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Review

Can physical activity prevent physical and cognitive decline in postmenopausal women? A systematic review of the literature

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ABSTRACT

Background: Participation in regular physical activity is among the most promising and cost effective strategies to reduce physical and cognitive decline and premature death. However, confusion remains about the amount, frequency, and duration of physical activity that is likely to provide maximum benefit as well as the way in which interventions should be delivered.
Aims: This paper aimed to review research on the impact of leisure-time and general physical activity levels on physical and cognitive decline in postmenopausal women. In a systematic review of the literature, empirical literature from 2009 to 2013 is reviewed to explore the potential impact of either commencing or sustaining physical activity on older women's health.
Results: All studies found that physical activity was associated with lower rates of cognitive and physical decline and a significant reduction in all-cause mortality. In this review we found that exercise interventions (or lifestyle activities) that improved cardiorespiratory exercise capacity showed the most positive impact on physical health.
Conclusions: Findings suggest that programs should facilitate and support women to participate in regular exercise by embedding physical activity programs in public health initiatives, by developing home-based exercise programs that require few resources and by creating interventions that can incorporate physical activity within a healthy lifestyle. The review also suggests that clinicians should consider prescribing exercise in a tailored manner for older women to ensure that it is of a high enough intensity to obtain the positive sustained effects of exercise.

Contents

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1. Background

In recent times, many parts of the world have seen changes to their population structure, with fewer children and more older people comprising the total population [1], and contemporaneous changes in patterns of illness and disability. More specifically, it has been estimated that most adults aged 65 years and older have at least one chronic health condition [2,3], and the prevalence of many of these conditions is expected to continue to rise [4]. Clearly, aging populations pose significant challenges to individuals, families and societies, [5] not only because of the increased burden of disease and disability but also the associated healthcare and social welfare costs [6,7].

As a result of these changes, reducing risk and promoting healthy ageing have become important strategies for reducing morbidity, mortality and other indirect costs to society. Undoubtedly, the absence of chronic conditions is associated with good physical health and cognitive functioning [2,3,8], though it is likely that a variety of factors also play a role. Indeed, healthy aging has been associated with a range of healthy lifestyle behaviours including participation in regular physical activity [4,9–12], healthy diet, moderate alcohol consumption, and abstinence from cigarette smoking [13,14]. Research also suggests that adopting these behaviours might slow physical or cognitive decline among those who have some existing illness or impairment [10,15,16].

Though adopting a variety of healthy lifestyle behaviours is likely to have a positive impact on health, physical inactivity has been increasingly recognized as an underlying cause of mortality and morbidity [17–19]. A number of studies have demonstrated positive outcomes associated with sustained regular physical exercise [20–28] though the activities, their amount, duration, and frequency have varied across studies. According to a study by Dalleck and colleagues, a dose–response relationship was found between exercise duration and biochemistry, physical fitness and anthropometric measures in postmenopausal women [21].

Older adults who undertake regular physical activity also report significantly less disability [13,29,30], and better physical function [24], regardless of body mass [31]. Research also suggests that exercise may improve the mental well-being of frail elders [27] and this is likely to yield significant cost-effectiveness ratios (per quality adjusted life year gained) when compared with minimal intervention [27]. Possibly, participation in regular physical activity is among the most promising and cost effective strategies to reduce physical and cognitive decline and premature death [4,10]. However, confusion remains about the amount, frequency, and duration of physical activity that is likely to provide maximum benefit as well as the way in which interventions should be delivered. Indeed, a recent Cochrane review concluded that there was insufficient data to conclusively determine whether regular cardiovascular activity was a leading factor in preventing cognitive decline [32]. Another limitation in current literature is the dearth of data exploring the long-term effects of changes in physical activity particularly among older populations who become physically active relatively late in life [33].

Empirical literature exploring the impact of physical activity specifically on women's health is also limited. Indeed, a recent review published in *Post Reproductive Health* on behalf of the British Menopause Society (BMS) suggested that women should be able to optimize their health and well-being through menopausal transition and into the older years, highlighting the importance of access to information on lifestyle factors, diet, and complementary and alternative therapies [34]. The paper elucidates to the importance of lifestyle interventions in improving women's health through midlife and beyond, however without specific reference to the importance of physical activity on preventing cognitive and functional decline.

This paper attempts to address some of these issues by drawing together empirical literature from 2009 to 2013 on the potential impact of either commencing or sustaining physical activity on older women's health. More specifically, this paper reviews recent research on the impact of leisure-time and general physical activity levels on physical and cognitive decline. It is hoped that this paper will provide clearer activity recommendations for older women to prevent cognitive and functional decline.

2. Methods

The aim of this paper is to review the recent empirical literature (2009–2014) on the impact of exercise on functional and cognitive decline in older women.

2.1. Search strategy

A standardized protocol was developed and followed for all steps of the review; see Fig. 1. Searches were conducted across MEDLINE, CINAHL, and PsycINFO databases using the All Text (TX) method for search terms: 'older women' OR 'elderly' OR 'geriatric' OR 'female' AND 'exercise' OR 'physical activity' OR 'leisure time activity' OR 'active' AND 'no exercise' OR 'sedentary lifestyle' OR 'inactive' AND 'physical decline' OR 'mental decline' OR 'poor mental health' OR 'poor physical health' OR 'functional abilities' OR 'functional ability' OR 'health status'. The searches were limited to peer-reviewed, published, human studies in English language within the date range of 2009–2014. All databases were accessed in March 2014.

In addition to searching academic databases, searches of unpublished and grey literature were also performed; Mednar, Open Grey, and trial registers (U.S. National Institutes of Health register, the EU Clinical Trials Register website, and the Australian New Zealand

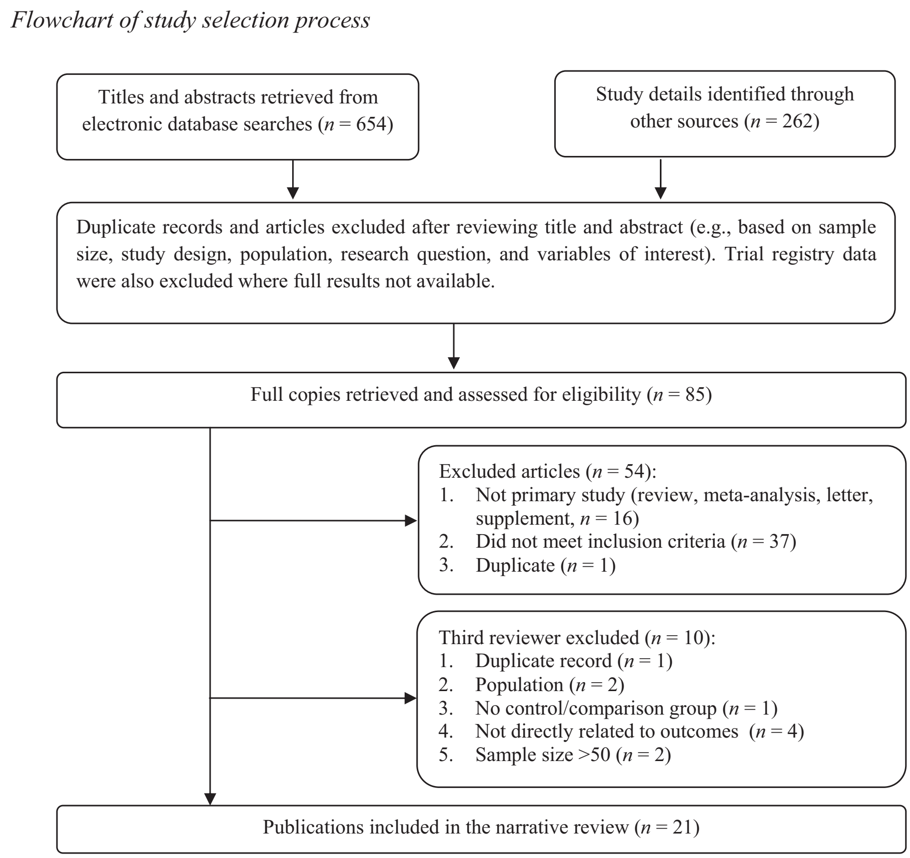

Fig. 1. Flowchart of study selection process.

