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The Effects of Yoga on Cognition and Memory: *A Systematic Review of Randomised Controlled Trials*

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Abstract

Background: Cognitive and memory impairments, prevalent in ageing populations and clinical conditions such as type 2 diabetes mellitus and subjective cognitive decline, contribute to diminished quality of life. Yoga, a mind-body practice, demonstrates promise for cognitive enhancement through stress reduction and neuroplasticity mechanisms. This systematic review examined the effects of yoga interventions on cognition and memory in adults.

Methods: Following PRISMA guidelines, we systematically searched PubMed, Scopus, Web of Science, and the Cochrane Library for English-language randomised controlled trials (RCTs) published between January 2020 and June 2025. Eligible studies included adult participants where yoga was the primary intervention and cognitive or memory outcomes were assessed. Data extraction and risk of bias assessment were conducted independently by two reviewers. Owing to heterogeneity across interventions and outcomes, a narrative synthesis was performed. The certainty of evidence was evaluated using GRADE.

Results: Eleven randomised controlled trials, involving 1,473 participants, evaluated yoga's effects on cognition in healthy and clinical adult populations, including those with subjective cognitive decline, Alzheimer's disease risk, type 2 diabetes mellitus, HIV, and young or older adults. Yoga interventions, lasting 8 to 12 weeks and utilising Kundalini, Hatha, or integrated styles, improved memory outcomes, enhancing working memory accuracy and sustaining everyday memory gains at 5 years. Executive function showed mixed results; global cognition had limited short-term benefits. Mechanisms included enhanced hippocampal connectivity ($p<0.001$), grey matter preservation, and theta increases ($p=0.018$). Adherence was high (75–86%); adverse events were minimal. Risk of bias was "some concerns"; GRADE: low-moderate.

Conclusion: Yoga yields preliminary benefits for memory and neuroprotection, particularly in clinical populations. Larger, standardised RCTs are needed to confirm effects and guide clinical integration.

Keywords: *Yoga, cognition, memory, systematic review, randomised controlled trials*
Running Title: *Yoga Effects on Cognition and Memory: A Systematic Review*

Introduction

Cognition and memory are foundational to human functioning, underpinning essential processes such as attention, executive function, learning, information retention, and retrieval. These faculties drive daily activities including problem-solving, decision-making, and social interactions, profoundly shaping quality of life [1]. Impairments in these domains are

alarmingly prevalent, particularly in ageing populations, where cognitive decline represents a growing public health challenge. Mild cognitive impairment (MCI), a precursor to dementia, affects up to 20% of adults over 60 years, with global dementia cases—currently exceeding 55 million—projected to triple by 2050 [2,3]. Beyond ageing, cognitive and memory deficits are common in clinical populations, including those with type 2 diabetes mellitus (T2DM), where up to 60% of patients experience cognitive dysfunction, and major depressive disorder (MDD), where persistent impairments linger in 60% of patients following symptom remission [4,5]. Neurological conditions such as Alzheimer's disease (AD), traumatic brain injury, and post-cancer treatment sequelae further exacerbate these deficits, increasing risks of disability, falls, social isolation, and diminished well-being [4]. The societal and economic burdens are substantial, with dementia-related healthcare costs projected to exceed $1 trillion annually by 2030 [3]. Pharmacological interventions for non-pathological cognitive decline often yield inconsistent or limited benefits, underscoring an urgent need for accessible, cost-effective, non-pharmacological strategies to preserve and enhance cognitive health across diverse populations.

Yoga, a mind-body practice integrating physical postures (asanas), controlled breathing (pranayama), and meditation (dhyana), has emerged as a promising intervention for cognitive enhancement. Unlike conventional exercise modalities such as aerobic or resistance training, yoga uniquely combines physical movement with mindfulness and breath regulation, potentially amplifying neurocognitive effects [6]. Its global adoption—evidenced by millions of practitioners, including 36 million in the United States—reflects its accessibility and appeal as a holistic health practice [7]. Yoga's potential to bolster cognition and memory rests on multifaceted neurobiological and psychological mechanisms, distinguishing it from other interventions.

Central to its efficacy is stress reduction, a critical factor given chronic stress's detrimental impact on cognitive function. Prolonged activation of the hypothalamic-pituitary-adrenal (HPA) axis elevates cortisol, which can cause atrophy of hippocampal neurones, disrupt synaptic plasticity, and impair memory consolidation and retrieval [8]. Yoga mitigates this by enhancing parasympathetic activity through vagal stimulation, reducing cortisol levels and restoring autonomic balance, as demonstrated in studies showing attenuated cortisol responses during cognitive tasks [9]. For example, yoga interventions in older adults have correlated reduced cortisol with improved executive function, highlighting its stress-modulating potential [10].

