The effects of sport participation on physical and cognitive function in older adults: systematic review and meta-analysis

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REVIEW

The effects of sport participation on physical and cognitive function in older adults: systematic review and meta-analysis

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Abstract

Background Physical activity has a positive impact on the ageing process, but little is known about the benefits of sport for older adults.

Aim The aim of this study was to review and synthesise the available literature regarding the effect of sport participation on physical and cognitive function in older adults.

Methods After searching databases, 2422 studies were screened and a total of 16 studies met the eligibility criteria. Quality assessment was undertaken.

Results The selected studies assessed either physical function, cognitive function or both. From the studies that assessed physical function ($n = 13$), 9 (70%) reported significant improvements in timed up and go, repeated sit to stand, static balance postural sway or walking performance ($p < 0.05$). Of the studies that assessed cognitive function ($n = 5$), 5 (100%) reported significant improvements in attention and memory ($p < 0.05$). The sport participation significantly improved physical function but not cognitive function. The physical benefits of sport participation could be explained through the quantity and quality of training.

Conclusion Sport participation can increase physical function in older adults and should be promoted alongside other modes of physical activity.

Keywords Physical functions · Review study · Ageing · Cognition · Sport

Introduction

The ageing population is growing due, in part, to changes in living conditions and improved access to health care services. The ageing process leads to changes in different body systems including impairment in cognitive function, a decline in walking performance, loss of postural stability and an increased risk of falls [1]. Ageing can produce other deteriorative structural changes in aerobic capacity and muscle function, impairing an individuals' ability to perform activities of daily living and subsequently increasing the risk of chronic disease [2, 3].

The scientific evidence supports the impact of lifestyle factors, such as physical activity, on slowing the rate of age-related physiological and functional decline in older adults [4]. The benefits of an active lifestyle in older adults are well documented [5]. Physical activity is associated with reduced mortality and risk of cardiovascular disease, diabetes, bone disease [6–8] and cognitive decline [9]. In late adulthood (+ 65 years), participation in moderate to vigorous physical activity is also associated with reduced risk of functional limitation and increased independence [10] and sustained physical function in elderly people [11].

Sport is defined as an institutionalised, organised activity with a gamelike structure that has rules and regulations, involves strategies, requires special facilities and equipment and takes place at a certain time and place [12]. The rate of

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participation in recreational and organised sport in adults varies by country [13]. Across Europe [14] and most other countries [15] it is clear that both general physical activity and specific sports participation decline with age especially in adults above 65 years old. Existing recommendations [16] suggest older adults should seek to maintain health-related fitness through regular physical activity (i.e. 150 min of moderate-intensity physical activity per week and 2 sessions per week for balance and strength training), but they are not explicit about how sport might contribute to this. These results from participation in physical activity suggests that sporting activities are perhaps a missed opportunity for older adults to achieve the physical activity recommendations [17].

Many sports including golf, racket sports, swimming, bowls, cycling and walking football could match the physical capacity of older adults and can offer potential health benefits for this population [18]. Studies have shown that participation in sport can reduce the rate of mortality and the risk of cardiovascular disease, diabetes and osteoporosis in older populations [7, 19, 20]. There is evidence that older adults who participate in sport maintain health and wellbeing, feel part of a community, and experience an enhanced sense of control over the ageing process [18, 21]. Stenner, Buckley and Mosewich [21] in a systematic review study showed that in 21 studies (out of 30 studies), health-related factors (physical, mental and cognitive) were the main determinants of participation in older adults who took part in Masters/Senior games (e.g. athletics, swimming, cycling, volleyball and gymnastics) or individual sports (e.g. golf, bowls, and cycling). The other benefits were friendship and being with the community. The barriers to sport participation in older adults were personal (competing priorities and social expectations), organisational (lack of playing facilities and risks) and policy barriers [18]. Despite older adults being aware of the physical health benefits of sport participation, their perception is only limited to the physical fitness components [21] that are usually improved through moderate to higher levels of physical exertion, or psychological factors (e.g. enjoyment) that are enhanced through competitions [22]. However, less is reported on the benefits of sport in terms of sustaining cognitive and physical function and independence for older adults [22]. Indeed, the movements and motor skills (i.e. types of tasks and the decision-making) that are required in sport could offer opportunities to stimulate cognitive activity and enhance executive system functions including reaction time, decision-making and anticipation through strategic and tactical elements [23]. Adherence to the rules of different sports could maintain working memory due to continuous adjustments and planning to meet the requirements of the tasks/game. In addition, many situations in sport (e.g. invasion sports, racket sports and net/wall games) require quick changes in body direction and postural adjustment that could improve dynamic balance and body reactions in older adults [24]. Sport participation has huge potential to improve physical and cognitive function and subsequently improve independence and confidence in older adults. A recent review study [49] showed that sport participants improved their physical fitness. Despite this, there is no up-to-date synthesis of the impact of sport participation on physical function (balance and gait), cognitive function (decision-making, attention) and balance confidence in older adults. This study aims to explore and synthesise the available literature on the effects of sport participation on physical function, cognitive function and balance confidence in older adults.

Methods

This systematic review was registered to PROSPERO (Code: CRD42021281964). Our systematic review addressing the question of the effects of sport participation on physical and cognitive function and confidence in older people was conducted in accordance with preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines.

Eligibility criteria

Studies that met the following criteria were included in this systematic review and meta-analysis: (1) older adults (≥ 65 years) without any physical, mental or cognitive impairments. (2) Participants took part in organised, recreational or competitive sports as an intervention. (3) Physical function, cognitive function and confidence were the main outcomes. (4) Research designs were pre–post-intervention assessments with/without a control group(s). (5) Articles published in peer-reviewed English journals between 1990 and November 2022. (6) Study contexts were in the community or sports clubs. (7) Only quantitative data were used as part of data collection.