Clinical Trials Registry) were searched using the strategies outlined previously.

Initial selection of studies was conducted by reviewing the title and abstract of each record for relevance to the review question, and studies were eliminated if components such as study design or population were not relevant. Duplicate publications yielded across searches were also removed. Following this process, full copies of studies were retrieved and further assessed for eligibility. Articles were excluded if they were not a primary study (i.e., meta-analysis, review, study protocol, or letter) and if participants or study design did not meet the inclusion criteria (published quantitative research involving women aged 65 years and older in peer-reviewed English language journals).

2.2. *Study selection criteria*

This review considered studies published in English that included women aged 65 years and older where the intervention or predictive variable was exercise, leisure time activity or physical activity not associated with improving functional abilities after serious illness or injury (for example, physical therapy or rehabilitation). Additionally, only studies that incorporated a control (or comparison) group comprising no exercise, or usual/routine care or activity were included. The primary outcomes considered in this review were a decline in either physical or mental health, functional abilities, or overall health status, or a combination of these variables.

This review considered both experimental and epidemiological study designs including randomized controlled trials, prospective and retrospective cohort studies, and cross-sectional studies. This review also considered systematic reviews and meta-analyses; however these studies were utilized only for background information and further identification of studies that met the inclusion criteria. Exclusion criteria were as follows: (1) qualitative research; (2) studies that did not include a control or comparison group; (3) duplicate publications or sub-studies of included research; (4) studies where full text or completed data were not able to be accessed, and; (5) sample size less than 50.

2.3. *Methods for data extraction and assessing data quality*

Data were abstracted by two investigators from academic databases, and unpublished, grey literature using a standardized form. Screening of the extracted data included reviewing titles and abstracts based on study design, year of publication, population (age range and percentage of women), and definition of variables of interest. Where necessary, screening was performed by a third reviewer and consensus achieved by discussion.

2.4. *Assessment of individual studies*

All included studies were assessed for potential bias associated with the mode, frequency and types of measurement; within-group and between-group similarities and differences; attrition; and adjustment for potential confounding variables.

The risk of bias in Randomized Controlled Trials (RCTs) was additionally assessed according to recommendations from the Cochrane Handbook [35] based on six criteria: Randomization, i.e., use of random sequence generation and few differences in groups at baseline (and none related to key variables); Blinding of study personnel before and during the trial (in this instance it was not pragmatic for participants to be blinded to the intervention); Blinding of the outcome assessor to participants group allocation; whether data were analyzed according to intention-to-treat principles (attrition and non-adherence was <50%), and finally; whether attrition was discussed in sufficient detail to give the reader confidence that it did not impact study quality. Each of these criteria was rated '*Yes*', '*No*', '*Unclear*' and studies were considered to have a low risk of bias if they scored affirmatively in four or more domains.

Observational epidemiological studies are often associated with an increased risk of bias, though a significant amount of health research has come from cohort, case-control, or cross-sectional studies [36]; therefore, the research team thought it necessary to consider these designs. The risk of bias in observational studies was based on recommendations outlined in the STROBE statement [37] and focused on: study design (design appropriate to the research question); setting (describes the setting, locations, and relevant dates); participants (eligibility criteria, and the sources and methods of selection of participants); variables (defines outcomes, exposures, predictors, and potential confounders); measurement (identifies measurements for each variable of interest); bias (describes any efforts to address potential sources of bias); study size (explains how the study size was derived); statistical methods (describes all statistical methods, including management of confounding, missing data, and any additional analysis as appropriate); descriptive statistics, main results (unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval); reports other analyses done (e.g., analyses of subgroups and interactions, and sensitivity analyses); discussion (discuss limitations of the study, taking into account sources of potential bias or imprecision; discuss both direction and magnitude of any potential bias; results are interpreted in light of study limitations) [37]. Prospective studies were also examined for attrition bias resulting from differential drop-out [35,37]. Each of these criteria was rated '*Yes*', '*No*', '*Unclear*' and studies were considered to have a low-moderate risk of bias that was managed appropriately if they scored affirmatively to eight or more of the above criteria.

3. Results

3.1. Literature search

Data were abstracted using a standardized form developed by two investigators, and verified through initial data abstractions. L.R. conducted the initial search ($n = 568$), screened titles and abstracts of identified articles, and undertook the first iteration of excluding studies based on study design, year of publication, population (age range and percentage of women), definition of variables of interest, and duplication. C.S. searched grey literature ($n = 262$) and undertook the first iteration of excluding studies based on the population, study design and objectives, data constructs and their measurement, whether trials had been completed and full data were available, and duplication.

In total, 85 full text articles were retrieved and reviewed by L.R and C.S. to determine eligibility for inclusion (see previous section) in the review. Both reviewers agreed that an additional 53 papers should be excluded as they were not primary studies (i.e., meta-analysis, literature review, systematic review, letter, or supplement; $n = 16$), they did not meet the inclusion criteria (e.g., no control group, control group including exercise, the population included men or women of all ages and did not isolate results for older women, the intervention was based ADLs, physical therapy, or rehabilitation, the intervention did not isolate exercise, for example the intervention being diet and exercise; $n = 37$), and one duplicate citation. Disagreements about the eligibility of an additional 10 extracted studies were resolved by a third reviewer (D.A) who excluded one duplicate record [13], two studies because of sample size [21,38], one because of lack of comparison/control [39], two because of the population under study [40,41], and four due to not being directly related to the research question [42–45]. In all, 21 studies met the inclusion criteria and were included in the narrative review [4,23,28,33,46–62].

3.2. Study characteristics

Table 1 outlines the characteristics of the sample, exposure variables or interventions, outcomes and results.

3.3. Setting and characteristics of participants

3.3.1. Randomized controlled trials (RCTs)

Of the 10 RCTs included in this review, five originated from the United States of America (USA) [48,51,53,59,60], two originated from Europe (one from Germany [23] and one from Spain [62]), and the remaining three RCTs originated from Brazil [50], Japan [55], and Australia [28]. An additional trial with randomization between intervention groups from Belgium [57] was also included in the review.

Several of these studies recruited participants via public advertisements and related community strategies [28,48,50], while others used multiple recruitment strategies including mailing lists, referrals from physicians, physical therapists, flyers, and senior education programs [53]. Still, other RCTs recruited participants from existing cohort studies and independent-living retirement villages [60], health clinics [62], and from a health insurance company membership database [23].

Two studies did not provide sufficient information about the recruitment strategies [51,59] though related papers provided more detail. Specifically, Earnest and colleagues stated that recruitment of minority groups occurred through medical facilities primarily accessed by minority women as patients [63], while Reibe used diverse recruitment strategies: media campaign; pamphlets and posters; targeted direct mailings; contacts with local physicians; person-to-person contact with potential participants and included health-related local community sites [64] (Tables 2–5).

Among the RCTs, some studies included both men and women (proportion female ranged from 44% [23] to 81% [53]) [23,28,48,53,59], while others recruited women only [50,51,55,62]. All studies included older people, though there were some small differences in the age ranges: 60 years and older [53,59,62]; 65 years and over [28]; 70 years and older [23,48], and; 75 years and older [55].

Eligibility criteria for most studies included generally good health, sedentary [48,50,51,60] but able to ambulate independently [23,28,48,53,55,60]. Additional inclusion criteria were noted for several studies, for example, adult-onset hyperkyphosis [53], sarcopenia [55], and falls in the past six months or feared falling [23]. In contrast, Yang recruited participants with mild balance dysfunction but who had no more than one fall in the previous 12 months [28]. An additional two studies only recruited postmenopausal women [51,62], though Earnest and colleagues included sedentary women aged 45 years and over who were overweight or obese [51] while Villaverde Gutierrez et al included women aged 60 and over who reported natural menopause and recent mood problems [62]. Participants were excluded if they had serious medical conditions or cognitive impairment that may have either limited adherence to physical activity, or in which case physical activity may have been contraindicated [23,48,50,51,53,55,59,60,62].