Beyond stress reduction, yoga promotes neuroplasticity through upregulation of brain-derived neurotrophic factor (BDNF), a key neurotrophin supporting neuronal survival, synaptogenesis, and hippocampal volume [11]. Meta-analyses of mindfulness-based interventions, including yoga, report significant BDNF increases, with effects comparable to exercise-focused practices [12]. Enhanced cerebral blood flow and oxygenation, facilitated by pranayama, further support neuroplasticity, potentially mitigating age-related atrophy in the prefrontal cortex and hippocampus [13]. Yoga's meditative components foster sustained attention and mindfulness, reducing mind-wandering and enhancing default mode network (DMN) efficiency, which bolsters working memory and executive function [14].

In clinical contexts, such as MDD, yoga combined with antidepressants has elevated BDNF and improved neurocognitive performance, suggesting adjunctive potential [15]. Additionally, yoga's anti-inflammatory properties reduce pro-inflammatory cytokines such as interleukin-6, addressing low-grade inflammation implicated in cognitive decline [11]. Neuroimaging studies further

reveal yoga's structural impact, with increased grey matter density in memory- and self-regulation-related brain regions, offering a mechanistic basis for cognitive resilience [16]. These mechanisms collectively position yoga as a versatile intervention for both healthy and clinical populations.

Empirical evidence supports yoga's cognitive benefits across diverse groups. Systematic reviews of RCTs in healthy older adults report moderate improvements in attention, processing speed, and executive function, with effect sizes ranging from 0.33 to 0.40 [17]. In populations with MCI or at risk for AD, yoga has shown equivalence or superiority to memory enhancement training, improving subjective memory and stabilising biomarkers such as eotaxin-1 [18,19]. Cancer survivors and individuals with ADHD also report cognitive gains, underscoring yoga's broad applicability [20,21]. However, significant gaps persist in the literature. Methodological limitations, including small sample sizes, heterogeneous yoga protocols, and short-term follow-ups, limit generalisability. Many studies rely on self-reported measures, and long-term outcomes or dose-response relationships remain underexplored.

Prior reviews often focus on specific populations (e.g., older adults or MCI), missing comprehensive syntheses across healthy and clinical groups. Underrepresentation of ethnic minorities and males further constrains insights into efficacy across diverse demographics. This systematic review addresses these gaps by synthesising recent RCTs to evaluate yoga's effects on cognition and memory in adults, integrating mechanistic insights to inform clinical applications and guide future research.

Methods

This systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency and reproducibility [22]. Search Strategy: Electronic databases, including PubMed, Scopus, Web of Science, and the Cochrane Library, were searched from January 2020 to June 2025, to capture recent randomised controlled trials (RCTs). The search strategy combined terms related to yoga and cognitive outcomes, such as "yoga" AND ("cognition" OR "memory" OR "neurocognitive" OR "executive function" OR "attention" OR "learning"), with database-specific adaptations using Boolean operators and MeSH terms where applicable [23]. Reference lists of included studies and relevant reviews were manually screened for additional eligible articles. Searches were restricted to English-language publications to ensure accessibility for the review team.

Eligibility Criteria: Eligibility was defined using the PICO framework (Population, Intervention, Comparator, Outcome) [24]:

- **Population:** Adults (≥18 years) from healthy individuals to those with clinical conditions, including cognitive impairment, type 2 diabetes mellitus (T2DM), HIV, or subjective cognitive decline.
- **Intervention:** Yoga as the primary experimental intervention, encompassing styles such as Hatha, Vinyasa, or Kundalini, involving a combination of physical postures, breathing exercises, and/or meditation.
- **Comparator:** Any comparator arm, including active treatments (e.g., memory enhancement training), waitlist control, usual care, or no intervention.
- **Outcome:** At least one objective or subjective measure of cognition or memory, such as neuropsychological tests for working memory, episodic memory, or global cognitive function (e.g., n-back tasks, Mini-Mental State Examination,

Rivermead Behavioural Memory Test).

Inclusion criteria encompassed fully published, peer-reviewed RCTs conducted between 2020 and 2025. Exclusion criteria included non-RCT designs (e.g., observational, cohort, cross-sectional, case-control, or pilot studies), articles published before 2020, non-English publications, conference abstracts, protocols without results, and studies involving participants under 18 years. Studies combining yoga with other major interventions (e.g., pharmacological treatments) were excluded unless yoga's effects could be isolated through subgroup analysis or study design. Systematic reviews, meta-analyses, and case reports were also excluded.

