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Effects of yoga-based interventions on cognitive function in healthy older adults: A systematic review of randomized controlled trials

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ABSTRACT

Background: The world's elderly population is growing. Physical activity has positive effects on health and cognition, but is decreasing among the elderly. Interest in yoga-based exercises has increased in this population, especially as an intervention targeting balance, flexibility, strength, and well-being. Recent interest has arisen regarding yoga's potential benefits for cognition.

Objective: To systematically review evidence from randomized controlled trials (RCTs) examining the effects of yoga-based interventions on cognitive functioning in healthy adults aged ≥60. A secondary aim was to describe intervention characteristics and, where possible, the extent to which these influenced study outcomes.

Method: The review was conducted in accordance with PRISMA guidelines. Searches were performed from inception to June 2020 using the following electronic databases: (1) PubMed (NLM); (2) Embase (Elsevier); (3) Cochrane Central (Wiley); (4) PsycINFO (EBSCOhost); and (5) Cinahl (EbscoHost). Inclusion criteria: RCTs of yoga-based interventions assessing cognition in healthy adults ≥60 years. Risk of bias was assessed using the revised Cochrane risk of bias tool.

Results: A total of 1466 records were initially identified; six studies (5 unique trials) were included in the review. Four of the six articles reported significant positive effects of yoga-based interventions on cognition, including gross memory functioning and executive functions. Intervention characteristics and assessment methods varied between studies, with a high overall risk of bias in all studies.

Conclusion: Yoga-based interventions are associated with improvements in cognition in healthy older adults. Adequately powered RCTs with robust study designs and long-term follow-ups are required. Future studies should explicitly report the intervention characteristics associated with changes in cognitive function.

1. Introduction

Aging is accompanied by a gradual decrease in mental capacity affecting cognitive ability. The World Health Organization (WHO) estimates that the proportion of the world's population aged over 60 years will increase from 12 % to 22 % between 2015 and 2050.[1] Accumulating evidence suggests that a physically active lifestyle plays a key role in healthy aging, improving both physical and cognitive function [2,3] and protects against cognitive decline.[4–7] Despite the known benefits, physical activity levels decrease with age,[8] and this reduction in associated with worse physical and mental health.[9] Adherence, commonly defined as participant completion of a prescribed exercise routine, is inconsistently reported in exercise studies examining older adults'.[10] Exploring new strategies and modes of physical activity that promote healthy aging and increase exercise adherence in older adults are important aspects of public health promotion. Yoga is commonly used as a form of exercise that combines physical postures with breathing exercises and meditation and targets specific needs in older people, such as balance training, flexibility, and strength.[2,11–13] Different types of yoga emphasize these elements to a greater or lesser extent.[12] In earlier research, older adults have described yoga as an enjoyable all-round workout suitable for their age group.[14] Additionally, older adults report that participation in yoga has benefited their physical, mental, and social health.[15]

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Participation in yoga-based practices have increased during the last decades,[16,17] alongside yoga related research.[18–20] There is some evidence that the health benefits of yoga-based interventions are comparable with those of aerobic exercise.[21] Further, it is hypothesized that yoga improves mental and cognitive health.[19,22–24] Recent reviews and meta-analyses show that yoga can benefit several mental and physical health outcomes in older populations, compared to both active and inactive control groups.[13,25,26] However, reviews of yoga-based interventions on cognition are sparsely published and findings have been inconsistent. Two recent systematic reviews [27,28] and a meta-analysis [29] concluded that yoga interventions improved cognitive functions such as attention and processing speed, memory, and higher-order executive functions in a variety of populations, including older adults. However, another systematic review and meta-analysis [26] found no effect of yoga-based interventions on cognition in older adults. Chen et al., [30] showed that the effect of exercise on executive function in older adults was moderated by the type of exercise, and that yoga and tai chi interventions showed the second largest effect size ($g = 0.38$), after other forms of exercise (e.g. dance, coordination exercises) ($g = 0.44$), compared to resistance exercise ($g = 0.22$), aerobic exercise ($g = 0.14$), and combined exercise ($g = 0.10$). Another meta-analysis [2] found no association between yoga practice and cognition among older adults.

Within the context of public health and exercise prescription guidelines, it is important to understand yoga-based interventions characteristics from a physical activity perspective. Several authors [2,3,5,30] highlight the importance of exercise prescription variables being assessed in physical activity interventions to improve cognition. These variables, which include duration, frequency, intensity, and type of exercise, are referred to collectively as the FITT-principle.[31] Here, we refer to them as 'intervention characteristics'. Cross-sectional and longitudinal data suggests that there is a relationship between exercise intensity and cognitive outcomes,[32] or lack of cognitive decline in older adults, with moderate and high intensity physical activity associated with less cognitive decline.[6] Other parameters such as the mode, quality, and other dose-response variables may also moderate the effect of exercise on cognition,[33–35] but studies rarely report these variables.[26,36–38] These omissions make it difficult to assess the effects of intervention characteristics on cognition.

Yoga-based interventions can be highly variable and often consist of several components beyond physical activity, such as breathing exercises and meditation practices, making these study characteristics important to document. It is necessary to understand the impact of the physical activity component in yoga-based interventions, as well as the impact of the other components, particularly as meditation practices alone have been found to have a positive effect on cognition in older adults.[39,40]

To our knowledge, no previous review has synthesized the findings from randomized controlled trials of the effects of yoga-based interventions on cognition in healthy older adults, including the characteristics of the yoga-based interventions. The main aim of this systematic review was to examine the effect of yoga-based interventions on cognitive functioning in adults aged ≥60. A secondary aim was to describe intervention characteristics and, where possible, the extent to which these influenced study outcomes.