Studies were excluded if they were (1) case studies, descriptive or cross-sectional study. (2) Exclusively reported qualitative outcomes. (3) They were abstracts from conferences. (4) Participants took part in physical activity (e.g. recreational swimming, cycling and running). (5) The outcome measures were fitness components (e.g. aerobic capacity and strength) or physiological parameters (e.g. Vo2max, respiratory capacity and power output).

Search strategy and study selection

The following databases were searched: Cumulative Index to Nursing and Allied Health Literature (CINAHL), MEDLINE, Health Source: Nursing/Academic Edition (HSNAE), SPORTDiscus, Scopus, PubMed, Cochrane Library and

Allied and Complementary Medicine Database (AMED). The search strategy involved multiple steps, with a combination of two search terms used at each step. The keywords included sport, ageing, body function, physical fitness, cognition/cognitive function, gait/walking, balance, memory, activity daily living and recreational activity. In the database searching, titles and abstracts were initially independently screened by two reviewers, to check for relevancy. If there were duplicates in the selected outputs, we removed them after carefully reading the titles and abstracts. Full texts were obtained from potentially eligible studies and were reviewed against the inclusion and exclusion criteria. Researchers hand-searched citations of relevant articles and reviews. Discrepancies in decisions were discussed amongst reviewers until consensus was achieved.

Synthesis of results

The synthesis methods were qualitative and quantitative reports (e.g. meta-analysis) in data analysis.

Qualitative data synthesis in this study was carried out on the main personal determinants of sport participation. These factors were the demographic measures of participants in control and intervention groups in terms of age groups, gender and their sport activity in each selected study. Then, the main characteristics of methodology in each study, such as intervention period, dose and statistical significance of each intervention, were obtained. Finally, we extracted the key points of the findings and whether the intervention was effective on the main outcomes of this study such as physical function, cognitive function and confidence. The qualitative method of data synthesis was the description of the above-mentioned variables in the form of a table for each selected study.

A meta-analysis was used to calculate the pooled effect size (ES) for the outcomes based on the differences between the pre-intervention (baseline) and post-intervention. A random-effect model was used at a 95% confidence interval using Cochran's Q test, with I^2 statistics as indices of heterogeneity. A random-effect model also accounts for differences in variability across studies by weighting each standardised effect based on its standard error. Standardised effects were calculated for each variable as the difference between time of assessment means (e.g. pre- and post-intervention) divided by the pooled standard deviation.

Data extraction process

Studies were organised in a Microsoft Excel worksheet according to methods, research outcome and findings information. Information extracted on methods specifically included sample size, sample population, type of interventions (sport) and outcomes by both reviewers.

Study quality assessment

The PEDro Scale [25] was used to assess study quality. The scale has 11 criteria, and 1 point was awarded to each. The possible total score in each study ranges between 0 and 11. Two reviewers screened the full texts and assessed their quality independently, and an agreed score was reported. Discrepancies in quality rating were resolved by discussion. Quality ratings were used to describe and contextualise findings but were not used to exclude studies.

Results

Search results

The search results yielded 2433 articles with an additional 86 articles from the review studies. After removing duplicates, 2422 articles were selected. After reading the titles, 2389 articles were excluded according to the inclusion and exclusion criteria. The full text of 20 articles was reviewed, and 16 articles were included for systematic review. Because of heterogeneity in tests, we selected 12 studies from 16 articles that used the same assessment method for meta-analysis. Studies without an intervention, outcome measures other than physical and cognitive functions, and the exercise-based activity were excluded (see Fig. 1).

Quality of studies

The overall quality of selected studies was above average (7.25 ± 1.8). The highest quality score was 11 [26] and the lowest score was 5 [27, 28]. The majority of the studies did not meet the criterion related to the concealed allocation of the participants (81%). All studies (100%) met the criteria related to inclusion/exclusion of the participants, reporting an outcome measure, comparison between groups and reporting central tendency and variability in the results.

The results of the study synthesis are presented in two distinct sections: systematic review and meta-analysis.

Systematic review

The characteristics of the studies are summarised in Table 1. The studies are reviewed based on target populations, types of sport, intervention period, research designs and outcomes.