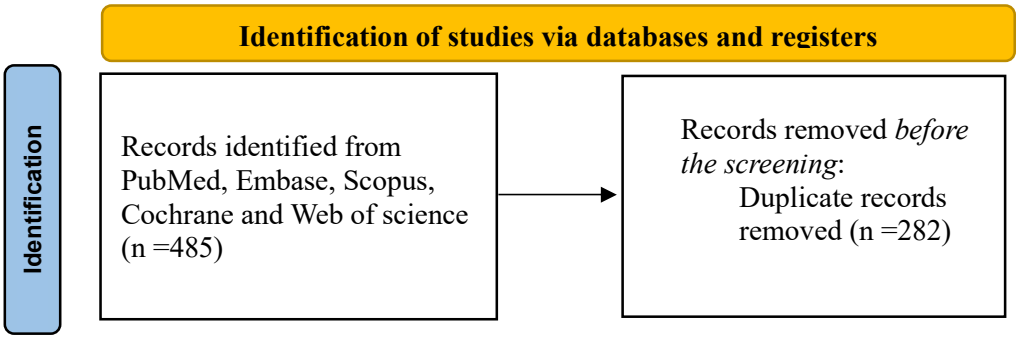
Study Selection and Data Extraction: Two reviewers independently screened the titles, abstracts, and full texts using Rayyan software, with disagreements resolved by consensus or by a third reviewer [24]. Data were extracted using a standardised form, capturing study design, sample characteristics (e.g., age, sex, health status), intervention details (e.g., yoga style, duration, frequency, intensity), comparator conditions, outcome measures (e.g., specific cognitive tests and domains), and main findings (e.g., effect sizes, statistical significance). Additional data on adverse events, adherence rates, and funding sources were also recorded.

Quality Assessment: Methodological quality was evaluated using the Cochrane Risk of Bias 2 (RoB 2) tool for RCTs, assessing domains such as randomisation, deviations from intended interventions, missing outcome data, outcome measurement, and selection of reported results [25]. Two reviewers independently conducted assessments, resolving discrepancies through consensus. The certainty of the evidence was assessed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach [26].

Data Synthesis: A narrative synthesis was performed to summarise findings, grouped by population (healthy vs clinical), intervention characteristics, and cognitive domains, following established guidelines for qualitative synthesis [27]. A meta-analysis was not conducted due to substantial heterogeneity in outcome measures (e.g., n-back tasks vs Rivermead Behavioural Memory Test), populations (e.g., healthy older adults vs T2DM patients), and intervention protocols (e.g., Kundalini vs integrated yoga), which precluded pooling homogeneous data. Heterogeneity was qualitatively assessed through narrative comparison, exploring variability by yoga style, participant age, or clinical status.

Results

A comprehensive systematic literature search identified 485 records across the selected databases. After removing 282 duplicates, 203 records underwent title and abstract screening. Of these, 152 were deemed irrelevant based on predefined eligibility criteria. Full-text review of the remaining 51 articles led to the exclusion of 40 studies that did not meet the inclusion criteria. Ultimately, 11 RCTs were included, as documented in the PRISMA flow diagram [Figure 1].



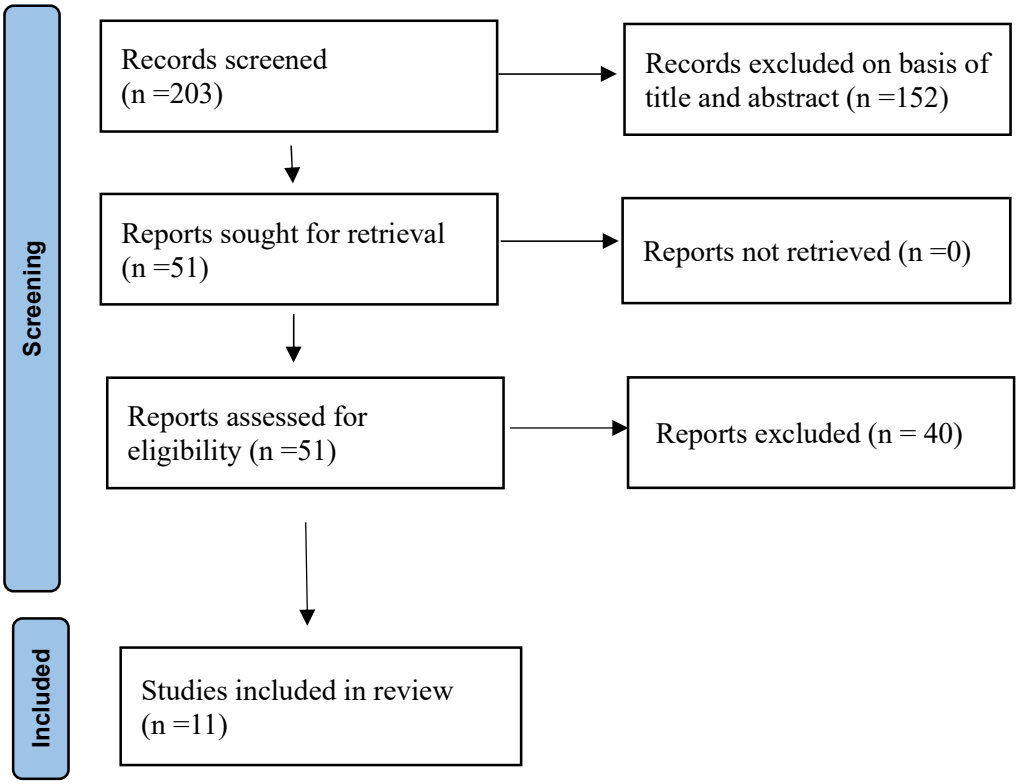


Figure 1: Summarized search strategy (Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram)