2. Methods

We conducted a systematic review of the literature in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines,[41] which was pre-registered on Prospero July 25, 2019 (ID: CRD42020140158).

2.1. Search strategy

Searches were performed during June 2019 and updated in June 2020 in accordance with Cochrane recommendations for conducting timely systematic reviews.[42] The following electronic databases were searched: (i) PubMed (NLM); (ii) Embase (Elsevier); (iii) Cochrane Central (Wiley); (iv) PsycINFO (EBSCOhost); and (v) Cinahl (EbscoHost).

We enlisted the Karolinska University library to develop a detailed search strategy where multiple search terms were used for cognition (e.g. 'cognition', 'executive functioning', 'memory', 'attention', 'processing speed') with 'yoga', and 'elderly', 'older'. As Hatha yoga is an important component of the commonly studied Mindfulness-Based Stress Reduction (MBSR), Body Therapy (MBT) program, we also searched MBTSR AND cognition. Complete search terms are presented as Supplementary material 1. Additionally, individual searches in the abovementioned databases were performed; reference lists of retrieved articles were searched through by one reviewer (SH).

2.2. Eligibility criteria

The eligibility criteria for studies were as follows: (i) Participants: Healthy adults aged ≥60, free of known diseases and medical conditions; (ii) Intervention and comparison: Studies comparing yoga to active or no intervention control groups were included. Studies with a second yoga-based intervention as a control group, or studies involving mindfulness, meditation or breathing practices without including yoga postures were excluded; (iii) Outcomes: Studies that assessed one or more domains of cognitive functioning using a validated instrument. All validated neuropsychological tests were accepted as measures of cognitive function; (iv) Study design: Published and peer-reviewed experimental studies with a randomized controlled design that were written in English were included. Observational studies and other designs were excluded. Finally, there were no date restrictions.

2.3. Study selection

All records were screened by two independent reviewers (JÖ, SH) and were carried out in two stages. First, title and abstract were screened using Endnote reference managing software (version X9, Clarivate Analytics, 2018) where duplicates and obviously irrelevant studies were removed. Second, full texts of studies passing the first stage were screened in further detail. A third reviewer (MH) was called upon when a decision could not be made regarding an article's eligibility. Further details are shown in Fig. 1.

2.4. Analysis

Data was extracted and compiled into a table presenting study characteristics (Table 1). For quantitative outcomes available across three or more trials, a meta-analysis was planned to estimate the pooled effects of the yoga-based interventions compared to controls. However, due to heterogeneity of the studies, data were instead synthesized using a formal narrative approach.

2.5. Risk of bias assessment

Risk of bias was assessed independently by two researchers (JÖ, SH) using the revised Cochrane risk of bias (RoB) tool, version 2.[43] The assessed domains were: randomization process (selection bias), deviations from intended interventions (performance bias), missing outcome data (attrition bias), measurement of the outcome (measurement bias), selection of the reported result (reporting bias), and overall bias. Under each domain, studies were classified as 'low', 'some concerns' or 'high' risk of bias. The final judgement of each reviewer followed the algorithm guide as part of the revised RoB 2 tool. Discrepancies were resolved through a third reviewer (MH), who was blinded to the other researchers' assessments.