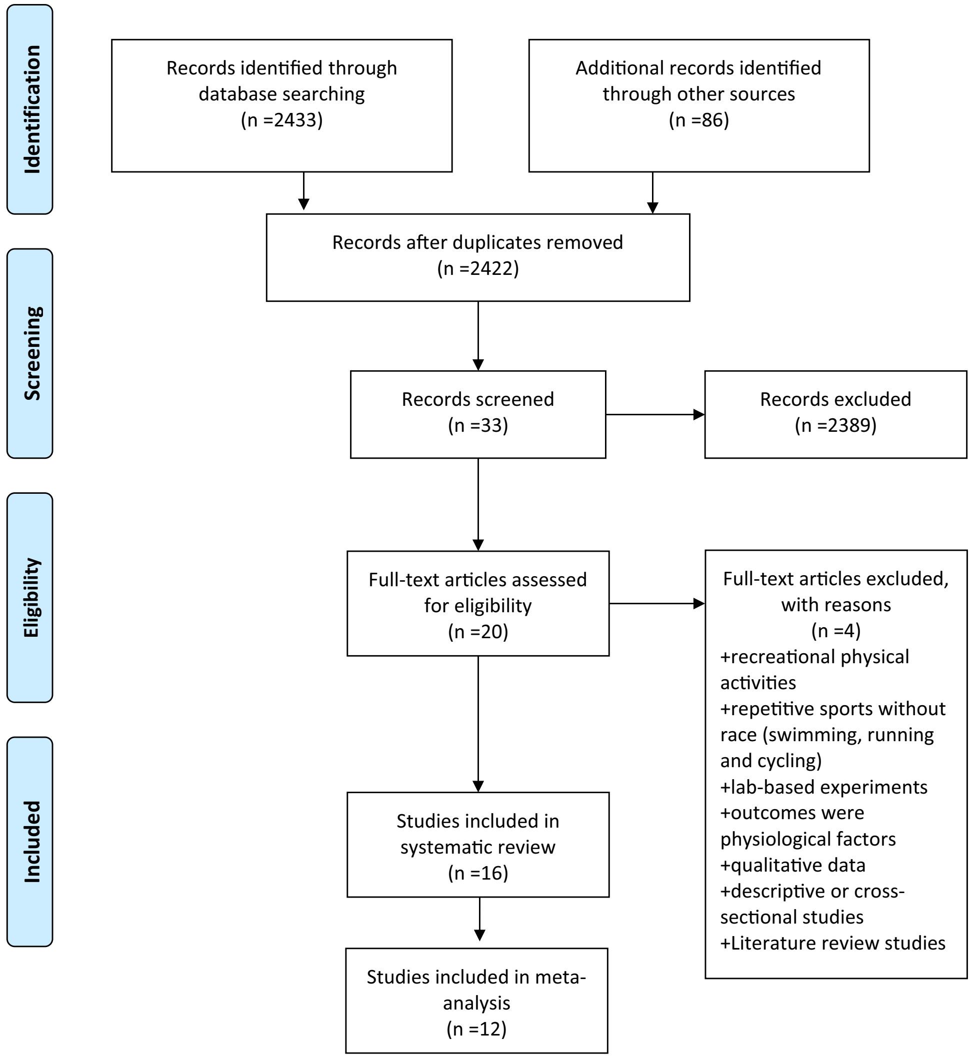

Fig. 1 PRISMA flow diagram for sport interventions in older adults

Populations of study

The studies recruited healthy older adults of both genders. Only one study [29] recruited men only for their intervention. The total sample size for the sport-related interventions was 411; the non-sport-related interventions were 129, and the control group was 285.

Types of sport

The types of sport were invasion sports such as football [29–31]; combat sports such as karate [32–35], boxing [26], martial arts [28, 36] and judo [37]; accuracy sports such as golf [38, 39]; net and wall games such as volleyball [27] and multiple sports [40, 41].

Intervention period and training dose

The dose of sport participation in previous studies differed in terms of length, session duration and aims, but was consistent on the plan for the control group because the control group only participated in daily routine activities and had no training session. The shortest intervention length was 4 weeks and in Thai boxing [26]. The longest intervention period was 12 months and in football [31]. The other studies had a range of intervention periods between 10 weeks [38] and 24 weeks [39].

The method of training was different among the studies due to the nature of sport. For example, football interventions were conducted in small-sided games format through interval training (e.g. 15 min training and rest). The combat sports were trained as forms of routine exercises and mainly focussed on basic movement skills. The golf intervention was focussed on both techniques and on-course play. Other types of sport (volleyball and multiple sports) were trained

Table 1 Main characteristics of studies such as participants, the type of intervention, main outcomes and key findings

Study	PEDro Score	Participants	Sport	Type of intervention	Outcome measures	Key findings	Effects
Anderson et al. (2014)	7	Healthy men older adults (mean age = 68.2 years) were randomly allocated into 3 groups: football ($n = 9$), strength training ($n = 9$) and control ($n = 8$)	Football	16-week football or strength training; 1 h per session and twice per week; football group trained small-sided games in natural grass for 15 min and 3–4 sets; strength training group performed 5 exercises and 5 min core training and progressive in terms of number of sets and repetitions. Control group only performed daily routines and no training	Vo2max; blood lactate; maximal oxygen uptake; Yo-Yo test; countermovement jump; ***30 s sit-to-stand test***	Sit-to-stand performance was significantly improved by 29% (17 ± 1 vs. 22 ± 1, $p < 0.05$) in the football group and 26% (19 ± 1 vs. 22 ± 2, $p < 0.05$) in the strength training group but not in the control group. Yo-Yo performance was significantly improved in the football group by 43% (421 ± 85 vs. 740 ± 198, $p < 0.01$) and unchanged in both strength training and control groups ($p > 0.05$)	(↑) Sit-to-stand reps (↑) Yo-Yo distance

Table 1 (continued)