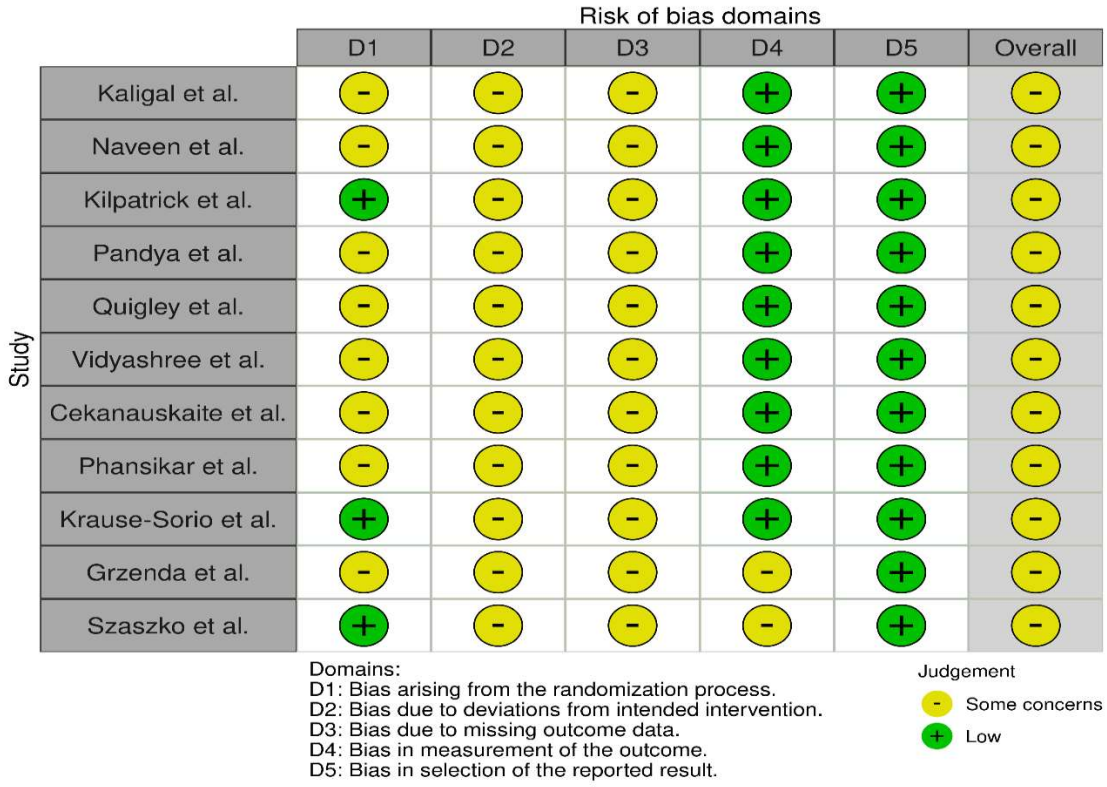


Figure 2: Traffic Light Plot of Risk of Bias Assessments for RCTs
RCT: randomised controlled trial.

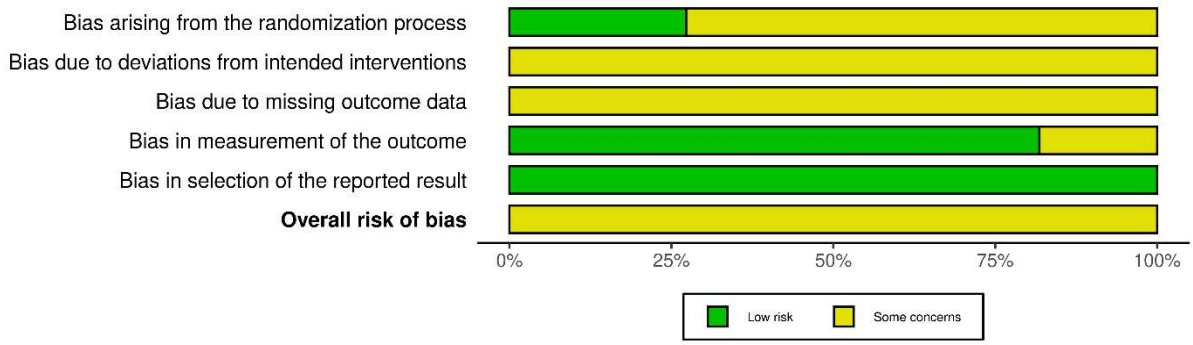


Figure 3: Summary Plot of Risk of Bias Assessments for RCTs

RCT: randomised controlled trial.

