; effects n=40, $P<.001$) as compared with 1119 controls. Figure 2 shows each ES drawn from the trials on health-related physical fitness (cardiovascular, strength, flexibility, BMI) of people with dementia and related cognitive impairments.

The following analysis compares the influence of exercise training on each ES from the health-related physical fitness (fig 3) and each ES from the behavioral, functional, and cognitive category (fig 4). It is apparent that the flexibility variable had a robust effect (ES ± SE, .91±.17, effects n=4, $P\leq.01$). The total sample size was 168 (experimental, n=79; control/comparison, n=89), the flexibility ES values were based on only 4 statistical evaluations, so this finding must be interpreted with caution.

The 487 cognitively impaired older adults who participated in strength training programs improved substantially more than the 492 control and comparison subjects in measures of strength (ES ± SE, .75±.06, effects n=17, $P<.001$). The 550 experimental participants improved on cardiovascular fitness measures (ES ± SE, .62±.06, effects n=18, $P<.001$) as compared with 509 controls.

Figure 4 shows that the 578 exercise training participants with cognitive impairments improved more than the 511 control and comparison subjects on functional performance measures (ES ± SE, .59±.06, effects n=20, $P<.001$). In addition, 445 experimental participants improved on behavioral measures (ES ± SE, .54±.07, effects n=13, $P<.001$) as compared with 474 control and comparison participants. Finally, the cognitively impaired exercise group (n=423) showed improvements in cognitive tasks (ES ± SE, .57±.07, effects n=2,

Table 2: Characteristics of Included Trials

Study	N Total	N Included*	n Exp	n Con	Age Mean (y)	Outcomes	MMSE Mean	Type of Intervention	Frequency (session/wk)	Intensity (total min/ session)	Duration	Study Quality Score
Alessi et al[23]	29	29	15	14	88	Cardiovascular and behavior	13	Functional and endurance exercises	5	35–78	14wk	22
Alessi et al[88]	65	65	33	32	85	Cardiovascular	14	Mobility and endurance exercises	3–5	≥60	9wk	22
Buettner[31]	36	34	18	16	83	Strength, flexibility, and behavior	6	Functional and recreational exercises	6	60	8wk	21
Chandler et al[81]	100	100	50	50	78	Strength	24	In-home lower-body strength resistance	3	NA	10wk	23.5
Clark et al[14]	23	23	10	13	69	Cardiovascular and functional	NA	Mobility and isotonic exercises	5	60	12wk	17
Cott et al[95]	74	49	30	19	82	Functional and cognitive	6	Mobility (walking-based)	5	30	16wk	21
Fiatarone et al[26]	100	51	25	26	87	Cardiovascular, strength, functional, and BMI	22	High-intensity exercises of progressive resistance with weight machines	3	45	10wk	22.5
Friedman and Tappen[32]	30	30	15	15	73	Cognitive	7	Mobility (walk individually)	3	30	10wk	22
Gillogly[33]	42	27	16	11	80	Behavior	NA	Mobility and isotonic exercises	3	60	12wk	20
Lazowski et al[83]	68	65	35	30	81	Cardiovascular, strength, flexibility, and functional	NA	Isotonic and endurance seated exercises	3	45	16wk	21
MacRae et al[86]	37	31	19	12	91	Cardiovascular, strength, functional, and behavior	20	Mobility (walk endurance)	5	30	12wk	18
McMurdo and Johnstone[34]	86	49	21	28	82	Strength, flexibility, functional, and behavior	25	In-home mobility and strength resistance	Daily exercises recommended	15–30	24wk	21.5
McMurdo and Rennie[89]	65	65	36	29	83	Strength and cognitive	15	Isotonic and isometric seated exercise-to-music	2	45	6mo	20
McMurdo and Rennie[38]	41	41	15	26	81	Strength, flexibility, functional, cognitive, and behavior	NA	Isotonic and endurance seated exercise-to-music	2	45	28wk	21
Meuleman et al[90]	78	58	26	32	76	Strength	23	Resistance and endurance training with machines (stationary cycle/stepper)	5	30	8wk	23.5
Molloy et al[39]	15	14	6	8	66	Cognitive	24	Light aerobic exercises	1	45	2wk	15
Molloy et al[97]	45	45	23	22	82	Cognitive	25	Light aerobic exercises	3	45	12wk	16.5
Morris et al[29]	468	248	124	124	85	Cardiovascular	NA	Progressive weight-lifting, walking, and isotonic exercises	3	60	40wk	20.7
Mulrow et al[98]	194	180	92	88	81	Cognitive	21	Range of motion, resistance, and mobility exercises	3	45	16wk	25