Study	PEDro Score	Participants	Sport	Type of intervention	Outcome measures	Key findings	Effects
Areeudomwong et al. (2019)	11	Healthy men and women older adults (mean age = 66.5 years) were randomly allocated into 2 groups: Thai boxing ($n = 39$) and control ($n = 39$)	Thai Boxing	4-week Thai boxing dance for 30 min per session after enough warm-up in small groups of participants. The programme had a routine exercises such as straight punch, hook, uppercut, downward elbow, side hook and low kick. The pace was progressive in different weeks (slow to fast). Each routine exercise was repeated 10 times. The control group participated in fall prevention education booklet that focussed on fall management, modified Otago exercise programme (15 min sit to stand, walking, knee extension); each exercise repeated 10 times per session and 3 sessions per week	***Timed-up and go test; 60 s tandem stance with open and closed eyes***; lower limbs dynamometer muscle strength for flexors and extensors in hip and knee	TUG score was significantly improved ($p < 0.05$) in the boxing group than the control group (mean difference = 1.43 ± 0.27 s; CI = 0.90–1.96) after 1 month and after 4 months (mean difference = 2.0 ± 0.33 s; CI = 1.42–2.74). Tandem stance time was significantly ($p < 0.05$) improved in the boxing group than the control group (mean difference = 8.51 ± 0.91 s; CI = 6.70–10.32) after 1 month and after 4 months (mean difference = 9.26 ± 0.61 s; CI = 8.05–10.48)) in open eyes	(↓) TUG time (↓) Tandem time
Ciaccioni et al. (2020)	7	Healthy men and women older adults (mean age = 71.2 years) were randomly allocated into 2 groups: judo ($n = 16$) and control ($n = 14$)	Judo	16-week judo programme comprised 1-h session twice per week along with judo-specific warm-up. The judo programme focussed on central parts (e.g. standing, ground and Ukemi breaking-fall, Uchi-Komi and Kata sequences individually and in couple). Four basic judo postures trained. The control group only performed their daily activity and no special training	Gait analysis in 2 min trials; ***gait speed, cadence***, ***step time and length*** (mean and variability)	The judo group significantly ($p < 0.001$) improved gait speed (1.66 ± 0.2 vs 1.7 ± 0.22 m/s) and step length (46 ± 4 vs 47 ± 4 cm). No significant changes were reported in other outcome measures ($p > 0.05$)	(↑) Gait speed (↑) Step length (=) Cadence (=) Step time

Table 1 (continued)

Study	PEDro Score	Participants	Sport	Type of intervention	Outcome measures	Key findings	Effects
Filho et al. (2019)	8	Healthy men and women older adults (mean age = 68.5 years) were randomly allocated into 2 groups: karate ($n = 16$) and control($n = 17$)	Karate	12-week specialised karate programme and 24 sessions twice a week for 60 min per session. The training routine had brief warm-up (5–10 min); kihon exercises, kata, kumite and breathing techniques—(40–45 min) and relaxation through brief meditation exercises tailored to the needs of the participants (10 min)	***Cognitive assessment battery; cognitive function scales*** (attention and memory)	The karate group significantly improved cognitive assessment in Trail Making Test-B (146 ± 92 vs. 121 ± 70 s, $p < 0.05$) and memory recalling (11.78 ± 6.12 vs. 14.38 ± 5.35 score, $p < 0.05$)	(↓) TMT-B time (↑) memory score

Table 1 (continued)

Study	PEDro Score	Participants	Sport	Type of intervention	Outcome measures	Key findings	Effects
Kanwar et al. (2021)	6	Healthy men and women older adults (age range = 60–80 years) were participated in the programme ($n = 15$)	Golf	10-week small group golf training, twice per week and 90 min per session. The program was progressive in nature and included warm-up, driving range, putting, and course activities. gradually, more time was devoted to on course play and less to the other activities. Participants received training in the essential elements of the full-swing and short game at the driving range. On-course play commenced during week four, with two holes of play. During each successive week, the driving range time was reduced, and the number of holes played was increased, until participants could play nine holes independently by week ten. Participants were asked not to practice any other golf-related activities during the study, to control for the amount of golf played across participants	***Walking speed, dual-task cost, stride length*** in single-task and dual-task (subtracting by 3) conditions. ***Cognition and attention*** by the National Institutes of Health Toolbox Cognition Battery (NIH–C) and verbal learning test; **working memory and speed of processing**	Walking speed was improved by 7.2% (1.95 ± 0.17 vs. 2.09 ± 0.21 m/s, $p < 0.05$) in single-task and by 9.1% (1.75 ± 0.19 vs. 1.91 ± 0.22, $p < 0.05$) in dual-task conditions. Stride length was increased by 4.4% (1.56 ± 0.2 vs. 1.63 ± 0.15 m, $p < 0.05$) in single-task and by 2.6% (1.56 ± 0.17 vs. 1.6 ± 0.17, $p < 0.05$) in dual-task conditions. The dual-task cost was decreased by 20% (0.10 ± 0.09 vs. 0.08 ± 0.09, $p < 0.05$). The cognition score in working memory score increased by 5.8% (53.43 ± 7.28 vs. 56.5 ± 11.34, $p < 0.05$) and in speed of processing score by 5.7% (50.43 ± 12.39 vs. 53.29 ± 9.6, $p < 0.05$)	(↑) Walking speed (↑) Stride length (↓) Walking cost (↑) Cognition
Leung et al. (2020)	5	Healthy men and women older adults (mean age = 74.2 years) were randomly allocated to volleyball ($n = 17$), tai chi ($n = 23$) and control ($n = 23$) groups	Volleyball	20-week intervention period (30 sessions), twice per week and 90 min per session. Each session had 10 min warm-up and 10 min cool down. The volleyball group practice basic skills such as services, spike, underarm pass, overhead pass and block	***Chair sit to stand, timed up and go***, physical fitness tests (grip force, flexibility and step test)	The volleyball intervention group was performed better than the control group in post-test in chair sit to stand (group difference = 5.02; 17.83 vs. 12.80 reps, $p < 0.01$) and TUG (group difference = − 1.37; 5.43 vs. 6.80 s, 0.01) test	(↑) Sit-to-stand reps (↓) TUG time

Table 1 (continued)