Overview of Included Studies: These trials involved a total of 1,473 participants (yoga group n=735; comparator n=738). Sample sizes ranged from 22 to 918 participants, with a median of 56. All studies were published between 2020 and 2025 and conducted in English [28-38]. Geographically, trials originated from the United States (n=5), India (n=3), Lithuania (n=1), Canada (n=1), and Austria (n=1). Populations included healthy community-dwelling older adults (n=2 trials; age 60-79 years), healthy yoga novices/young adults (n=2; age 18-40 years), working adults with stress (n=1; mean age 41 years), and clinical groups such as women at risk for Alzheimer's disease (AD) with subjective cognitive decline (SCD) and cardiovascular risk factors (CVRFs; n=3; mean age 61-65 years), people living with HIV (PLWH; n=1; age ≥35 years), and adults with type 2 diabetes mellitus (T2DM; n=2; age unspecified but adults). Interventions primarily involved Kundalini yoga (n=3), integrated or unspecified yoga (n=5), Raja yoga meditation (n=1), or Hatha yoga (n=1), with durations of 8-12 weeks (median 12 weeks) and frequencies of 1-3 sessions per week (median 2; 50-90 min/session). Comparators were memory enhancement training (MET; n=3), waitlist control (n=4), usual care/conventional treatment (n=3), or no intervention (n=1). Cognitive outcomes were assessed using validated tools, including n-back tasks for working memory, Mini-Mental State Examination (MMSE) for global cognition, Rivermead Behavioural Memory Test-Third Edition (RBMT-3) for everyday memory, Stroop/digit span for executive function, and Corsi block tapping for visuospatial memory. Mechanistic outcomes (e.g., neuroimaging, biomarkers, electrophysiology) were reported in six trials. Follow-up durations varied: immediate post-intervention (n=11), 24 weeks (n=1), and 5 years (n=1). The characteristics of the included studies are summarised in Table 1.

Table 1. Characteristics and Key Findings of the included studies

Study (Author, Year, Country)	Population (n, Age, Health Status)	Intervention (Style, Duration, Frequency)	Comparator	Cognitive Outcomes (Tests)	Main Findings	Adherence/Attrition
Kaligal et al., 2023, India [28]	T2DM adults (n=50, age NR, T2DM)	Integrated yoga, 12 weeks, 1 hr/day	No intervention	Working memory (n-back)	Improved WM accuracy (+3.15%, 95% CI	NR/None reported

					[2.33, 3.96], p=0.001), reaction time (-100.8 ms, 95% CI [-166.6, -35.1], p=0.002); higher PFC oxygenation (p=0.018–0.049)	
Naveen et al., 2022, India [29]	Young adults (n=50, age NR, healthy)	Raja yoga meditation, 12 weeks, NR frequency	No intervention	Spatial/verbal memory (NR tests)	Improved spatial (p<0.05) and verbal memory (p<0.05)	NR/None reported
Kilpatrick et al., 2023, USA [30]	Women with SCD + CVRFs (n=22, 61–65 yrs, AD risk)	Kundalini yoga + Kirtan Kriya, 12 weeks, 1x/wk. + daily homework	MET	Subjective memory (MFQ); hippocampal connectivity (rs-fMRI)	Increased left anterior hippocampal-DMN connectivity (p<0.001); no cognitive test changes; PSS correlation (r=-0.47 to -0.56, p<0.05)	78.8% class, 86.4% homework/None
Pandya, 2020, Canada [31]	Older adults (n=918, 60–79 yrs, healthy)	Yoga education, 12 weeks, 1x/wk + self-practice	No intervention	Everyday memory (RBMT-3); global cognition (MMSE)	Sustained RBMT-3 (p<0.05) and MMSE gains (p<0.05) at 5 yrs	NR/None reported
Quigley et al., 2020, Canada [32]	PLWH (n=22, ≥35 yrs, HIV)	Yoga, 12 weeks, 3x/wk	Usual care	HRQoL cognition (NR test)	Trend toward improved HRQoL cognition (p=0.063); no objective memory changes	75–86%/0–14%

Vidyashree et al., 2024, India [33]	T2DM adults (n=75, age NR, T2DM)	Integrated yoga, 12 weeks, NR frequency	Control (NR)	Cognition (NR test); CBF (Doppler)	Improved CBF (-10.85%, p<0.001), CVR (-0.23%, p=0.02), cognition (-12.13%, p≤0.001); no between-group effect	NR/None reported
Čekanauskaitė et al., 2020, Lithuania [34]	Older adults (n=33, 60–79 yrs, healthy)	General yoga, 10 weeks, 2x/wk, 90 min	No intervention	Cognition (Stroop, digit span); BDNF	No cognitive changes (p>0.05); BDNF attenuated (-15.2%, p<0.05)	100%/None
Phansikar et al., 2023, USA [35]	Working adults (n=86, mean 41 yrs, stressed)	Moderate yoga, 8 weeks, 3x/wk, remote	Waitlist control	Working memory (n-back)	Improved WM accuracy (p<0.05)	75–86%/0–14%
Krause-Sorio et al., 2022, USA [36]	Women with SCD + CVRFs (n=22, 61–65 yrs, AD risk)	Kundalini yoga + Kirtan Kriya, 12 weeks, 1x/wk + daily homework	MET	GMV (MRI); anxiety/resilience	Prevented GMV reductions (p<0.05); right hippocampal GMV increase (p<0.05, uncorrected); no cognitive changes	78.8% class, 86.4% homework/None
Grzenda et al., 2024, USA [37]	Women with SCD + CVRFs (n=79, 61–65 yrs, AD risk)	Kundalini yoga, 12 weeks, NR frequency	MET	Global cognition (MMSE); biomarkers	Improved subjective cognition (p<0.05, large ES); stabilized eotaxin-1; no MMSE changes	65%/35%
Szaszkó et al., 2024, Austria [38]	Young adults (n=116 behavioral, 47 EEG,	Hatha yoga, 8 weeks, 3x/wk, 60 min	Waitlist control	Task switching (RT/accuracy); EEG (theta/alpha)	Reduced mixing costs (10 ms, p=0.042, d=0.41);	2.55 sessions/wk/14–23%