3.3.2. Quasi-experimental designs

One controlled trial with randomization between the intervention groups was included in the review [57]. In this study, participants were recruited through advertisements and mailing lists of sociocultural organizations for seniors and retired university

Table 1
Summary of the impact of physical activity on health and quality of life identified in recent studies (2009–2013).

Authors	Country	Purpose	Year study commenced	Design	*n*	Sample characteristics	Predictors	Outcomes	Result
Aichberger [46]	EU	Examine the association between physical activity and cognitive performance	2004–2005	Cohort study (FU 2.5 years)	17333, 55% ♀	People aged 50 years or older from 11 European countries participating in the Survey of Heath, Ageing, and Retirement in Europe (SHARE).	Physical activity Covariates: age, education, somatic comorbidities, functional impairment, depressive symptoms, and BMI	Cognitive performance was measured by delayed word recall (DWR) and a semantic verbal fluency test (VF)	After adjustment, physical inactivity was associated with a higher rate of cognitive decline over a mean FU of 2.5 years ($\beta = -1.79$, $SE = 0.17$) for verbal fluency; $\beta = -0.35$, $SE = 0.04$) for delayed word recall).
Chale-Rush [48]	USA	Determine whether participation in moderate or vigorous physical activity is associated with physical function performance	2005	Baseline results from RCT	424, 70% ♀	Older adults aged 70–89 at risk for mobility disability $M_{age} = 76.8 \pm 4.2$	Minutes of usual moderate-intensity or more-vigorous physical activity (MVPA) Covariates: sex, BMI, depressive symptoms, age, medical history, medications	Physical functioning measured by Short Physical Performance Battery (SPPB) and 400-m walk test	Mean SPPB score was higher for participants reporting ≥150 min/wk of MVPA (8.0 ± 1.2) compared with those reporting < 150 min/wk of MVPA (7.4 ± 1.5). Mean 400-m walk time was less for those doing ≥1150 min/wk of MVPA (7.5 ± 1.6 minutes) compared to those < 150 min/wk of MVPA (8.4 ± 2.1)
Chen [49]	Taiwan	Association between physical activity and mortality	1999	Cohort study (FU 8 years)	2133, 49% ♀	Whole population aged 65+ from Hunei, Taiwan	Physical Activity Scale for the Elderly (PASE) Covariates: age, education, marital status, BMI cigarette smoking, alcohol consumption, chronic disease.	All-cause mortality	Women in low leisure activity group experienced an increased all-cause mortality than high leisure activity group (AHR = 1.75, 95%CI 1.26–2.44). Differences in women undertaking moderate and high activity groups not significant (AHR = 1.15, 95% CI 0.80–1.65)
Correa [50]	Brazil	Compare the physical function of older women participating in a exercise trial	Not stated	RCT	58, 100% ♀	Women not engaged in regular exercise but without major comorbidities $M_{age} = 67 \pm 5$ years	12 week exercise intervention (week 1–6 traditional resistance exercise for the lower extremity and week 7–12 randomised into traditional group (TG), power group (PG) and rapid strength group (RG). Covariates: BMI, skin fold thickness	Physical function measured by maximal dynamic strength, muscle thickness (MT), muscle activation, counter movement jump (CMJ), reaction time, muscle onset latency	At 6 weeks intervention group showed knee extension one-repetition (1RM) maximum strength (+19%), knee extensor muscle thickness (MT, +15%), maximal muscle activation (+44% average) for major leg muscles compared with controls. At 12 weeks all groups reported increase in 1RM (+21%), MT (+25%), and activation of major leg muscles (+44% and +26%). However, the rate of force development (RFD) over 150 meters ($TG = 2.3 \pm 9.8$ N s − 1, $PG = 3.3 \pm 3.2$ N s − 1, $RG = 3.8 \pm 6.8$ N s − 1, $CG = 2.3 \pm 7.0$ N s − 1) differed between groups.

Table 1 (*Continued*)

Authors	Country	Purpose	Year study commenced	Design	*n*	Sample characteristics	Predictors	Outcomes	Result
Earnest [51]	USA	Expose dose–response relationship between amount of exercise and cardiorespiratory function and and heart rate variability	Not stated	RCT	365 ♀	Postmenopausal, sedentary and hypertensive women	Exercise intervention (three groups exercising at (50%, 100%, and 150% of minimal energy expenditure) Covariates: age, BP, ethnicity, BMI, waist–hip circumference, biochemistry.	Cardiorespiratory exercise capacity ($VO2_{max}$), heart rate variability (HRV)	A significant improvement in parasympathetic tone (rMSSD and high frequency power) for both age strata at 8 KKW and 12 KKW. For women ≥60 years rMSSD responses were, controls, 0.07 ms, 95% CI—3.64, 3.79; 4-KKW, 1.20 ms, 95% CI—1.82, 4.22; 8-KKW, 5.75 ms, 95% CI 1.89, 9.61; and 12-KKW, 4.28 ms, 95% CI 0.42, 8.14.
Freiberger [23]	Germany	Intervention to determine the long-term effects of strength and balance exercises on physical performance, fall-related psychological outcomes	Not stated	RCT	280, 44% ♀	Community-dwelling adults aged 70 to 90 who had fallen in the past 6 months or reported fear of falling	Four group intervention 1. Strength training and challenging balance exercises (SBG); 2. Endurance training (FG) 3. Fall risk education (MG); 4. Control group. Covariates: age, sex, education, income, living situation, medications and medical conditions, falls history, cognitive status	Physical function measured by the Timed Up and Go test Chair Stand Test (CST), and modified Romberg test (mod Rom) were used German version of the Falls Efficacy Scale – International (FES-I)	Analyzes showed improved short- and long-term (12 and 24 months, respectively) physical performance for the SBG and FG, particularly regarding mobility, balance, and walking speed ($p < .05$). The improvements in physical performance outcomes were most prominent in the FG.
Gow [52]	Denmark	Examine the cognitively protective effect of leisure and physical activities	Not stated	Cohort study (FU 30 years)	802, 46% ♀	Participants born in 1914 were assessed at ages 50, 60, 70, and 80	Physical activity, cumulative physical activity. Leisure activity, and cumulative leisure activity Covariates: sex, education, social class	Cognitive abilities measured by the Wechsler Adult Intelligence Scale	A small correlation between physical activity (r = 0.10–0.25) and leisure activity (r = 0.10–0.26) slowed cognitive decline was noted over time. Physical activity was associated with a higher level of cognitive ability though adjustment for baseline cognitive ability (age 50) attenuated these associations.
Greendale [53]	USA	Determine whether yoga intervention can improve hyperkyphosis	2005–2006	RCT	118, 81% ♀	People aged 60 and older with a kyphosis angle of 401 or greater but no serious medical comorbidity or use of a mobility aide	Yoga intervention Covariates: demographics, health conditions, health behaviours, and quality of life; anthropometrics; and physical performance testing.	Kyphosis angle, physical function, HRQoL (secondary outcome) measured using the SF-36	The intervention did not result in statistically significant improvement in physical performance or HRQoL.
Hamer [33]	UK	Association between physical activity and healthy aging	2002–2003	Cohort study (FU 8-years)	3454, 47% ♀	Probability sample of disease-free, community dwelling adults, M_{age} = 63.7 ± 8.9	Self-reported vigorous, moderate, light physical activity (more than once per week, once per week, one to three times per month, hardly ever) or inactively (no moderate or vigorous activity on a weekly basis) Covariates: Age, sex, smoking, alcohol, marital status, income	Healthy aging defined by absence of major chronic disease, good cognitive and physical function and mental health.	Adjusted ORs suggested those engaged in moderate (OR = 2.67, 95% CI 1.95–3.64) or vigorous activity (3.53, 2.54–4.89) at least once a week was associated with healthy ageing compared with inactive adults. Adjusted ORs showed becoming active (OR 3.37, 1.67–6.78) and remaining active (7.68, 4.18–14.09) was associated with healthy ageing compared with inactive adults.