Study	PEDro Score	Participants	Sport	Type of intervention	Outcome measures	Key findings	Effects
Lip et al. (2015)	5	Older adults (mean age = 72.5 years) without any health condition were divided into the intervention ($n = 8$) and control ($n = 22$) groups	Martial arts	12-week intervention period, once per week and 1 h per session, then daily home practice. They practised the forms, Siu Lim Tau and Chum Kiu, and Chi Sau (sticking-hand exercises) progressively. The control group did not receive any physical training and only joined other activities at the elderly centre	***5 sit to stand, Berg Balance Scale***, grip force, shoulder flexibility and fear of falling	The time to complete the sit to stand was reduced in the intervention group by 0.82 s (10.12 ± 2.81 vs. 9.30 ± 2.19 s), whereas in the control group was increased by 0.76 s (14.33 ± 4.62 vs. 15.09 ± 7.53 s). Balance score was increased in the intervention and control groups by 1.54 (48.82 ± 4.33 vs. 50.36 ± 5.37 score) and 1.26 (42.52 ± 7.98 vs. 43.78 ± 10.25 score), respectively. None of the effects were significant ($p > 0.05$)	(=) Sit-to-stand time (=) Balance score
Ma et al. (2019)	10	Older adults (mean age = 70.3 years) without any health condition were divided into the intervention ($n = 13$) and control ($n = 11$) groups	Martial arts	12-week intervention period (24 sessions), twice per week and 1 h per session. This training regimen was specifically designed to improve reactive balance control, lower limb muscular performance, and balance confidence in the older adults. It had nine sticking-hand drills that must be practised with a partner. The control group received no training but continued their usual daily activities and medical care. They were advised not to participate in any martial art training during the intervention period	***Balance confidence, centre of pressure (COP) displacement and velocity***, lower limbs strength and muscle activity	No significant improvement or group differences ($p > 0.05$) were found on balance confidence score (post-test group difference = 76.12 ± 22.62 vs. 78.76 ± 18.61 score), COP area (post-test group difference = 98.00 ± 142.92 vs. 74.25 ± 77.01 mm) and COP velocity (post-test group difference = 52.00 ± 14.88 vs. 49.75 ± 8.06 mm/s)	(=) Balance confidence score (=) COP area (=) COP velocity

Table 1 (continued)

Study	PEDro Score	Participants	Sport	Type of intervention	Outcome measures	Key findings	Effects
Pedersen et al. (2016)	8	Older adults (mean age = 80.2 years) without any health condition were divided into the team sports ($n = 13$), resistance training ($n = 19$) and control ($n = 12$) groups	Team sports (hockey, coneball and hula ball)	12-week intervention period. The training sessions were organised as intervals with 4 min of playing followed by 4 min of rest with three intervals (12 min per session) during the first 4 weeks, four intervals (16 min per session) during week five to eight, and five intervals (20 min per session) in week nine to twelve. The team sport group completed 2–3 sessions per week. The resistance training group completed 1–2 sessions per week and focussed on 3 main exercises with 10RM intensity	***TUG test, 30 s sit to stand*** and arm curl test	The sit to stand only improved in both intervention groups and no difference ($p > 0.05$) between the intervention groups (12.1 ± 3.5 vs. 11.8 ± 1.9 reps). No change in TUG test (7 ± 1.4 vs. 7.4 ± 1.9 s, $p > 0.05$)	(=) Sit-to-stand reps (=) TUG time

Table 1 (continued)

Study	PEDro Score	Participants	Sport	Type of intervention	Outcome measures	Key findings	Effects
Pliske et al. (2016)	8	Healthy men and women older adults (mean age = 69.1 years) were randomly allocated into 3 groups: karate ($n = 25$), fitness ($n = 24$) and control ($n = 19$)	Karate	20-week intervention period, twice per week and 1 h per session. The control group remained without training and only continued their regular activities. The karate group primarily focussed on the basic techniques and katas. The fitness group performed exercises for balance, strength and coordination and some fun games	***Walking speed, cadence and step length*** in single-task and dual-task (subtracting by 3) conditions	Cadence was improved in karate (120.83 ± 9.37 vs. 123.9 ± 9.67, $p < 0.01$) in simple and cognitive dual tasks (111.58 ± 13.73 vs. 116.9 ± 10.47, $p < 0.01$). Walking speed was improved in karate (1.36 ± 0.13 vs. 1.44 ± 0.14, $p < 0.01$) in simple and cognitive dual tasks (1.2 ± 0.17 vs. 1.3 ± 0.14, $p < 0.01$). Step length was improved in karate (0.67 ± 0.06 vs. 0.68 ± 0.05 m, $p < 0.05$) in simple and cognitive dual tasks (0.64 ± 0.08 vs. 0.66 ± 0.06 m, $p < 0.05$)	(↑) Cadence (↑) Gait speed (↑) Step length
Pringle et al. (2014)	6	Males and females ($n = 108$) older adults (mean age = 69.3 years) participated in the community sport-related health intervention	Multi-sport programme	Weekly attendance for 12 weeks. The sports included cricket, walking football, indoor bowls, table tennis along side board games	Health screening and ***quality of life questionnaire***	No significant change in the quality of life following the intervention ($p > 0.05$)	(=) QoL score
Reddy et al. (2017)	6	Males and females ($n = 20$) older adults (age range = 50–65 years) were randomly allocated to football ($n = 11$) and control ($n = 9$) groups	Walking football	12 weeks, 1 h per session small-sided football training once per week	***Flamingo balance test and cognitive measures such as divided attention, selective attention processing speed***	Balance score was increased in football group (9 ± 3 vs. 6 ± 3, $p < 0.01$). Selective attention was improved in football group (180.63 ± 87.88 vs. 123.55 ± 49.13, $p < 0.05$). Divided attention did not change ($p > 0.05$)	(↑) Balance score (↑) Selective attention (=) Divide attention

Table 1 (continued)