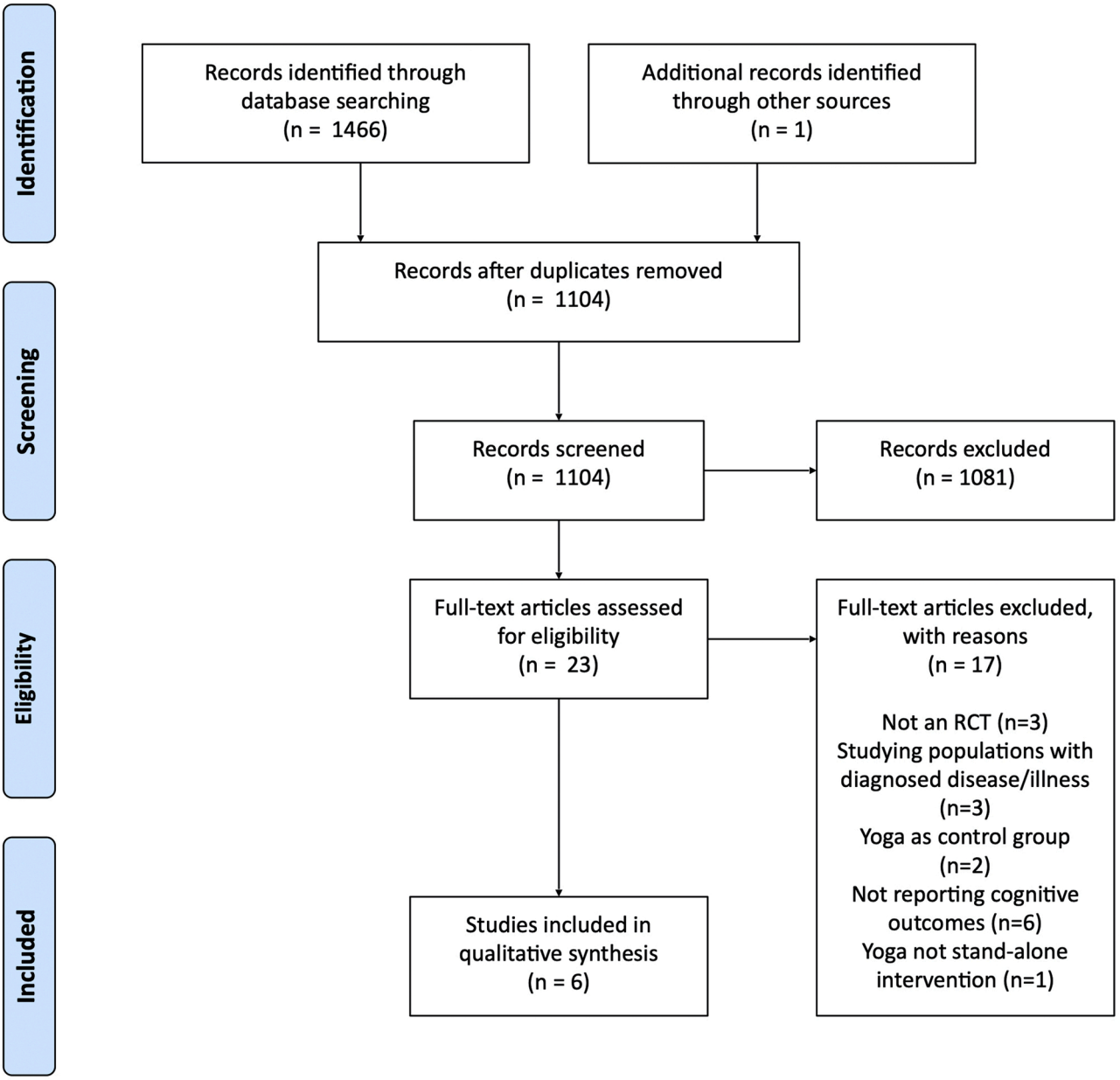

Fig. 1. PRISMA flow chart of study selection.

3. Results

A total of 1466 records were initially identified through the data searches. After the first stage of screening, 22 articles were retrieved for full-text review. Out of these, only five studies were included in the systematic review. The second search gave 399 records, of which 10 were retrieved for full-text review. None of these articles were included, nor from the searches through reference lists. One of the additional searches resulted in the inclusion of one article. In total, six articles including five original studies were identified for final inclusion; see Fig. 1.

3.1. Study and participant characteristics

The six articles included were RCTs from the USA,[44–46] India,[47,48] Lithuania,[49] and multiple countries from the Asia Pacific region and Africa.[48] The number of participants ranged from 33 to 792; mean age = 62–76 years. Most participants were female ranging between 60–90 % of the study populations. Only one study [48] had an even distribution between men and women. All study details are shown in Table 1.

3.2. Intervention characteristics

The yoga intervention characteristics (type, frequency, duration, intensity, length of intervention) varied between studies with; 1–7 sessions per week, 40−90 min per session, and the length of intervention varying between 8–260 weeks. Three studies used hatha yoga,[44,45,47,48] one study used iyengar yoga,[46] and one did not specify the style of yoga.[49] The intensity level was not reported in any of the included studies. All studies stated that the yoga-based interventions included meditation practices and breath awareness techniques, however, the proportion of each component (physical postures, breathing, and meditation exercises) was not specified. All interventions were delivered in person by a qualified yoga instructor. Home practice was included in two of the studies, but was not the primary mode of delivery [46,47] (Table 1).

Table 1
Participant and study characteristics.