Table 1 (*Continued*)

Authors	Country	Purpose	Year study commenced	Design	*n*	Sample characteristics	Predictors	Outcomes	Result
Josefsson [54]	Sweden	Examine longitudinal trajectories in episodic memory over 15 years	1988–1990	Cohort study (FU 15 years)	1954, 55% ♀	Random sample of healthy people aged 35–85 years	Physical activities during the previous 3 months Covariates: education, employment, self-reported health (feeling well), and SNP genotypes	Episodic memory comprising a composite score for five tasks	Compared to those with average baseline scores and average overall rate of change, those with moderate to high baseline scores and a better-than average rate of change were more likely to report physical activity (AOR = 2.19, 95% CI 1.21–5.93).
Kim [55]	Japan	Evaluate the effectiveness of exercise and amino acid supplementation in enhancing muscle mass and strength	2008	RCT	155♀	Women aged 75 and older with sarcopenia	3 month intervention: exercise and amino acid supplementation (exercise + AAS; *n* = 38), exercise (*n* = 39), amino acid supplementation (AAS; *n* = 39), or health education (HE; *n* = 39). Covariates: history of fractures and falls, urinary incontinence, exercise habits, smoking status, MMSE score, BMI	Physical function measured by muscle strength and walking ability	Walking speed increased in all three intervention groups, leg muscle mass in the exercise + AAS and exercise groups, and knee extension strength only in the exercise + AAS group (9.3% increase). The odds ratio for leg muscle mass and knee extension strength improvement was more than four times as great in the exercise + AAS group (OR = 4.89, 95% CI 1.89–11.27) as in the HE group.
Lin [47]	Taiwan	Explore the trajectory stability and its association with l change in physical performance	1989	Cohort study (FU 10 yeas)	4049, 36%	Probability sample of all those aged 60 years or over	Physical performance determined by ability to perform seven activities Covariates: age, sex, education, marital status, BMI, history of chronic health conditions, depressive symptoms, betel chewing, alcohol consumption, cigarette smoking, and routine exercise	Functional disability based on ability to perform six basic self-care tasks without help	Reduced physical performance significantly reduced trajectory performance in women (OR = 7.76, 95% CI 5.04–11.93) whereas routine exercise (OR = 1.57, 95% CI 1.23–1.99)
Middleton [4]	USA	Determine how physical activity over the life course is associated with cognitive impairment in late life	1986–1988	Cross-sectional study	9344 ♀	Participants of the Study of Osteoporotic Fractures	Physical activity (modified Paffenbarger questionnaire) Covariates: age, education, marital status, diabetes mellitus, hypertension, depressive symptoms, smoking, and BMI	Cognitive impairment measured by the modified Mini-Mental State Examination (mMMSE)	Physically active women had lower cognitive impairment in late life than women who were inactive at each time (teenage: AOR = 0.65, 95% CI 0.53–0.80; age 30: AOR = 0.80, 95% CI 0.67–0.96); age 50: AOR = 0.71, 95% CI 0.59–0.85; old age: AOR = 0.74, 95% CI 0.61–0.91).

Table 1 (*Continued*)

Authors	Country	Purpose	Year study commenced	Design	n	Sample characteristics	Predictors	Outcomes	Result
Nicklett [56]	USA	Relationship between diet, physical activity, and mortality	1992–1995	Cohort study (FU 5 years)	713, 100% ♀	Probability sample of community dwelling ♀ aged 70–79 years	Total serum carotenoids and physical activity (kcal/kg per day determined through the Minnesota Leisure Time Physical Activity Questionnaire) Covariates: age, education, BMI, cigarette smoking, alcohol consumption, diet, ethnicity, chronic disease.	All-cause mortality	Physical activity improved survival (AHR = 0.52, 95% CI 0.41–0.66). The most active women were more likely to survive than the least physically active women (AHR = 0.28, 95% CI 0.13–0.59).
Opdenacker [57]	Belgium	Evaluate the long term effects of exercise intervention on physical fitness and cardiovascular risk	2004	Trial with randomised two-group intervention	186, 48% ♀	Sedentary older adults aged 60 and over	Lifestyle intervention to integrate physical activity into daily life Covariates: BMI, BP	Cardiorespiratory fitness Muscular strength and functional performance	At 23 months, participants in both groups still showed improvements in cardiorespiratory fitness. The structured group showed long-term improvements in muscular fitness, whereas the lifestyle group showed long-term improvements in functional performance.
Ottenbacher [58]	USA	Association between physical activity and risk of 3 year mortality	2005–2006	Cohort study (FU 3 years)	948, 63% ♀	Probability sample of Mexican-Americans living in the community, $M_{age} = 82.2 \pm 4.5$	PASE Covariates: socio-demographic characteristics, BMI, Katz ADL scale, depressive symptoms (CES-D), cognitive function (MMSE), and comorbid conditions	Mortality was determined according to report of relatives at 3-year FU and from the National Death Index	Adjusted HR 0.36 (95% CI 0.21–0.62) and HR 0.50 (95% CI 0.31–0.82) for those engaged in moderate and high activity levels respectively compared to those with low activity.
Riebe [59]	USA	Investigated the relationship between adiposity, age, and gender with physical activity and physical function	1999	Follow-up data from RCT	821, 72% ♀	Community-dwelling people aged 60 years+	4-arm intervention: physical activity; diet; physical activity and diet; control. Covariates: age, marital status, race, education, smoking status, self-reported health, functional mobility (TUG), BMI	Exercise measured by Yale Physical Activity Survey (YPAS) and diet	Inactive individuals had significantly less functional mobility (i.e., TUG scores > 8.5 seconds) compared to those who were active.
Teri [60]	USA	Compare the efficacy and impact of physical activity programs for low-exercising older adults	2001	RCT	273, 62% ♀	Older adults from a Group Health Cooperative/University of Washington cohort without cognitive impairment and who were living independently	4-arm exercise intervention: in-class exercises with home assistance; health promotion; exercise and health promotion; control. Covariates: baseline exercise, body mass index (BMI), depression, age, sex, and marital status)	Self-rated health (SF-36, GDS), physical performance and functioning, and treatment adherence	At 18 months, participants in both exercise groups maintained improvements in general health perceptions and physical function (SF-36) Exercise groups also reported increased muscle strength and endurance, lower anxiety, and greater self-efficacy (depression and social/recreational subscales) than others

Table 1 (*Continued*)

Authors	Country	Purpose	Year study commenced	Design	*n*	Sample characteristics	Predictors	Outcomes	Result
Tsubota-Utsugi [61]	Japan	Determine the health behaviours related to functional decline	1998	Cohort study (FU 7 years)	1050, 59% ♀	Older community-dwelling adults without functional decline $M_{age} = 67.5 \pm 5.6$	Exercise Covariates: age, smoking, alcohol consumption, diet, BMI, past medical history	Functional capacity (TMIG and IADLs)	Compared to those doing 3 or more hours exercise weekly, those doing < 1 hour exercise reported greater decline (AOR = 1.94 95% CI 1.12–3.35) but no decline in intellectual activity (AOR = 1.50, 95% CI 0.91–2.46). Differences in the social roles or intellectual activity in those undertaking 1–2 h exercise per week were not significant (AOR = 1.24, 95% CI 0.66–2.34 and AOR = 0.87, 95% CI 0.49–1.57 respectively)
Villaverde Gutierrez [62]	Spain	Evaluate impact of exercise intervention on anxiety and depression in postmenopausal women	Not stated	RCT	60 ♀	Women aged 60–70 years who had natural menopause and mood problems	Exercise intervention with musical support Covariates: BMI	Hamilton Anxiety Scale and Brink and Yesayage Depression Scale	Among the exercise group, those with moderate and severe depression (18 and 22%, respectively) and anxiety reported significant improvements.
Yang [28]	Australia	Evaluate the effectiveness of a home balance and strength exercise intervention	Not stated	RCT	225, 56% ♀	Community dwelling adults aged 65 years and over with mild balance dysfunction	6-month intervention involving physical therapist–prescribed balance and strength home exercise program and the Visual Health Information Balance and Vestibular Exercise Kit.	Physical function measured by balance, muscle strength, sit-to-stand tests, walking speed, HRQoL	The intervention group improved Functional Reach Test (mean diff = 2.95 cm, 95% CI 1.75–4.15), the Step Test (2.10 steps/15 seconds, 95% CI 1.17–3.02), hip abductor strength (0.02, 95% CI 0.01–0.03), and gait step width (2.17 cm, 95% CI 1.23–3.11). There were NS trends for improvement on most other measures.