Table 2 (Cont'd): Characteristics of Included Trials

Study	N Total	N Included*	n Exp	n Con	Age Mean (y)	Outcomes	MMSE Mean	Type of Intervention	Frequency (session/wk)	Intensity (total min/ session)	Duration	Study Quality Score
Nowalk et al[82]	110	110	67	43	85	Cardiovascular, functional, and cognitive	25	Strength, resistance, mobility, and cardiovascular exercises	3	NA	28mo	23
Pomeroy et al[84]	81	78	41	37	82	Cardiovascular and functional	NA	Mobility training (walking)	5	30	2wk	22
Powell[17]	30	30	11	19	69	Cognitive and behavior	NA	Mobility and isotonic exercises	5	≥60	12wk	17.5
Schnelle et al[92]	190	147	73	74	88	Strength, functional, and behavior	13	Functional skills and mobility exercises	5	≥60	8mo	23.2
Schnelle et al[91]	97	72	35	37	84	Cardiovascular, strength, and cognitive	10	Cardiovascular and mobility exercises	3	20–35	9wk	19
Schnelle et al[93]	76	76	36	40	85	Cardiovascular and functional	12	Functional skills and mobility exercises	5	30–55	8wk	18.7
Stamford et al[85]	17	17	9	8	68	Cardiovascular	NA	Cardiovascular and mobility training using a treadmill	5	6–20	12wk	16
Tappen et al[30]	65	45	23	22	87	Cardiovascular	11	Mobility training (walking)	3	30	16wk	23
Tappen[96]	42	42	21	21	84	Functional	6	Skill training (ADLs)	5	150	20wk	22.5
Teri et al[99]	153	153	76	77	78	Behavior	17	Aerobic, strength, flexibility, endurance, and balance	2–4–2	30	24mo	24.5
Worm et al[94]	46	46	22	24	81	Strength and functional	24	Aerobic, strength, flexibility, endurance, and balance	2	60	12wk	16.5

Abbreviations: ADLs, activities of daily living; Con, control; Exp, experimental; N, total number of participants in the study; NA, characteristic was not reported by the author.
*Number excludes additional trial groups (only 2 groups; control and exercise intervention were selected).

Table 3: Training Characteristics and ES Means

Effect Magnitude (no. of effects)	Studies N		Mean	Min	Max	Sum
Large effect (n=24)	9		1.32	.85	3.06	
Intensity (min)	8		36	20	60	290
Frequency (sessions)	9		4	2	6	33
Duration (wk)	9		14.5	2	32	116
MMSE (SD, ±7.38)	6	Moderate-severe	14.7	6.0	24.6	
Medium effect (n=40)	10		.62	.50	.80	
Intensity (min)	10		45	30	99	449
Frequency (sessions)	10		3	2	5	34
Duration (wk)	10		23.4	2	112	234
MMSE (SD, ±6.0)	8	Moderate	16.9	6.0	25.3	
Small effect (n=21)	11		.31	−.16	.45	
Intensity (min)	10		49.5	30	90	495
Frequency (sessions)	11		3.5	1	5	39
Duration (wk)	11		14	9	24	153
MMSE (SD, ±5.7)	8	Moderate	19.6	6.4	25.4	

Abbreviations: Max, maximum; Min, minimum.

$P<.001$) when compared with the control and comparison group (n=397). Figure 4 shows each of the ES values from the trials on functional and cognitive performance, and behavioral outcomes. Table 1 shows the summary of the ES statistics from each outcome.

Training Characteristics

The mean training duration from all studies was 23 weeks, ranging from 2 to 112 weeks. There was an average of 3.6 sessions per week, ranging from 1 to 6 sessions, with a session lasting 45 minutes (mean) and ranging from 20 to 150 minutes.