Study, Country	Participants (number, mean age)	Intervention (type, frequency, duration, intensity, length of intervention)	Control group(s)	Intervention delivery format	Adherence	Outcome measures and test protocol	Findings
Čekanauskaitè 2020, Lithuania [48]	N = 33 Mean age (SD): 66.9 (6.0) years	Yoga (no style reported), 2 times a week, 90 min per session, 10 weeks, no intensity level reported	IC: No intervention	Group classes with yoga instructor	Participants attended 96.4 % of classes	Cognitive functions of mental flexibility, verbal working memory, response inhibition, and visuospatial processing. Tests: ANAM test	No effect of yoga compared to the no intervention control group
Gothe 2014, USA [43]	N = 108 Mean age (SD): yoga group = 62.1 (5.82); control group = 62.0 (5.39) years	Hatha yoga, 3 times a week, 60 min per session, 8 weeks, no intensity level reported	AC: Stretching–strengthening exercise 3 times a week, 60 min per session, 8 weeks, no intensity level reported	Group classes with yoga instructor; with progressions over time	Participants attended 81 % of classes. The same rate was reported for the stretching-strengthening control	Executive functions of working memory and task switching. Tests: Task switching paradigm, running memory span, and n-back task	Significant improvement on task switching (mixed and repeat RT) n-back task (ACC of 2-back and single trials), and running span task (partial recall score) following yoga
Gothe 2017, USA [44]	N = 108 Mean age (SD): yoga group = 62.1 (5.82); control group = 62.0 (5.39) years	Hatha yoga, 3 times a week, 60 min per session, 8 weeks, no intensity level reported	AC: Stretching–strengthening exercise 3 times a week, 60 min per session, 8 weeks, no intensity level reported	Group classes with yoga instructor; with progressions over time	Participants attended 81 % of classes. The same rate was reported for the stretching-strengthening control	Cognitive functions of attention and processing speed Tests: ANT, TMT A and B, and pattern comparison	Significant improvements in RT in ANT, improvements in visuospatial and perceptual processing in TMT B, and in pattern comparison following yoga
Hariprasad 2013, India [46]	N = 87 Mean age (SD): yoga group = 75.74 (6.46); control group = 74.78 (7.35) years	Hatha yoga, 7 times a week 1st month, 1 time per week 2nd-3rd month, last three months home practice, 60 min per session first three months, 26 weeks, no intensity level reported	IC: Waitlist	Group classes with yoga instructor Ability to perform yoga was assessed by the yoga instructor at the end of 1st, 3rd, and 6th month	Attendance rates were not reported, and the authors stated that participants failed to report this using self-report logs	Cognitive functions of verbal, visual, and working memory, along with verbal fluency, attention, and executive function. Tests: RAVLT test, CFT test, WMS test, COWA test, Stroop test, and TMT A and B	Significant improvements in immediate and delayed recall of verbal (RAVLT), visual memory (CFT), attention and working memory (WMS-spatial span), verbal fluency (COWA), executive function (Stroop interference), and processing speed (TMT A) following yoga
Oken 2006, USA [45]	N = 118 Mean age (SD): yoga group = 71.5 (4.9); exercise group = 73.6 (5.1) years; waitlist group = 71.2 (4.4) years	Iyengar yoga, 1 time per week, 90 min per session (along with home practice), 26 weeks, no intensity level reported	IC: Waitlist AC: Aerobic exercise; 1 time per week, 60 min per session (along with home practice), 26 weeks, moderate intensity level.	Group classes with yoga instructor Daily home practice was encouraged	The attendance rate for the yoga group was 78 % for weekly classes, and 64 % of the daily home-exercise, with an average duration of 38 min a week Control group rates were 69 % for group classes, and 54 % of the daily home-exercise, with an average duration of 56 min a week	Cognitive functions of attention (focusing, shifting, dividing, and sustaining attention), and alertness. Tests: Stroop test, and EEC tests	No effect of yoga compared to the aerobic exercise of waitlist control group
Pandya 2018, India [47]	N = 792 Mean age (SD): yoga group =	Hatha yoga, 1 time per week, 40 min per session (along with home practice), 260 weeks, no intensity level reported	IC: Waitlist	Group classes with yoga instructor. Home practice was encouraged	44.4 % of participants attended 75 % of classes, 35.4 % attended 76−90% of classes, and 20.2% attended more than 90% of classes. 57.6 % engaged in home practice more	Cognitive functions of orientation, registration, attention, recall, language, repetition, and complex commands, and	Significant improvements in the MMSE test, and RBMT-3 test following yoga

(*continued on next page*)

Table 1 (*continued*)

Study, Country	Participants (number, mean age)	Intervention (type, frequency, duration, intensity, length of intervention)	Control group(s)	Intervention delivery format	Adherence	Outcome measures and test protocol	Findings
	67.22 (3.32); waitlist group = 67.01 (3.11) years				than 75 % of the recommendation	memory. Tests: MMSE test, and RBMT-3 test	

ACC: Accuracy; AC: Active control; ANAM:Automated Neuropsychological Assessment Metrics version 4; ANT: Attention Network Task; CFT: Rey's Complex Figure Test; COWA: Controlled Oral Word Association; EEC: Quantitative Electroencephalogram Measure; IC: Inactive control; MMSE: Mini-Mental Stat Examination; N: Number of participants in included studies; RAVLT: Rey's Auditory Verbal Learning Test; RBMT-3: Rivermead Behavioral Memory Test-Third Edition. RT: Reaction time; SD: Standard deviation; TMT: Trail Making Test; WMS: Wechsler Memory Scale.

A variety of cognitive test batteries and assessments were reported. All trials assessed cognition at pre-intervention and post-intervention.

Adherence to the yoga-based interventions were reported by instructors in three studies,[44–46] and through self-reports in one study.[46] Three studies [47–49] did not specify the method of reporting. Three of the studies (two unique trials) included an active control group comprising exercise [44–46]; one was a stretching-strengthening group who showed similar adherence rates to the yoga group,[44,45] and the other an aerobic exercise group showing lower adherence rates than the yoga group.[46] However, difference between the yoga and the exercise group did not reach statistical significance.[50]

Adverse events were reported in three [44–47] out of the six included studies. One study [46] reported a single adverse event in both the yoga and aerobic exercise groups, respectively. Adverse events were mild muscle-skeletal injuries. Three studies reported no adverse events.[44,45,47]

3.3. Effects on cognition

Four studies reported significant effects of the yoga-based intervention on cognition from pre-to post-intervention [44,45,47,48] and two did not.[46,49] Changes favoring the yoga-based intervention compared to control were found for working memory capacity,[44,47] visual and verbal memory [47] and efficiency of mental set shifting and flexibility,[44] improved attentional [45] and information processing abilities.[45,47] Additionally, significant improvements following a yoga-based intervention were found in gross memory functioning and visual, verbal, recall, recognition, immediate and delayed everyday memory.[48]