Table 2
Summary of exposure variables or activity interventions of included studies.

	Activity assessments			Interventions		
	Type	Frequency	Physical performance test	Cardiovascular exercise and strength	Balance and flexibility	Health promoting behaviour
Aichberger [46]	√ (mod/vig)	√				
Chale-Rush [48]	√	√	√ (yes/no)			
Chen [49]	√ (7/7)	√ (7/7)				
Correa [50]				√		
Earnest [68]				√		
Freiberger [23]				√	√	√
Gow [52]	√ (4-point scale)	√				
Greendale [53]					√ (yoga)	
Hamer [33]	√ (3-point scale)	√				
Josefsson [54]	√ (3/12)	√ (3/12)				
Kim [55]				√		
Lin [47]		√				
Middleton [4]	√ (3-point scale)	√				
Nicklett [56]	√ (2/52)	√ (2/52)				
Opdenacker [57]				√	√	√
Ottenbacher [58]	√ (7/7)	√ (7/7)				
Riebe [59]	√	√				
Teri [60]				√	√	√
Tsubota-Otsugi [61]		√				
Yang [28]				√	√	

employees. These recruitment strategies yielded a sample of 235 older adults aged 60 and older (48% women), who had not participated in endurance or strength training in the two years preceding the study, or had been physically active at moderate intensity for more than two hours a week at the moment of recruitment.

3.3.3. Cohort studies

Nine cohort studies were included in the review. Four studies originated in the European Union (one from Denmark [52], one from Sweden [54], one from the UK [33], one comprised 11 European countries [46]), three originated in Asia (two from Taiwan [47,49] and one from Japan [61]), and two originated from the USA [56,58]. The follow-up (FU) period varied from around 2.5 years [46] to 25 years [52] (3 year FU [58], between 5 and 8 year FU [33,47,49,56,61], 15 year FU [54]). One study recruited people born in 1914 and commenced data collection at 50 years of age [52], while most participants were aged in their 60s [33,46,47,49,54,61] or 70s [56,58] at baseline. The size and gender composition for the studies varied ($n = 713$, 100% women [56], $n = 802$, 46% women [52], $n = 948$, 63% women [58], $n = 1050$, 59% women [61], $n = 1954$, 55% women [54], $n = 2133$, 49% women [49], $n = 3454$, 47% women [33], $n = 4049$, 36% women [47], $n = 17333$, 55% women [46]).

3.3.4. Cross sectional studies

One cross-sectional study was included in the review [4]. This large study ($n = 9344$) stemmed from the Study of Osteoporotic Fractures (SOF), which comprised women aged 65 and older and commenced in 1986. The SOF was a nationwide longitudinal study which examined fractures and fall risks associated with aging in women [65]. Eligible participants included women who were able to walk independently, and who had not had a previous hip replacement.

3.4. Exposure variables or interventions

3.4.1. Observational studies

The included studies used a number of psychometric instruments to measure the exposure variable (i.e., physical activity). Two studies used the Physical Activity Scale for the Elderly (PASE) [49,58], an instrument specifically designed to measure self-reported occupational, household and leisure items over a one-week period in people aged 65 years and older. Other studies used items from the Minnesota Leisure Time Physical Activity Questionnaire [56], comprising questions on walking for exercise, doing strenuous household chores, doing strenuous outdoor chores, dancing, bowling, and exercise over a two-week timeframe; or grouping physical activity into vigorous, moderate and light physical activities (more than once per week, once per week, one to three times per month, hardly ever) using validated items previously employed in the Health Survey for England (HSE) [66]. Other studies have examined exposure through various items related to frequency and duration of moderate and vigorous activity [46] or using scales (from sedentary to vigorous activity and competitive sport) [4,52]. Still others have grouped exercise in relation to frequency (<1, 1–2, ≥3 h/week) [61,67] or combined the Short Performance Physical Battery (SPPB) summary score and walk time to determine level of physical functioning [48].

3.4.2. Exercise intervention

The exercise intervention was also administered differently in the included studies. For example, Earnest and colleagues administered a cardiovascular exercise training program which consisted of expending 4, 8, or 12 kcal/kg per week (KKW) whereby women trained at 50% of their maximal cardiorespiratory exercise capacity ($VO2_{max}$) at 50%, 100%, and 150% of the minimal recommendation for energy expenditure [51,68]. In contrast, Opdenacker compared a structured exercise intervention (three 60–90 min group exercise sessions weekly at 70% and 80% of individual heart rate reserve) with a home-based lifestyle intervention (whereby participants were assisted to integrate physical activity into their daily routines) [57], others compared several interventions (home-based exercise interventions that were administered alone or in combination with other health-promoting activities) [23,55,60], Yang examined the effectiveness of a physical therapist—prescribed balance and strength home exercise program on balance [28], and Greendale examined the impact of attending regular yoga classes [53].

Table 3
Summary of outcome measures in recent studies (2009–2013).

	Specific domain	Aichberger [46]	Chale-Rush [48]	Chen [49]	Correa [50]	Earnest [51]	Freiberger [23]	Gow [52]	Greendale [53]	Hamer [33]	Josefsson [54]
Standing balance assessment	PPF		√				√		√		
Gait assessment	PPF		√						√		
Chair rise assessment	PPF		√						√		
Walk time	PPF		√				√		√		
Muscle strength	PPF				√		√				
Muscle thickness	PPF				√						
Muscle activation	PPF				√						
Counter movement jump	PPF				√						
Reaction time and muscle onset latency	PPF				√						
Rate of force development	PPF				√						
Sit-to-stand	PPF				√		√				
Bathing	FD										
Walking 200 m independently	FD										
Eating	FD										
Dressing	FD									√	
Transferring	FD										
Walking across a room	FD									√	
Personal grooming	FD									√	
Stooping, crouching, or kneeling	PPF										
Lifting or carrying weights	PPF										
Pulling or pushing a large object	PPF										
Writing or handling small objects	PPF										
Extending arms above own shoulders	PPF										
Timed Up-and-Go	PPF						√				
Weekly energy expenditure (kcal × wee−1)	PPF										
Social role	FC										
Intellectual activity	FC										
Instrumental activities of daily living	FC										
Mortality	Ext			√							
Cardiovascular fitness	PF					√					
Memory	CF	√									√
Executive functioning	CF	√									
Depression	AD	√								√	
Cognitive function	CF							√			
HRQoL	CF										
Anxiety	AD										

Table 3 (*Continued*)

Kim [55]	Lin [47]	Middleton [4]	Nicklett [56]	Opdenacker [57]	Ottenbacher [58]	Riebe [59]	Teri [60]	Tsubota-Utsugi [61]	Villaverde Gutierrez [62]	Yang [28]
										√
										√
	√									
√										√
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Chale-Rush used the SPPB to assess performance on each of the three elements is scored between 0 and 4, with a summary score computed for the three elements ranging from 0 to 12. Summary scores approaching 12 reflect a higher level of physical functioning; Riebe used the Yale Physical Activity Survey (YPAS) to calculate energy expenditure; Tsubota-Utsugi used the TMIG; Aichberger used Delayed Word Recall (DWR) to examine memory, the Semantic Verbal Fluency test (VF) to examine executive functioning and the EURODEP to assess depression; Gow used the Wechsler Adult Intelligence Scale to assess cognitive function; Josefsson examined episodic memory measure was a composite of five tasks; Middleton used the mMMSE to examine cognitive function; Hamer used the CES-D scale to examine depression; Earnest measured cardiorespiratory exercise capacity ($VO2_{max}$) and heart rate variability (HRV); Teri used several measures to assess HRQoL and depression including the SF-36, GDS, PGWB, PQOL, PSWQ, and the Chronic Disease Self-Efficacy scale; Villaverde Gutierrez used Hamilton Anxiety Scale and Brink and Yesayage Depression Scale.