	18–40 yrs, healthy)				increased theta (p=0.018); no switching cost changes	

Abbreviations: T2DM = type 2 diabetes mellitus; SCD = subjective cognitive decline; CVRFs = cardiovascular risk factors; PLWH = people living with HIV; AD = Alzheimer's disease; WM = working memory; MET = memory enhancement training; NR = not reported; RBMT-3 = Rivermead Behavioural Memory Test-Third Edition; MMSE = Mini-Mental State Examination; fMRI = functional magnetic resonance imaging; GMV = Gray matter volume; CBF = cerebral blood flow; CVR = cerebrovascular reserve; BDNF = brain-derived neurotrophic factor; PSS = Perceived Stress Scale; HRQoL = health-related quality of life; ES = effect size. Adherence/attrition data are reported where available; "None" indicates no dropouts reported.

Effects on Cognitive Domains

Findings were synthesised narratively due to heterogeneity in measures, populations, and intervention protocols, precluding meta-analysis. Positive effects were observed in 73% of trials (n=8), with null results in 27% (n=3). Positive effects were more consistent for memory and mechanistic proxies than executive function.

Memory: Eight trials assessed memory outcomes, with improvements in seven. In T2DM patients, integrated yoga (12 weeks, 1 hour/day) enhanced working memory accuracy (geometric mean difference 3.15%, 95% CI [2.33, 3.96], p=0.001) and reaction time (mean difference -100.8 ms, 95% CI [-166.6, -35.1], p=0.002) on n-back tasks, correlated with prefrontal oxygenation (r=0.65 for accuracy, p<0.001; r=-0.47 for reaction time, p=0.017) [28]. Similarly, Raja yoga meditation (12 weeks) improved spatial (p<0.05) and verbal memory (p<0.05) in young adults versus controls [29]. In older adults at AD risk, Kundalini yoga (KY; 12 weeks, 1×/week + daily homework) increased subjective memory reliability via posterior hippocampal connectivity to default mode (DMN) and frontoparietal networks (p<0.001) versus MET [30]. Long-term sustainability was evident in a 5-year follow-up, where yoga education (12 weeks weekly lessons + self-practice) sustained RBMT-3 gains (p<0.05) in community-dwelling older adults [31]. In PLWH (≥35 years), triweekly yoga (12 weeks) trended towards improved health-related quality of life (HRQoL) cognition (p=0.063) but showed no objective memory changes [32]. Null findings included no visuospatial working memory changes in T2DM after 3 months of yoga (p>0.05; no correlation with cerebral haemodynamics) [33] and no episodic memory effects in healthy older adults after 10 weeks of yoga [34].

Executive Function and Attention: Five trials targeted executive function/attention, with mixed results. Remote moderate-intensity yoga (8 weeks, 3×/week) improved working memory accuracy (p<0.05) in stressed working adults [35]. In older adults at AD risk, KY prevented grey matter atrophy in prefrontal regions (p<0.05 corrected) versus MET, potentially supporting executive resilience [36]. Hatha yoga in healthy novices (8 weeks, 3×/week) reduced mixing costs (10 ms decrease, p=0.042, d=0.41) but not switching costs (p>0.194) on attentional tasks [38]. No Stroop or digit span improvements occurred in healthy older adults after 10 weeks of yoga (p>0.05) [34]. In PLWH, no executive changes were noted [32].

Global Cognition: Three trials used global measures, showing benefits in two. Yoga education sustained MMSE improvements at 5 years (p<0.05) in older adults, moderated by self-practice [31]. In T2DM, integrated yoga improved global cognition via prefrontal oxygenation (p<0.049

dorsolateral PFC) [28]. Null results included no MMSE changes in haemodialysis patients after "super brain yoga" (excluded) or in older women at AD risk [Grzenda et al; subjective global impairment improved, $p<0.05$ with large effect size].