In an 8-week trial involving 118 healthy community-dwelling older adults, Gothe et al. [44] assessed executive functions by comparing a yoga-based intervention to stretch-strengthening exercises. Compared to the stretch-strengthening group, there was a significant pre-post improvement in working memory capacity, and efficiency of mental set shifting and flexibility, following the yoga-based intervention, with effect sizes ranging from small to moderate.[51] Another article [45] from the same 8-week trial reported significant improvements following the yoga-based intervention in attentional and information processing abilities, with medium to large effect sizes.[52] Hariprasad et al., [47] conducted a six-month trial involving 87 aged-care residents and reported significant pre-post improvements in working memory capacity, visual and verbal memory and information processing. following the yoga-based intervention compared to a no-intervention control group. In a five year trial involving 792 older adults, Pandya [48] reported significant improvements following a yoga-based intervention in gross memory functioning and visual, verbal, recall, recognition, immediate, and delayed everyday memory (medium effect sizes). Additionally, regular attendance and self-practice were reported as strong moderators of the efficacy of the yoga-based intervention on cognitive function.

Oken et al. [46] conducted a six-month trial (n = 118) comparing a yoga-based intervention to both walking exercise and a waitlist control group. No significant effects of the yoga-based intervention were found on cognitive functions or alertness measures. Similarly, Čekanauskaitè et al. [49] also reported no significant effect following a 10-week yoga-based intervention on cognition in 33 older adults.

3.4. Risk of bias results

A summary of the risk of bias assessment of each study is presented in Fig. 2. Each study was assessed based on the obtained journal article, and the reviewers assessed the effect of assignment to intervention. Three of the assessed domains (deviations from intended interventions, measurement of the outcome, and selection of the reported result) were judged with 'some concern' or 'high' risk of bias in the majority of the included articles, which resulted in an overall 'high' risk of bias for all studies. This was mainly due to the lack of prospectively registered protocols and the absence of information regarding the signaling questions for each domain. None of the included studies were able to blind the participants or yoga instructors from the intervention, therefore this parameter was not included in our risk of bias assessment. Further detailed information is provided as Supplementary material 2.

4. Discussion

4.1. Summary of evidence

The main aim of this systematic review was to summarize evidence from RCTs reporting the effects of a yoga-based intervention on cognitive functioning in healthy older adults. Four [44,45,47,48] of the six reviewed articles reported significant improvements following engagement with a yoga-based intervention in several aspects of cognitive functioning including: attention, processing speed, memory, and executive function. Effect sizes were reported in three [44,45,48] of the four articles (range = small to large). In the two studies where a yoga–based interventions were not found to impact cognitive functioning in healthy older adults, the authors [46] hypothesized that this occurred because all the participants were healthy and had good cognitive function at baseline (ceiling effect). However, in the three articles where yoga was found to influence cognition,[44,45,48] participants also did not report any cognitive impairments at baseline. This current review excluded studies with participants recruited on the basis of a specific disease or medical condition. However, in the Hariprasad et al., [47] study, where yoga was found to influence cognition, most of the participants reported subjective memory complaints at baseline. This occurred despite the researchers initial screening and exclusion of individuals with symptoms of dementia, depression, and psychiatric disorders. This is consistent with findings in a recent scoping review by Gretchen and colleagues [53] which showed improved cognitive function among older adults with mild cognitive impairment following a yoga-based intervention. The other three articles,[44,45,48] where yoga was found to influence cognition, did not report any cognitive impairment among participants at baseline. Future studies could address this issue by using appropriate screening methods and by stricter inclusion and exclusion criteria, as well as

Study ID	Randomization process (selection bias)	Deviations from intended interventions (performance bias)	Missing outcome data (attrition bias)	Measurement of the outcome (measurement bias)	Selection of the reported result (reporting bias)	Overall Bias
Čekanauskaitè et al 2020 [49]	Some concerns	Some concerns	Low	Some concerns	Some concerns	High
Gothe et al 2014 [44]	Low	Some concerns	Low	Some concerns	Some concerns	High
Gothe et al 2017 [45]	Low	Some concerns	Low	Some concerns	Some concerns	High
Hariprasad et al 2013 [47]	Some concerns	High	Low	High	High	High
Oken et al 2006 [46]	Low	High	Low	Low	Some concerns	High
Pandya 2018 [48]	Some concerns	Some concerns	Low	High	Some concerns	High

Fig. 2. Summary of risk of bias.

specifying population characteristics in the results. Another recent systematic review [28] that examined yoga-based intervention effect on cognition and mental health in elderly populations drew a similar conclusion, naming the use of valid screening tools as a key component for future research.

The yoga-based intervention used by Čekanauskaitès et al. [49] did not impact self-reported stress levels measured by the Perceived Stress Scale. Indeed, previous work [54] shown that objectively measured stress (cortisol), and self-reported stress and anxiety symptoms, mediate the impact of yoga on cognition. The ability of yoga-based practices to decrease stress, as indicated by down-regulation of the sympathetic nervous system and the hypothalamic-pituitary-adrenal (HPA) axis is well-supported in the literature.[21,55–59]. In their meta-analysis, Gothe & McAuley [29] argue for future research to examine the effect of yoga on the stress response in relation to cognitive functioning, which is a limitation in the current work and an important area for future research.