Table 4
Correlations between exercise and health markers identified in recent intervention studies (2009–2013).

Authors	Sample characteristics				Intervention type	Duration	Outcome	Result[a]	Study Quality[b]					
	n	% women	Mean (SD or range) age	Other characteristics					Ran	Con	Bl1	Bl2	ITT	Att
Correa [50]	58	100	67 ± 5 years	Mean height of 158.1 ± 10.2 cm and 38.0 ± 5.3% body fat Exclusion criteria ♀ engaged in strength training in the year before the study or a history of severe endocrine, metabolic or neuromuscular disease	Weeks 1–6: intervention group (*n* = 41) performed traditional resistance exercise for the lower extremity. Weeks 7–12: EG divided into 3 specific ST groups Traditional group (TG, *n* = 14) Power group (PG, *n* = 13) that performed the concentric phase of contraction at high speed Rapid strength group (RG, *n* = 14) that performed a lateral box jump exercise emphasizing the stretch shortening-cycle (SSC). Control group: Usual care	12 weeks	Body composition (skinfold), physical performance (muscle strength, thickness, activation, reaction time)	Weeks 1–6: EG+Weeks 7–12: RG++Positive outcomes Muscle strength, thickness and activation	U	U	N	U	Y	N
Earnest [51]	365	100	57 ± 6	Postmenopausal women who were sedentary, overweight or obese with SBP 120–160 mm Hg Exclusion criteria Serious medical condition	Group 1: Exercising at 50% (4 KKW) Group 2: Exercising at 100% (8 KKW) Group 3: Exercising at 150% (12 KKW) Control group: Usual care	6 months	Biochemistry, BMI, waist–hip circumference, BP, HRV, VO_2	Group 2+ Group 3+ Positive outcomes Improved parasympathetic tone No improvement for women ≥60	Y	Y	Y	Y	U	N
Freiberger [23]	280	44	76 ± 4	Community-dwelling adults aged 70–90 who had fallen in the past 6 months or reported fear of falling	Group 1: 32 × 1 h strength and balance group (SBG; strength and balance only; *n* = 63) Group 2: 32 × 1 h fitness group (FG; strength and balance plus endurance training; *n* = 64) Group 3: 32 × 1 h multifaceted group (MG; strength and balance plus fall risk education; *n* = 73) Control group: Usual care	16 weeks	Physical performance, fall-related psychological measures, incidence of falls	FG++ Positive outcomes Physical performance Results did not reduce fall-related fear or incidence of falls.	Y	Y	Y	Y	Y	Y

Table 4 (*Continued*)

Authors	Sample characteristics				Intervention type	Duration	Outcome	Result[a]	Study Quality[b]					
	n	% women	Mean (SD or range) age	Other characteristics					Ran	Con	Bl1	Bl2	ITT	Att
Greendale [53]	118	81	75 (range 60–90)	Women and men aged 60 and older with kyphosis angle of 401 or greater Exclusion criteria Serious medical comorbidity, use of assistive device	Intervention group: 1 hour yoga classes 3 days per week Control group: monthly luncheon and seminar and postal material	24 weeks	Debrunner kyphometer-assessed kyphosis angle, standing height, timed chair stands, functional reach, walking speed	Yoga + Positive outcomes Decrease in flexi-curve kyphosis angle of spines Results did not physical performance or HRQoL	Y	Y	Y	Y	Y	Y
Kim [55]	155	100	79 ± 3	Urban dwelling women aged 75 years with sarcopenia	Group 1: 60-min exercise session 2 × weekly for 3 months + Amino Acid Supplementation (AAS) (*n* = 38) Group 2: Exercise program only (*n* = 39) Group 3: AAS only (*n* = 39) Control group: Monthly health education classes for 3 months (*n* = 39)	3 months	Body composition (bioelectrical impedance analysis) and physical fitness tests	Group 1 ++ Group 2+ Group 3+ Positive outcomes Increased walking speed, leg muscle mass and strength	Y	U	Y	Y	N	Y
Opdenacker [57]	186	48	68 (range 60–83)	Healthy but inactive men and women aged 60 and older Exclusion criteria Endurance or strength training in 2 years preceding study, medical contraindications	Group 1: Individualized home-based physical activity program supported by telephone calls Group 2: Three weekly 60-90 minute supervised exercise sessions in a fitness centre Control group: Usual care	11 months	VO_2, BMI, BP, Function performance, muscular fitness	Group 1 + Group 2+ Positive outcomes Cardiorespiratory fitness, muscular Strength (Group 2++), functional performance (Group 1++)	N	N	N	N	Y	N
Teri [60]	273	62	79 ± 5	Cognitively intact, community dwelling older adults	Group 1: 9 × Seattle Protocol for Activity (SPA; in-class exercises with assistance setting weekly home exercise goals) program for 3 months Group 2: 9 × Health Promotion (HP; information about age-appropriate topics relevant to enhancing health) program for 3 months Group 3: 9 × SPA + HP programs for 3 months Control group: Routine care	3 month intervention and 1 year FU	Self-rated health (SF-36), depression (Geriatric Depression Scale), physical performance	SPA +SPA+HP +Positive outcomes HRQoL, muscle strength and endurance, exercise in minutes, sustained physical activity (at 18 months)	Y	U	Y	Y	Y	Y

Table 4 (*Continued*)

Authors	Sample characteristics				Intervention type	Duration	Outcome	Result[a]	Study Quality[b]					
	n	% women	Mean (SD or range) age	Other characteristics					Ran	Con	Bl1	Bl2	ITT	Att
Villaverde Gutierrez [62]	60	100	64 (range 60–70)	Older women presenting at primary health clinic with natural menopause and mood problems (anxiety and depressive symptoms)	Weeks 1–7: intervention group received 2×50 min exercise sessions per week Weeks 8–12: intervention group received 3×60 min exercise sessions per week Control group: Usual care	6 months	BMI, Hamilton Anxiety Scale and Brink and Yesayage Depression Scale	Intervention group +Positive outcomes Decreased depressive symptoms and anxiety	U	U	N	U	Y	U
Yang [28]	165	56	81 ± 6	Older people aged 65 or older with mild balance dysfunction but no aide and who lived in the community	Intervention Group: personalized home exercise program developed by a physical therapist. Week 1: for the home exercise prescription Weeks 4 and 8: Followed up for adjustments to the exercise program Control group: Usual activities and a falls prevention booklet	6 months	Laboratory and clinical measures of balance, mobility and strength Covariates: age, living situation, medications and medical conditions, BMI	Intervention group+Positive outcomes Laboratory and clinical measures of balance, mobility, and strength	Y	Y	N	Y	N	Y

‡Control group comprised equivalent non-exercising sample; [a] + indicates a positive correlation between exercise and health; — indicates equivocal or non-significant correlations; [b] Abbreviations under Study Quality - Ran denotes Randomisation (i.e., sequence generation); Con denotes Concealment; Bl1 denotes Blinding of personnel; Bl2 denotes Blinding of outcomes; ITT denotes intention to treat analysis, and; Att denotes Attrition; Y = Yes, N = No, U = Unsure/not-stated.