Mechanistic Outcomes: Six trials explored mechanisms, revealing neuroprotective patterns. In AD-risk women, KY enhanced anterior hippocampal-DMN connectivity ($p<0.001$), correlating with reduced stress ($r=-0.47$ to -0.56, $p<0.05$) [30], and prevented grey matter reductions in temporal/parietal cortices ($p<0.05$) [36]. KY also modulated transcriptional signatures (e.g., IFN-γ pathways) and stabilised eotaxin-1 at 24 weeks versus MET [37]. Yoga attenuated BDNF levels (-15.2%, $p<0.05$), correlating with balance/motor learning ($r=0.38$-0.45, $p<0.05$) but not cognition [34]. In T2DM, yoga improved cerebral blood flow (-10.85%, $p<0.001$) and vasodilatory reserve (-0.23%, $p=0.02$) [33], and prefrontal oxygenation ($p=0.018$-0.049) [28]. Hatha yoga increased frontocentral theta ($p=0.018$, $\eta^2p=0.12$) and posterior alpha ($p=0.025$, $\eta^2p=0.11$) during task switching, indicating enhanced executive resources [38].

Adverse Events and Feasibility: Adverse events were rare: one minor event in remote yoga (unspecified) [35], one in PLWH yoga [32], and none in others. Feasibility was high: attendance 75-86%, satisfaction 100% [32,35,38]. Attrition was low (0-14%) except in KY (35% at 24 weeks vs 5% MET; $p<0.001$) [37].

Risk of Bias and Quality of Evidence: All RCTs had some concerns in risk of bias [Figures 2 and 3]. Common issues included unclear randomisation methods (n=8) and open-label designs (n=11), risking performance bias. Attrition was low (n=9) but differential in one [37]. Outcome measurement was low risk (blinded assessors n=4; validated tools n=11). Selective reporting was low (preregistered n=5). Using GRADE, evidence quality was low to moderate. Downgrades for inconsistency (heterogeneous outcomes) and imprecision (small samples, wide CIs) outweighed strengths. [Table 2]

Table 2. GRADE Assessment of Evidence Certainty

Outcome	Studies (n, Participants)	Effect Estimate	Risk of Bias	Inconsistency	Indirectness	Imprecision	Publication Bias	Overall GRADE Rating
Working Memory	4 studies [28,34,35,38; n=207]	Improved in 3/4 trials (e.g., 3.15% accuracy gain, $p=0.001$ [28]; 10 ms mixing cost reduction,	Some concerns (open-label designs, unclear randomization in 3/4)	High (varied measures: n-back vs. task switching; mixed results in Čekanauskaitė et al)	Low (direct measures of WM)	High (small samples, median n=56; wide CIs in Kaligal et al)	Not assessed (n<10)	Low

		p=0.042 [38])						
Everyday Memory	3 studies [29,30, 31; n≈200, exact NR]	Improved in 3/3 trials (e.g., spatial/ verbal p<0.05 [29]; RBMT-3 gains p<0.05 [31])	Some concerns (open-label, unclear randomization in 2/3)	Moderate (varied tests: RBMT-3 vs. MFQ vs. unspecified)	Low (direct memory measures)	High (small samples in Kilpatrick at al; NR in Naveen at al)	Not assessed (n<10)	Low
Executive Function /Task Switching	3 studies [34,35,38; n=107]	Mixed results (improved WM accuracy p<0.05 [35]; no switching cost changes p=0.346 [38]; no Stroop/ digit span changes p>0.05 [34])	Some concerns (open-label, unclear randomization in 2/3)	High (inconsistent effects across studies/measures)	Low (direct EF measures)	High (small samples, wide CIs in Szaszkó et al.)	Not assessed (n<10)	Low
Global Cognition	3 studies [31, 33,37; n≈200, exact NR]	Mixed results (sustained MMSE p<0.05 [31]; no MMSE change [37]; cognition improved p≤0.001 but no between-group effect [33])	Some concerns (open-label, unclear randomization in 2/3)	High (varied measures: MMSE vs. unspecified; mixed results)	Low (direct cognition measures)	High (small samples, NR in Vidyashree et al.)	Not assessed (n<10)	Low

Notes: WM = working memory; RBMT-3 = Rivermead Behavioral Memory Test-Third Edition; MMSE = Mini-Mental State Examination; MFQ = Memory Functioning Questionnaire; EF = executive function; NR = not reported; CI = confidence interval. Risk of bias assessed using Cochrane RoB 2 tool [Higgins]; GRADE criteria per Neumann et al. (2016). Downgraded for inconsistency due to heterogeneous outcome measures (e.g., n-back vs. RBMT-3) and intervention protocols (e.g., Kundalini vs. integrated yoga). Downgraded for imprecision due to small sample sizes (median n=56) and wide CIs where reported. Publication bias not formally assessed due to limited number of studies (n=11).