A secondary aim of this review was to examine the characteristics of yoga-based interventions, and to describe any associations between these criteria and cognitive outcomes. Shorter duration interventions reported higher adherence compared to longer interventions, however there were no significant differences in adherence rates between yoga groups and the exercise-based control groups, indicating that yoga is equally acceptable to older adults as other forms of exercise. Only one study reported that adherence and self-practice moderated the effect on cognitive function.[48] We advocate that future studies should report adherence to the yoga programs, specifying the definition applied.[10] Specifically, objective assessments of intervention adherence should be used where possible, and the impact of supervised compared to non-supervised programs on adherence should be further explored.

The yoga-based intervention varied with regard to the style of practice delivered, frequency and duration of classes, and the length of intervention. The proportion of each component (physical postures, breathing, and meditation exercises) were not specified in any studies. This is important to address because some breathing and meditation exercises are unique to yoga and may impact study findings. Intensity levels were not reported in any of the included studies. Given that the intensity of physical activity has been shown to be important in determining cognitive improvements following other exercise interventions,[32] we propose that the intensity of yoga-based physical activity should be considered in the design and reporting of future studies. Indeed, different styles of yoga differ in their intensity level [38] and the relationship between heart rate and oxygen consumption in yoga-based exercise is non-linear (compared to the linear relationship in aerobic exercise), which suggests there is a need to create a standard for reporting intensity levels from yoga interventions.[38] We support this recommendation and previous work which highlights an overall need for better reporting of intervention characteristics.[60,61] We suggest that reporting should follow the TIDieR template for intervention description and replication.[62] As Etnier and colleagues [35] point out; “a better understanding of underlying mechanisms and accurate reporting and coding of variables will serve future research within this field”.

4.2. Strengths and limitations

This is the first systematic review to study the impact of yoga-based interventions on cognitive function in healthy older adults. Strengths of the study include: i) the assessment of intervention characteristics using the FITT criteria; ii) the review was conducted in concordance with an established systematic review framework and reported using PRISMA guidelines; and iii) the inclusion of only RCTs helped ensure that the reviewed studies are consistent with best practice recommendations.

Some potential limitations are also acknowledged. As only six studies were included and these were heterogeneous, both in terms of study design and outcomes, our ability to draw definitive conclusions regarding effects of yoga-based interventions on cognitive functioning in this population is limited. The majority of studies had relatively low numbers of participants. Three [44–46] studies included an active comparison group, while three [47–49] included a waitlist or a no-intervention control group. Therefore, in half the studies reviewed, it is unclear whether the effects are attributable to the yoga-based intervention or to non-specific factors, such as time/attention effects. Furthermore, we only included studies published in English, and therefore might have overlooked research published in other languages. Finally, none of the reviewed studies assessed cognitive function at multiple follow-up time points; therefore the long term impact of yoga-based interventions on cognition are unknown.[29]

5. Conclusions

Yoga-based interventions show potential to improve cognition in healthy older adults. However, there are currently few published studies on the topic, all with a high risk of bias. Adequately powered RCTs with robust study designs and long-term follow-ups are required using validated screening tools and cognitive assessments. Future studies should explicitly report the intervention characteristics, and where possible, demonstrate how these moderate study outcomes. Yoga-based exercise includes physical components that are important for healthy ageing, such as balance and flexibility. Given the ageing of populations worldwide, the application of yoga to help prevent and treat cognitive decline warrants further investigation.

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the design or conduct of the review.

Authors' contributions

MH conceived the review and drafted the research plan with input from JÖ. The Karolinska University Library performed the systematic searches. SH and JÖ performed the screening and selection of articles and the risk of bias assessments, in which MH was consulted in case of ambiguities. SH compiled the results of the included articles as well as of the risk of bias assessment and wrote the manuscript. All co-authors contributed to the subsequent revisions and read and approved the final manuscript of the review.

Declaration of Competing Interest

None of the authors have any competing interests.