Table 5
Quality assessment of observational studies.

	Middleton [4]	Aichberger [46]	Chen [49]	Gown [52]	Hamer [33]	Josefsson [54]	Lin [47]	Nicklett [56]	Ottenbacher [58]	Tsubota-Utsugi [61]
Study design	+	+	+	+	+	+	+	+	+	+
Setting	?	+	+	+	+	+	+	+	+	+
Participants	?	+	+	+	+	+	+	+	?	+
Variables	+	+	+	+	+	?	+	+	+	+
Measurement	+	+	+	+	+	?	+	+	+	+
Bias	?	?	?	?	?	+	+	?	?	+
Study size	?	+	?	?	?	?	?	?	?	?
Statistical methods	+	+	?	+	?	+	+	?	+	+
Descriptive results	+	+	+	+	+	?	+	+	+	+
Main results	+	+	+	+	+	+	+	+	+	+
Other analysis	+	+	?	+	?	+	?	+	+	+
Discussion	+	+	?	?	+	?	?	+	+	+
Attrition		?	+	?	?	+	+	?	?	+

+ indicates yes, – indicates no,? indicates unsure/not stated.

3.5. *Outcome measures*

3.5.1. *Mortality*

Mortality was significantly reduced among those who reported high physical activity levels. For example, Nicklett [56] and Ottenbacher [58] suggested that most active women were more likely to survive than the least physically active women (Adjusted Hazard Ration (AHR) = 0.28, 95% CI 0.13–0.59 and AHR = 0.34, 95% CI 0.16–0.73, respectively) even after adjusting for age, education, ethnicity, depression and comorbidities. Similarly, Chen [49] reported that women who were sedentary reported 98% higher risk of mortality (95% CI 1.36–2.89) compared with those who were most active. Results were less consistent for moderate levels of activity; Ottenbacher [58] reported 62% reduction in three-year mortality (95% CI 0.19–0.75) while others did not find that moderate activity significantly improved survival [49,56].

3.5.2. *Physical functioning and health*

Numerous trials [23,28,48,50,51,53,55,57,59,60] and three cohort studies [33,47,61] examined various aspects of physical health including cardiorespiratory fitness [4,51,57], absence of chronic disease [33], heart rate variability (HRV) [51], muscular strength [28,50,53,55,57], and physical functioning and capacity [28,33,47,48,50,55,57,59–61].

Cardiorespiratory exercise capacity is a predictor of cardiovascular disease. Earnest et al. found that $VO2_{max}$ improved incrementally with increased dose of exercise (control: 2.86 mL/kg/min, 95% CI 0.6–0.10; 4 KKW: 0.64 mL/kg/min, 95% CI 0.35–0.98; 8 KKW: 1.41 mL/kg/min, 95% CI 1.01–1.81; 12 KKW: 1.60 mL/kg/min, 95% CI 1.22–1.98), though the effect was only sustained in those aged ≥60 years in subgroup analysis [51]. Similarly, Van Roie and colleagues found that following a six-month exercise intervention, $VO2_{peak}$, time until exhaustion, and peak work load improved [69], although a two-year FU showed that this effect was best sustained in the lifestyle intervention group (compared with the structured intervention group) [57]. In contrast, Middleton and colleagues suggested that their preliminary analyses showed no evidence of a dose–response between physical activity and cognition at any age [4].

A number of different exercise interventions were implemented over varying timeframes, and with mixed results. Specifically, Greendale and colleagues reported that following a six-month yoga intervention, the treatment group showed improvements in flexicurve kyphosis angle and kyphosis index but not in Debrunner kyphometer angle or physical performance [53]. Other studies however, found that the exercise improved balance, lower limb muscle strength and a corresponding increase in physical functioning and capacity [28,47,50,55,57,60,69] when compared with usual care groups. Other studies found that exercise, among other factors, was associated with functional decline and poor physical health [47,48,59,60].

Interestingly, a trial by Van Roie [69] found that at the end of the 11-month trial both the structured exercise and lifestyle intervention groups improved their functional performance. However, one year following the completion of the intervention, cardiorespiratory fitness, muscular fitness, and functional performance improved in the structured intervention group that was not seen in either the lifestyle or control groups [57]. This is supported by others, who found that among older adults, establishing and maintaining a home-based exercise program can yield immediate and long-term physical and affective benefits [60].

Finally, Hamer examined multiple aspect of health associated with healthy aging (defined as an absence of major chronic disease, having no major impairment of cognitive function, having no major limitation of physical functions, and generally good mental health) over an eight-year period [33]. This study suggested a dose–response association between participation in moderate or vigorous activity, regardless of whether participants commenced physical activity later in life (Adjusted Odds Ratios (AOR) = 3.37, 95% CI 1.67–6.78), or sustained existing physical activity levels (AOR = 7.68, 95% CI 4.18–14.09) [33].

3.5.3. Cognition

Compared to studies incorporating physical outcomes, fewer studies examined the effects of exercise on cognitive outcomes for older women. Across these studies, conceptualisations and measurement of cognitive outcomes varied, to include global cognitive function (e.g., assessed via the Wechsler Adult Intelligence Scale (WAIS) [52] and Mini-Mental State Examination (MMSE) [4]), specific cognitive functions (i.e., memory and executive function; episodic memory [54,61]), and intellectual activity (i.e., intellectual curiosity and exploration [61]). Five studies determining the cognitive outcomes of exercise in older women met the selection criteria for inclusion in this review, and are discussed here.

All studies found that physical activity was associated with lower rates of cognitive decline, though the magnitude of the effect differed between studies. For example, the strength of association between general activity and cognition was largely explained by baseline cognitive ability (age 50), with only a modest effect remaining between cognitive decline and physical activity at age 60 or 70 [52]. Others however, have suggested that even after adjusting for potential confounders, being inactive was associated with greater cognitive decline ($\beta = -1.79$, $SE = 0.17$ for verbal fluency; $\beta = -0.35$, $SE = 0.04$ for delayed word recall [46]), particularly among those participating in vigorous activities more than once a week. Still, others have found that functional decline was most strongly predicted by current tobacco smoking (odds ratio (OR) = 1.58, 95% CI 1.06–2.36), excess sleeping (OR = 2.15, 95% CI 1.49–3.11), and poor self-reported health (OR = 1.93, 95% CI 1.40–2.67) [61], while a retrospective study found that teenage physical activity was most strongly associated with lower odds of late-life cognitive impairment (OR = 0.73, 95% CI 0.58–0.92), though participants becoming active in later life had lower risk than those who remained inactive [4].

3.5.4. Health-related quality of life (HRQoL), anxiety and depression

Three studies compared the impact of physical activity on HRQoL [28,53,60]. Overall, two studies failed to find improvements in HRQoL over the course of the intervention [28,60], while another trial reported improvements in quality of life in both intervention groups ($p = .03$), general well-being ($p = .03$), perceived self-control ($p = .009$), and vitality ($p = .04$) [60]. Interestingly, this effect was maintained 12 months after the end of the study (as well as new differences in worry scores, depression, and positive well-being) [60].

Three studies (two RCTs and one cohort) examined the impact of physical activity on anxiety and depression [33,60,62], and results were conflicting. A trial found that compared to the control group, the intervention group reported significant improvements in mood (defined by anxiety and depression) after the intervention [62]. Similarly, Hamer suggested that over time, participants who engaged in either moderate (AOR = 0.67, 95%CI 0.53–0.85) or vigorous activity (AOR = 0.51, 95%CI 0.39–0.67) reported less depressive symptoms, even after adjusting for age, sex and other components of healthy ageing. In contrast, Teri found no differences in depression scores among intervention groups when measured by the Geriatric Depression Scale (GDS), although lower depressive symptoms were noted when using the Psychological General Well-Being Index (PGWB) [60].