Study	PEDro Score	Participants	Sport	Type of intervention	Outcome measures	Key findings	Effects
Shimada et al. (2018)	10	Males and females ($n = 100$) older adults (age range = 70.2 years) were randomly allocated to golf ($n = 53$) and control ($n = 47$) groups	Golf	24-week intervention period; 90–120 min per session. The golf programme included 14 practice sessions and 10 golf course sessions. The practice session had a starter and driving range contents. Golf course sessions began with a 10-min warm-up period and stretching exercises, followed by a half-round of golf (100 min) and a 10-min cool-down period. Participants also performed home-based golf practice each day and were encouraged to continue learning about golf. Participants in the control group attended two 90-min health education classes focussed on health promotion during the study period. The instructors provided participants with information regarding exercise and healthy diets, although no specific information or recommendations regarding cognitive health were provided	***Mini mental state examination. Cognitive functions were assessed using the National Centre for Geriatrics and Gerontology-Functional Assessment Tool***. Secondary outcome measures included changes in physical performance, grip strength, ***walking speed*** and depressive symptoms	The golf group only improved memory functions (mean group difference = 0.26, CI = − 0.01–0.54, $p < 0.05$) relative to the control group and no changes in mini mental state examination (mean group difference = 0.19, CI = − 0.28–0.66, $p > 0.05$) and walking speed (mean group difference = 0.01, CI = − 0.06–0.04 m/s, $p > 0.05$) were reported	(↑) Memory score (=) MMSE score (=) Gait speed

Table 1 (continued)

Study	PEDro Score	Participants	Sport	Type of intervention	Outcome measures	Key findings	Effects
Sundstrup et al. (2016)	6	Healthy older adults (mean age = 68.2 years) were randomly allocated into football training ($n = 10$), strength training ($n = 9$) and control ($n = 8$) groups	Football	12-month intervention period, 1 h per session and 2–3 times per week. Each training session over the first 3 months was initiated with 15 min of low intensity warm-up followed by 3 × 15 min of 4v4 and 5v5 games on small pitches. The playing periods were interspersed by 2-min rest periods. For the following 9 months, warm-up was performed prior to the 1 h football training session and the training sessions consisted of 4 × 15 min of active play interspersed by 2-min rest periods. The intensity of the training sessions was 138 ± 3 and 143 ± 3 bpm during training in week 1 and week 16, respectively. Subjects performed high-intensity strength training with five exercises targeting the muscles in the lower extremity and upper body (leg press, seated leg extension, prone hamstring curl, pull-down and lateral raise). Each training session was additionally completed with 5 min of body-weight exercises for the core muscles (back extension and abdominal crunch). Training was performed in a progressive manner with weights ranging from 16 to 8RM	***Postural sway during single leg balance test, 30 s sit-to-stand test***, isokinetic test and jump test	Football and strength training improved sit to stand by 32% (18.5 ± 1.2 vs. 25.1 ± 1.2, $p < 0.01$) and 21%, (19.4 ± 1.1 vs. 23 ± 1.3, $p < 0.05$), respectively. No improvement or group differences on postural sway area (football: 3234 ± 587 vs. 2498 ± 587; strength: 3890 ± 620 vs. 2557 ± 661; control: 3890 ± 620 vs. 2557 ± 661 mm^2)	(↑) Sit-to-stand reps (=) Postural sway area

Table 1 (continued)

Study	PEDro Score	Participants	Sport	Type of intervention	Outcome measures	Key findings	Effects
Witte et al. (2016)	6	Male and female older adults (mean age = 70 years) were randomly allocated to karate ($n = 28$), fitness ($n = 24$) and control ($n = 26$) groups	Karate	20 weeks intervention period, twice per week and 1 h per session. The control group remained without training and only continued their regular activities. The karate group focussed on balance exercise, reactions and specific training along with cool-down phase. The specific training included stances such as forward stances, back stances (Jap. kokutsudachi), and straddle-leg stances to train leg and trunk musculature as well as balance skills. Also included were several arm techniques in standing positions and during forward and backward walking, lunge punches, reverse punches, and upper blocks to improve arm–leg coordination. In order to facilitate cognitive processes (reactivity, learning processes, memory, and attention) the participants executed simple attack and respond exercises as well as the special karate form. The fitness training focussed on improvement of balance ability, coordination reaction, rhythm, body awareness, and strengthening of muscles	Cognitive functions such as DemTect test, divided attention and motor reactivity by rod test	Karate group improved cognitive function in motor reactivity and divided attention scores ($p < 0.05$)	(↑) Motor reactivity score (↑) Divided attention score

Table 1 (continued)

Study	PEDro Score	Participants	Sport	Type of intervention	Outcome measures	Key findings	Effects
Witte et al. (2017)	7	Male and female older adults (mean age = 70.3 years) were randomly allocated to karate ($n = 30$), fitness ($n = 30$) and control ($n = 30$) groups	Karate	20-week intervention period, twice per week and 1 h per session. The control group remained without training and only continued their regular activities. The karate group focussed on balance exercise, reactions and specific training along with cool-down phase. The specific training included stances such as forward stances, back stances (Jap. kokutsudachi), and straddle-leg stances to train leg and trunk musculature as well as balance skills. Also included were several arm techniques in standing positions and during forward and backward walking, lunge punches, reverse punches, and upper blocks to improve arm–leg coordination. In order to facilitate cognitive processes (reactivity, learning processes, memory, and attention) the participants executed simple attack and respond exercises as well as the special karate form. The fitness training focussed on improvement of balance ability, coordination reaction, rhythm, body awareness, and strengthening of muscles	***5 times sit to stand, walking speed, static and dynamic balance tests***	The karate group had greater improvements than fitness and the control groups on sit to stand (pre-post: 8.15 ± 1.14 vs. 7.26 ± 1.47 s, $p < 0.05$) and walking speed (pre-post: 1.91 ± 0.24 vs. 2.14 ± 0.44 m/s). Dynamic balance was improved karate (pre-post: 2.29 ± 1.38 vs. 4.43 ± 1.23 points) and fitness groups	(↓) Sit-to-stand time (↑) Walking speed (↑) Dynamic balance score

(↑): increase; (↓): decrease; (=): no change or no difference

Bold texts are tests that have been used in the meta-analysis as funcational tests with a focus on fundamental techniques. All sport- and non-sport-related interventions had 10–15 min warming-up and cooling-down phases. The intervention groups trained 2–3 times per week and between 60 and 120 min in each session.