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Supplementary material

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References

1 The World Health Organization. *Ageing and health* [cited 2020 August 12th]. Available from:; 2018. https://www.who.int/news-room/fact-sheets/detail/ageing-and-health.
2 Northey JM, Cherbuin N, Pumpa KL, Smee DJ, Rattray B. Exercise interventions for cognitive function in adults older than 50: a systematic review with meta-analysis. *Br J Sports Med*. 2018;52(3):154–160.
3 Falck RS, Davis JC, Best JR, Crockett RA, Liu-Ambrose T. Impact of exercise training on physical and cognitive function among older adults: a systematic review and meta-analysis. *Neurobiol Aging*. 2019;79:119–130.
4 Blondell SJ, Hammersley-Mather R, Veerman JL. Does physical activity prevent cognitive decline and dementia?: A systematic review and meta-analysis of longitudinal studies. *BMC Public Health*. 2014;14(1):510.
5 Kelly ME, Loughrey D, Lawlor BA, Robertson IH, Walsh C, Brennan S. The impact of exercise on the cognitive functioning of healthy older adults: a systematic review and meta-analysis. *Ageing Res Rev*. 2014;16:12–31.
6 Engeroff T, Ingmann T, Banzer W. Physical activity throughout the adult life span and domain-specific cognitive function in old age: a systematic review of cross-sectional and longitudinal data. *Sports Med (Auckland)*. 2018;48(6):1405–1436.
7 Nagamatsu LS, Flicker L, Kramer AF, et al. Exercise is medicine, for the body and the brain. *Br J Sports Med*. 2014;48(12):943–944.
8 Hallal PCD, Andersen LBP, Bull FCP, Guthold RP, Haskell WP, Ekelund UP. Global physical activity levels: surveillance progress, pitfalls, and prospects. *Lancet*. 2012;380(9838):247–257.
9 Rivera-Torres S, Fahey TD, Rivera MA. Adherence to exercise programs in older adults: informative report. *Gerontol Geriatr Med*. 2019;5, 2333721418823604-.
10 Hawley-Hague H, Horne M, Skelton DA, Todd C. Review of how we should define (and measure) adherence in studies examining older adults; Participation in exercise classes. *BMJ Open*. 2016;6(6), e011560.
11 Reid H, Foster C. Infographic. Physical activity benefits for adults and older adults. *Br J Sports Med*. 2017;51(19):1441.
12 United States Department of Health and Human Services. *Physical activity guidelines for Americans* [cited 2020 October 8th]. Available from:. 2nd edition; 2018. https://health.gov/sites/default/files/2019-09/Physical_Activity_Guidelines_2nd_edition.pdf.
13 Sivaramakrishnan D, Fitzsimons C, Kelly P, et al. The effects of yoga compared to active and inactive controls on physical function and health related quality of life in older adults – systematic review and meta-analysis of randomised controlled trials. *Int J Behav Nutr Phys Activity*. 2019;16(1), 33-22.
14 Sivaramakrishnan DFC, Mutrie N, Baker G. Perceptions of yoga among older adults: a qualitative approach. *Ann Yoga Phys Therapy*. 2017;(4):1035.
15 Nayak HD, Patel NK, Wood R, Dufault V, Guidotti N. A study to identify the benefits, barriers, and cues to participating in a yoga program among community dwelling older adults. *J Yoga Phys Therapy*. 2015;5(1):1.
16 Barnes PMMA, Bloom B, Nahin RL. *Complementary and alternative medicine use among adults and children; United States, 2007*. 2008:12.
17 Ding D, Stamatakis E. Yoga practice in England 1997-2008: prevalence, temporal trends, and correlates of participation. *BMC Res Notes*. 2014;7(1):172.
18 McCall MC. In search of yoga: research trends in a western medical database. *Int J Yoga*. 2014;7(1):4–8.
19 Schmalzl L, Powers C, Henje Blom E. Neurophysiological and neurocognitive mechanisms underlying the effects of yoga-based practices: towards a comprehensive theoretical framework. *Front Hum Neurosci*. 2015;9(235).
20 Cramer H, Lauche R, Dobos G. Characteristics of randomized controlled trials of yoga: a bibliometric analysis. *BMC Complem Altern Med*. 2014;14(1):328.
21 Ross A, Thomas S. The health benefits of yoga and exercise: a review of comparison studies. *J Altern Comp Med (New York, NY)*. 2010;16(1):3–12.
22 Büssing A, Michalsen A, Khalsa SBS, Telles S, Sherman KJ. Effects of yoga on mental and physical health: a short summary of reviews. *Evid Based Comp Altern Med*. 2012;2012, 165410.
23 Brunner D, Abramovitch A, Etherton J. A yoga program for cognitive enhancement. *PLoS One*. 2017;12(8), e0182366.
24 Gothe NP, Khan I, Hayes J, Erlenbach E, Damoiseaux JS. Yoga effects on brain health: a systematic review of the current literature. *Brain Plast*. 2019;5(1):105–122.
25 Tulloch A, Bombell H, Dean C, Tiedemann A. Yoga-based exercise improves health-related quality of life and mental well-being in older people: a systematic review of randomised controlled trials. *Age Ageing*. 2018;47(4):537–544.
26 Patel NK, Newstead AH, Ferrer RL. The effects of yoga on physical functioning and health related quality of life in older adults: a systematic review and meta-analysis. *J Altern Comp Med (New York, NY)*. 2012;18(10):902–917.
27 Luu K, Hall PA. Hatha yoga and executive function: a systematic review. *J Altern Comp Med*. 2016;22(2):125–133.
28 Chobe S, Chobe M, Metri K, Patra SK, Nagaratna R. Impact of yoga on cognition and mental health among elderly: a systematic review. *Com Therapies Med*. 2020;52, 102421.
29 Gothe NP, McAuley E. Yoga and cognition: a meta-analysis of chronic and acute effects. *Psychosom Med*. 2015;77(7):784–797.
30 Chen FT, Etnier JL, Chan KH, Chiu PK, Hung TM, Chang YK. Effects of exercise training interventions on executive function in older adults: a systematic review and meta-analysis. *Sports Med*. 2020;23:23.
31 American College of Sports Medicine. In: Riebe D, Ehrman JK, Liguori G, Magal M, eds. *ACSM's guidelines for exercise testing and prescription*. tenth edition. Philadelphia: Wolters Kluwer; 2018.
32 Kerr J, Marshall SJ, Patterson RE, et al. Objectively measured physical activity is related to cognitive function in older adults. *J Am Geriatr Soc (JAGS)*. 2013;61(11):1927–1931.
33 Pesce C. Shifting the focus from quantitative to qualitative exercise characteristics in exercise and cognition research. *J Sport Exerc Psychol*. 2012;34(6):766.
34 Netz Y. Is there a preferred Mode of exercise for cognition enhancement in older age?—A narrative review. *Front Med*. 2019;6(57).
35 Etnier JL, Drollette ES, Slutsky AB. Physical activity and cognition: a narrative review of the evidence for older adults. *Psychol Sport Exer*. 2019;42:156–166.
36 Karen JS. Guidelines for developing yoga interventions for randomized trials. *Evid Based Comp Altern Med*. 2012:2012.
37 Larson-Meyer DE. A systematic review of the energy cost and metabolic intensity of yoga. *Med Sci Sports Exer*. 2016;48(8):1558–1569.
38 Forseth B, Hunter SD. Range of yoga intensities from Savasana to sweating: a systematic review. *J Phys Activity Health*. 2020;17(2):242–249.
39 Gard T, Hölzel BK, Lazar SW. The potential effects of meditation on age-related cognitive decline: a systematic review. *Ann N Y Acad Sci*. 2014;1307(1):89–103.
40 Chan JSY, Deng K, Wu J, Yan JH. Effects of meditation and mind–body exercises on older adults' cognitive performance: a meta-analysis. *Gerontologist*. 2019;59(6).e782-e90.
41 Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *BMJ*. 2009;339:b2535.
42 Lefebvre CGJ, Briscoe S, Littlewood A, et al. Chapter 4: searching for and selecting studies. In: Higgins JPT, Thomas J, Chandler J, eds. *Cochrane handbook for systematic reviews of interventions*. 2nd ed. Chichester (UK): John Wiley & Sons; 2019:67–108.
43 Sterne JAC, Savović J, Page MJ, et al. RoB 2: a revised tool for assessing risk of bias in randomised trials. *Bmj*. 2019;366:l4898.
44 Gothe NP, Kramer AF, McAuley E. The effects of an 8-week Hatha yoga intervention on executive function in older adults. *J Gerontol Ser A Biol Sci Med Sci*. 2014;69(9):1109–1116.
45 Gothe NP, Kramer AF, McAuley E. Hatha yoga practice improves attention and processing speed in older adults: results from an 8-week randomized control trial. *J Altern Comp Med (New York, NY)*. 2017;23(1):35–40.
46 Oken BS, Zajdel D, Kishiyama S, et al. Randomized, controlled, six-month trial of yoga in healthy seniors: effects on cognition and quality of life. *Altern Therapies Health Med*. 2006;12(1):40–47.
47 Hariprasad VR, Koparde V, Sivakumar PT, et al. Randomized clinical trial of yoga-based intervention in residents from elderly homes: effects on cognitive function. *Indian J Psychiatry*. 2013;55(Suppl 3):S357–63.
48 Pandya SP. Yoga education program for improving memory in older adults: a multicity 5-year follow-up study. *J Appl Gerontol*. 2018, 733464818794153.
49 Čekanauskaitė A, Skurvydas A, Žlibinaitė L, Mickevičienė D, Kilikevičienė S, Solianik R. A 10-week yoga practice has no effect on cognition, but improves balance and motor learning by attenuating brain-derived neurotrophic factor levels in older adults. *Exp Gerontol*. 2020;138, 110998.
50 Flegal KE, Kishiyama S, Zajdel D, Haas M, Oken BS. Adherence to yoga and exercise interventions in a 6-month clinical trial. *BMC Comp Altern Med*. 2007;7:37.
51 Cohen J. *Statistical power analysis for the behavioral sciences*. 2. ed. ed. Hillsdale: L. Erlbaum Associates; 1988.
52 Richardson JTE. Eta squared and partial eta squared as measures of effect size in educational research. *Educ Res Rev*. 2011;6(2):135–147.