3.6. Quality assessment

A proportion of the trials examined in this review had a moderate to high risk of bias. For example, two studies did not provide clear or sufficient detail about the process of randomization [50,62], and one study randomized only between intervention groups, while those who were first to volunteer for the study were allocated to the control group [57] increasing risk of selection bias. Only three trials provided detail about the concealment of allocation, one using sequentially numbered, opaque, sealed envelope [53], and two used a third party not associated with the recruitment or assessment of study participants randomization and allocation [23,28]. The remainder of studies did not include concealment [57], or it was unclear upon reading the article [50,55,60,62]. For example, one study stated that group allocation was mailed to participants but the authors do not outline when or by whom [55].

With regard to blinding, the reviewers did not think given the intervention, that it was feasible or pragmatic to blind participants to their allocation for the duration of the study, and so only blinding of study personnel and outcome assessors were considered. Almost half of the studies either failed to blind study personnel and/or the outcomes, or provided insufficient information to determine whether blinding had occurred [50,57,62], while an additional study used blinded assessors only [28]. Intention-to-treat analysis was undertaken in five studies [23,50,53,57,62]. Earnest and colleagues did not perform intention-to-treat analysis [51] although retrieval of earlier papers by the same authors suggested an initial sample of 464 sedentary, postmenopausal overweight or obese women and performed an intention-to-treat analysis where missing follow-up data inserted baseline values [70]. It is unclear in the current paper however, why only 365 of the original sample were included in the final analysis.

Generally, observational studies are at greater risk of bias and for this reason careful consideration of their quality should be considered before inclusion in systematic reviews. We used a modified version of a standard assessment tool to determine risk of bias [37,71] and concluded that most of the prospective studies in this review were considered to have a moderate risk of bias. The study design and settings were discussed in varying detail by authors and was appropriate to the study objectives/research questions though at times the reviewers were required to search related papers for additional detail [33,46,47,49,52,54,56,58,61]. Study participants were drawn at random from various sampling frames [47,49,54,56,58] in an effort to provide a population representative sample [6,46,52,61], though only four studies provided significant detail about attrition over time, its impact on the representativeness of the sample, and the way authors managed it [13,17,54,61]. Moreover, though many of these studies reported samples in exceed of 1000 participants (sample size ranged from 713 to 17333 [46]), only one study provided detail about how sample size was derived [46]. Finally, given the potential biases inherent in the study design, most studies provided insufficient detail about these risks or the ways in which they were addressed [33,46,47,49,52,54,56,58,61].

Middleton and colleagues provided cross-sectional data from a large prospective study [4]. Though this study was undoubtedly sufficiently powered to examine the research question, like other cross-sectional studies it has an increased risk of bias [36,37]. Indeed, the average age of women in this study was 71 years of age and they were asked to recall events during their teens. Other studies that have examined recall bias have suggested that it might result in significant underestimation of exposures [72]. As the cross-sectional data from this paper were taken from a prospective study, it might have been possible to compare findings with data from earlier waves, however this was not done.

4. Discussion

There is growing impetus on women's health and wellness during midlife and beyond. Indeed, in postmenopausal women, body composition and higher levels of physical activity are associated with better physical function performance [73] while another study has suggested that 'frailty' is likely to already have begun in midlife [74]. Clearly, developing or maintaining a healthy lifestyle in the middle years is likely to provide ongoing benefits in older age. Central to this is access to resources on modifiable lifestyle factors [34] like diet, sleep and physical activity. One of the limitations of the current literature however, is the extent, frequency, location, and intensity of exercise that is likely to yield the greatest benefit.

We systematically reviewed the recent literature on the impact of physical activity in preventing decline in cognitive and physical functioning in postmenopausal women. While evidence supports the protective properties of exercise on physical and mental health in older women, research has explored various elements of physical activity in order to determine the most effective exercise methods in promoting good health for older women. The studies with this objective and included in this review examined exercise duration, exercise program composition, location of exercise intervention (i.e., gym vs. home), exercise targeted to specific needs for older adults such as muscle strengthening and balance, and specific exercise styles including yoga and walking.

All studies found that physical activity was associated with lower rates of cognitive decline, though the magnitude of the effect differed between studies. While some studies found that cognitive decline was largely a result of cognitive ability earlier in life [52] and lifestyle factors like cigarette smoking (OR = 1.58, 95% CI 1.06–2.36) and sleep disturbance [61], others have suggested that cognition decline was strongly associated with being sedentary (particularly relative to others engaged in vigorous activities in their younger years) [4,46].

Higher physical activity levels were also associated with a significant reduction in all-cause mortality, showing that the most active women were more likely to survive than the least physically active. This relationship remained constant even after adjusting for age, education, ethnicity, depression and comorbidities. Women who were more sedentary reported a 98% higher risk of mortality than their physically active counterparts.

In this review we found that exercise interventions (or lifestyle activities) that improved cardiorespiratory exercise capacity showed the most positive impact of physical health. These results are consistent with Kodama and colleagues who reported that compared to individuals with high cardiorespiratory function (CRF), those with low CRF had a 70% increase risk of all-cause mortality (95% CI 1.51–1.92) and a 56% increased risk of coronary heart disease events (95% CI 1.39–1.75) [75]. It is important to note however, that the effect was only sustained in those $\geq$60 years of age and also in the lifestyle intervention group (compared with the structured intervention group), which raises the question: do we need to prescribe exercise differently*; i.e. higher intensity and incorporated into their lifestyle*, as women get older to obtain the positive sustained effects of exercise?

Findings on the impact of physical activity on HRQoL were less consistent with changes in general well-being, perceived self-control and vitality apparent in one study with the effects sustained after 12 months, while two studies failed to find improvements in HRQoL [28,60]. Further research needs to occur in this area to provide conclusions on health related quality of life [76]. Indeed, several studies suggested that health improved incrementally with increased dose of exercise [21,33,51,68] irrespective of when the physical activity commenced (whether it is in earlier life or the later years) [33].

Clearly, one of the difficulties associated with activity interventions is adherence. Many of the trials included in this review reported attrition of between 20 and 30% [23,28,57,60] and non-compliance of up to 15% [57]. In these studies, the rationale for not continuing exercise interventions was similar to those echoed in earlier studies; that is non-adherence, particularly in midlife and older women, is associated with time constraints, cultural factors, personal factors and environmental factors [76–80]. Moreover, McArthur and colleagues reported that the most common barrier to regular exercise in midlife women was related to the demands and multiple roles of their life stage [80].

From this perspective, programs should facilitate and support women to participate in regular exercise by embedding physical activity programs in public health initiatives [33], by developing home-based exercise program that require few resources [60], and by creating interventions that can incorporate physical activity within a healthy lifestyle [57].

This study has several limitations. First, the data extraction was unblended, and this may have been a source of bias. Another potential source of bias was related to study quality; some of the studies included in the review were of low and moderate quality, included numerous methodological differences (instruments, design, analysis, etc.), and were conducted over varying timeframes. This contributed to heterogeneity and prevented meta-analyses. Despite these limitations however, this review pulls together five years of research on the impact of physical activity on cognitive and functional decline. Results suggest that regular (at least 150 min per week) moderate to vigorous activity is likely to provide benefits to both mental and physical health particularly if embedded within a broader lifestyle program. Findings also suggest there may be a dose–response relationship between exercise and health which may have clinical implications in prescribing exercise for postmenopausal women.

Contributors

All authors contributed to the manuscript. LR acted as first reviewer for the literature review, CS as second reviewer and DA as third reviewer. LR did a first search of the literature; CS constructed the tables for inclusion in the manuscript with LR and DA completing the first draft and CS significantly contributed and refined the second draft of the paper. All authors commented on and contributed to the final paper.

Competing interests

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