Research design

The designs of studies were randomised-controlled trials [26, 34–36, 39], experimental designs with a comparable group [27–29, 31, 33, 37, 40] and pilot/case studies [30, 38, 41].

Outcome measures

The studies that measured physical function mainly used timed up and go (TUG) test [26, 27, 29, 40], repeated sit-to-stand test [27, 28, 31, 34, 40], agility tests such as Yo-Yo [29], static balance by postural sway [26, 28, 30, 31, 34, 36] and walking performance for cognitive load, speed and step length [33, 34, 37, 38]. Cognitive function was measured by standard pen-and-paper tools for assessment of attention, memory, and general cognition [30, 32, 35, 38, 39, 41]. The balance confidence was measured by self-report balance confidence scale [28, 36].

Meta-analysis

Physical function

The sports intervention significantly improved physical functions (see Fig. 2) such as sit-to-stand (ES = − 4.98 [CI − 6.44:− 3.52], $I^2 = 0\%$, $Z = 6.7$, $p < 0.05$), walking speed (ES = −0.41 [CI − 0.82:− 0.002], $I^2 = 56\%$, $Z = 1.98$, $p < 0.05$) and TUG tests (ES = 0.76 [CI 0.43:1.08], $I^2 = 85\%$, $Z = 4.54$, $p < 0.05$).

Participation in sports did not change static balance ($p > 0.05$).

Cognitive function

Participation in sports did not change any cognitive function ($p > 0.05$).

Confidence

Participation in sports did not change balance confidence ($p > 0.05$).

Discussion

The aim of this study was to review and synthesise the available literature on the effects of sport participation on physical function, cognitive function and balance confidence in older adults. The findings of meta-analyses showed that participation in sport can improve physical function (e.g. dynamic balance, agility and walking performance) but not cognitive function and confidence in healthy older adults. The following sections explain the reasons for the functional benefits of sport participation in older adults.

Sport participation effects on physical function

The benefits of sport participation on physical function were demonstrated holistically, and its benefits depended on the nature of physical function. Findings here suggest that it might be important to match the type of sport with the specific physical capacity of older adults as they age to drive health benefits, as reported elsewhere [18]. In this review, the sports that resulted in improvements in physical functions related to dynamic balance (sit to stand), body transportation (walking) and manoeuvring (TUG) were football [29, 31], karate [33, 34] and boxing [26].

The improvements in physical function following sport participation reported in this review could be explained in a number of ways. First, the majority of the studies in this review had an acceptable amount of training physical stress to stimulate physical exertion and subsequently resulted in improvements in physical function. The ranges of training frequency were 2–3 sessions per week, and the ranges of training duration were 60–120 min that produced enough functional adaptations in older adults. The recommendation of regular physical activity to maintain health-related physical fitness for older adults is 150 min of moderate-intensity per week [16] and it seems that the sport participants in these studies met this requirement. The actual physical exertion/training intensity of the sport intervention groups was not monitored and reported (e.g. heart rate and perceived exertion) in these studies, but they were progressive. Previous studies showed that football is a sport that can stimulate both the aerobic and anaerobic energy systems and elevate heart rate and blood lactate in older adults [20, 42]. Second, the improvements in physical function through sport participation noted in this review indicate that the types of activity and tasks in organised/recreational sports can positively transfer to the ADLs because of similarities in motor skills and movements. The physical functional assessments that have been used in previous studies were TUG, repeated sit to stand and walking that require leg strength, postural stability, balance and ability to change the direction that are extensively used and practised in sport contexts. The stepping skills and agility in boxing and martial arts [26, 28], counteracting and resistance against postural destabilisation along with foot works in judo [37], using lower and upper body parts for offensive and defensive performances in volleyball [27, 43] and walking football [29] are examples of