The exercise treatments of the majority of the primary studies (n=17) were based on walking (mobility training), or combined walking with different types of isotonic exercises. The other interventions were based on mixed modalities. Three studies used chair exercises and 3 studies use an aerobic dance class format. Two studies had interventions based on strength training with weights. Two studies used home-based exercise programs: 1 intervention included stationary cycling combined with exercises, and the other training programs were skill-based functional exercise programs (table 2).

The studies were coded with regard to the intensity (minutes per session), frequency (times per week), and the length of the exercise intervention (number of weeks). The effect of the main explanatory variable, exercise intervention, was categorized using different levels of ES values. The 30 studies were divided into 3 groups: large effect, medium effect, and small effect (table 3). The ES groups were also aggregated with the training characteristics for comparisons. The training characteristics did not differ considerably for the 3 ES exercise training groups, showing no significant marker of training characteristics' influence on the large effect as compared with the medium or small. The large effect group, however, contained the most cognitively impaired subjects, and a higher number of mean sessions per week. The medium effect group contained interventions that delivered the longest exercise training (mean, 23.4wk; see table 3).

DISCUSSION

This meta-analysis investigated the effectiveness of exercise training for people with dementia and calculated the ES of exercise training on physical, behavioral, functional, and cognitive outcome measures. To our knowledge, this is the first research synthesis to evaluate the effects of physical training on older people with cognitive impairment. Previous studies of exercise interventions in older adults have not specifically targeted people with cognitive impairments,[46] have excluded older people who were not able to cooperate or were cognitively and behaviorally dysfunctional,[6,68,69] or included older adults with multiple health conditions.[11]

The finding that exercise training resulted in improvements in health-related physical fitness and cognitive function is encouraging. The positive effects of exercise training highlight the need to further understand the role of exercise on brain function and development of dementia.

Although most studies provided data on exercise training modes and related program characteristics, it was not clear whether subjects maintained the intensity throughout the exercise session, or if additional devices were used to enhance subject motivation. Very few studies reported the qualifications of the exercise leader, or reported adverse events and/or injuries. Further research is needed to document safety, preparedness, and appropriateness of exercise programs for older adults with dementia.

The impact of the environment on increasing levels of physical activity in institutionalized older adults is another area for future scientific exploration. To effectively increase the levels of physical activity and engagement among elderly people with Alzheimer's disease and related dementia, research is needed to determine how to motivate persons with Alzheimer's disease to exercise regularly, and also to engineer and adapt exercises to fit various health needs.

The present meta-analysis found important limitations related to the quality of study design, including the absence of blinding procedures and small sample sizes. Future studies involving multicenter trials with rigorous experimental controls will help resolve some of the issues not addressed or left unanswered in this investigation. Most of the studies included in this meta-analysis focused on the short-term effects of exercise and physical activity. Frail sedentary older adults have good short-term responses to physical exercise.[87] There is a need for long-term follow-up and longitudinal investigations with this population.

Limitations

Although these results support that exercise training improves physical fitness, behavioral symptoms, functional performance, and cognitive performance in patients with dementia and related cognitive impairments, this review has several limitations. The literature search was limited to articles published in English because the authors did not have the resources to translate articles written in other languages. Second, there is heterogeneity in the outcomes that could be explained by differences in study methods, subjects' mental status, or other characteristics not reported. Finally, because of the lack of raw data and the need to estimate ES values, the combined ES estimates for selected outcomes may not be precise.

CONCLUSIONS

Exercise was associated with statistically significant positive treatment effects in older patients with dementia and cognitive impairments. The meta-analysis results suggest a medium to large treatment effect for health-related physical fitness components, and an overall medium treatment effect for combined physical, cognitive, functional, and behavioral outcomes. The results provide preliminary evidence for the effectiveness of exercise treatments for persons with dementia and related cognitive impairments.

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Suppliers

a. Microsoft Corp, One Microsoft Way, Redmond, WA 98052-6399.
b. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.
c. Biostat Inc, 14 N Dean St, Englewood, NJ 07631.