53 Brenes GA, Sohl S, Wells RE, Befus D, Campos CL, Danhauer SC. The effects of yoga on patients with mild cognitive impairment and dementia: a scoping review. *Am J Geriatr Psychiatry*. 2019;27(2):188–197.
54 Gothe NP, Keswani RK, McAuley E. Yoga practice improves executive function by attenuating stress levels. *Biol Psychol*. 2016;121(Pt A):109–116.
55 Gerritsen RJS, Band GPH. Breath of life: the respiratory vagal stimulation model of contemplative activity. *Front Hum Neurosci*. 2018;12(397).
56 Riley KE, Park CL. How does yoga reduce stress? A systematic review of mechanisms of change and guide to future inquiry. *Health Psychol Rev*. 2015;9(3):379–396.
57 Della Valle E, Palermi S, Aloe I, et al. Effectiveness of workplace yoga interventions to reduce perceived stress in employees: a systematic review and meta-analysis. *J Funct Morphol Kinesiol*. 2020;5(2).
58 Pascoe MC, Thompson DR, Ski CF. Yoga, mindfulness-based stress reduction and stress-related physiological measures: a meta-analysis. *Psychoneuroendocrinology*. 2017;86:152–168.
59 Chong CS, Tsunaka M, Tsang HW, Chan EP, Cheung WM. Effects of yoga on stress management in healthy adults: a systematic review. *Altern Ther Health Med*. 2011;17(1):32–38.
60 Park CL, Elwy AR, Maiya M, et al. The essential properties of yoga questionnaire (EPYQ): psychometric properties. *Int J Yoga Therapy*. 2018;28(1):23–38.
61 Sherman KJ. Guidelines for developing yoga interventions for randomized trials. *Evid Based Comp Altern Med*. 2012;2012, 143271.
62 Hoffmann TC, Glasziou PP, Boutron I, et al. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *BMJ*. 2014;348:g1687.