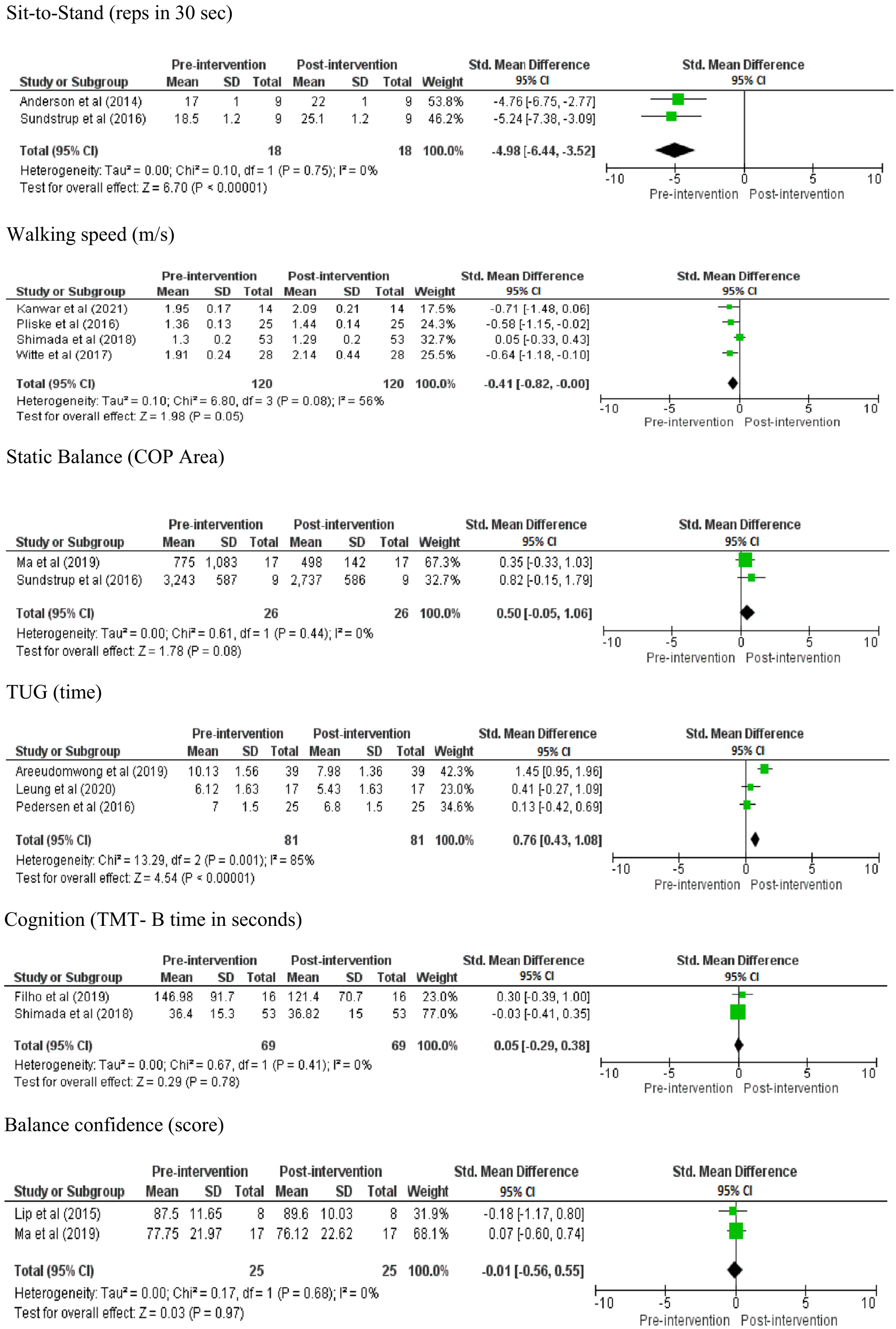

Fig. 2 Meta-analysis results for the effects of sport interventions on physical function, cognitive function and balance confidence

cognitive declines, and it seems that they were not sensitive to changes to some performance outcomes, such as time in TMT-B because they reached the ceiling. Another reason might be the nature of assessment (pen and paper) which was not specific to the physical tasks that are usually used in sport contexts.

The lack of any improvement in balance confidence could be related to the above-mentioned measurement issues and the nature of the sport (martial arts) that were not adequate for changes in balance efficacy. The studies that assessed balance confidence [28, 36] also did not show any improvement in physical balance tests (sit to stand and posture control) that further support the nature of the sport.

This review study has some implications for practitioners who work with older adults. First, organised or recreational sports can improve physical function in community-dwelling older adults. The sport interventions could be alternative methods for traditional physical activity (e.g. resistance training and aerobic exercises) in the ageing population to increase participation motivation and neuromotor fitness. The second application of these findings is to recommend training guidelines for sport participation in older adults to enhance physical function. Based on the findings of this review, it is recommended:

- The content and type of sport activities emphasise motor skills and movements that are similar to ADLs and mainly involve physical qualities such as leg and upper body strength, muscular endurance, multi-limb coordination, reaction and anticipation, agility, balance and postural stability.
- The quality and quantity of training are decided based on the individual's constraints.
- The training sessions have adequate activity and rest periods (e.g. interval mode) and separate phases (warming-up, main activity and cooling-down).
- The training sessions have sufficient weekly stimulations (2–3 times per week) and adequate physical stress (minimum 60 min per session and at moderate intensity).

Quality of studies and risks of bias

The results showed that the main study biases were the random allocation of participants and using a randomised-controlled trial study in this area. This is even more essential in ageing studies because of individual differences and the effects of confounding variables due to personal and living environments. However, the other quality criteria were met in the selected studies, which can prove the strength of the current review study and its findings on the impacts of sports on physical and cognitive functions and future decision-making.

We acknowledge some limitations in this study. There were a limited number of studies that assessed cognitive function and balance confidence in sport participation, and more studies in this field are required. The method of assessment was pen and paper via questionnaires or other methods that might not be suitable for sport contexts. Using other techniques such as probe reaction time and mobile eye-tracking systems might be more appropriate to assess perceptual-cognitive skills. Additional studies are required to evaluate the effectiveness of sport participation on QoL and independence.

Conclusion

The findings of this systematic review study suggest that participation in sports has beneficial effects on the physical function of healthy older adults. Sport-based physical activity can be an alternative to traditional methods of physical activity (e.g. walking, running and gym exercises) in increasing physical function. For practitioners, these findings are helpful as they provide insight into factors that are likely to influence the quality and quantity of training programmes for maximising the effectiveness of sport participation for older adults.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interest The authors declare no competing interests.

Ethical approval The nature of study was review that was registered in the international review studies databases as part of the ethical consideration (PROSPERO). The registration code is CRD42021281964.

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