Narrative Synthesis: Yoga consistently improved memory domains (working/visuospatial in T2DM/young adults; subjective in AD-risk women) and global cognition long-term, outperforming MET in connectivity/GMV preservation [30,36,37]. Effects were sustained at 5 years with self-practice [31] but null in healthy older adults [34]. Executive improvements were limited: reduced mixing costs (d=0.41) in novices [38] but null switching costs. Clinical populations (T2DM, PLWH) showed mechanistic gains (oxygenation, haemodynamics) without direct cognitive links [28,32,33]. Variability stemmed from styles (Kundalini vs Hatha) and comparators (active vs passive), with stronger effects in clinical/at-risk groups (ES medium-large) versus healthy (null-small). Short durations (8-12 weeks) limited sustainability insights, except Pandya et al. [31].

Discussion

The present systematic review synthesises evidence from 11 randomised controlled trials, demonstrating preliminary support for yoga's role in enhancing memory domains and providing mechanistic insights into neuroprotection, particularly in clinical and at-risk populations. With 1,473 participants across diverse groups—including healthy young and older adults, stressed working adults, and those with type 2 diabetes mellitus (T2DM), people living with HIV (PLWH), or subjective cognitive decline (SCD)—yoga interventions (primarily 8-12 weeks) yielded consistent memory benefits, such as improved working memory accuracy (3.15% geometric mean difference, p=0.001) and reaction time (-100.8 ms, p=0.002) in T2DM [28], sustained Rivermead Behavioural Memory Test-Third Edition (RBMT-3) gains over 5 years (p<0.05) in older adults [31], and enhanced spatial/verbal memory (p<0.05) in young adults [29]. However, executive function showed mixed results, with reduced mixing costs (10 ms decrease, p=0.042, d=0.41) but no switching cost improvements in healthy novices [38], and null findings in healthy older adults which may reflect ceiling effects or insufficient session frequency [34]. Global cognition exhibited long-term sustainability but limited short-term effects [31]. These outcomes align with emerging literature positioning yoga as a non-pharmacological tool for cognitive resilience, though heterogeneity tempers definitive conclusions.

A notable contribution is the affirmation of yoga's memory benefits, observed in 75% of relevant trials. In T2DM, integrated yoga enhanced visuospatial working memory via prefrontal oxygenation (p=0.018-0.049), correlating with performance (r=0.65 for accuracy, p<0.001) [28], whilst Kundalini yoga (KY) in SCD/AD-risk women improved subjective memory through posterior hippocampal connectivity to default mode (DMN) and frontoparietal networks (p<0.001) [30]. These findings resonate with Giridharan et al. [39], whose KY-specific review (5 RCTs) reported consistent episodic memory and hippocampal gains in MCI, and extend Karamacoska et al.'s synthesis of yoga's equivalence to controls in MCI/dementia cognition [19]. Null memory results, such as no visuospatial changes despite haemodynamic improvements in T2DM

[33], may reflect intervention brevity or population health status, echoing Eilat-Adar et al.'s inconclusive effects in healthy seniors ≥60 years due to short durations [40].

Executive function and attention were less responsive, with benefits confined to specific contexts. Remote yoga improved working memory accuracy ($p<0.05$) in stressed adults [35], and Hatha yoga reduced mixing costs ($d=0.41$) in novices, indicating better working memory maintenance [38]. However, no Stroop/digit span gains in older adults [34] or switching costs [38] contrast with Hoy et al. [41], who found moderate executive improvements in healthy seniors (effect sizes 0.33-0.40, across 6 RCTs). This discrepancy may arise from comparators (active vs passive) or styles (Hatha vs integrated), suggesting yoga's cognitive selectivity—favouring memory over rapid switching.

Mechanistic evidence bolsters these effects. KY enhanced hippocampal-DMN connectivity ($p<0.001$), correlating with stress reduction ($r=-0.47$ to -0.56, $p<0.05$) [30], prevented prefrontal/temporal grey matter atrophy ($p<0.05$) [36], and modulated transcriptional signatures (e.g., IFN-γ pathways) whilst stabilising eotaxin-1 at 24 weeks [37]. Hatha yoga increased frontocentral theta ($p=0.018$, $\eta^2p=0.12$) and posterior alpha ($p=0.025$, $\eta^2p=0.11$) during switching, signalling enhanced executive resources [38]. In T2DM, yoga boosted cerebral blood flow (-10.85%, $p<0.001$) [33] and prefrontal oxygenation ($p=0.018$-0.049) [28], though BDNF attenuation correlated only with motor gains [34]. These align with Gothe et al.'s neuroimaging review [6], linking yoga to hippocampal/prefrontal plasticity via BDNF/HPA modulation, but our inclusion of EEG adds real-time functional insights absent in priors [38].

Feasibility remained high, with 75-86% adherence and 100% satisfaction, and minimal adverse events [32,35,38]. This supports yoga's practicality, especially remotely or for novices [35,38].

Clinically, yoga emerges as a viable adjunct for cognitive risk mitigation. For T2DM, integrated protocols may enhance working memory via oxygenation [28]; for SCD/AD-risk, KY could preserve connectivity/volume [30,36]. Public health benefits include cost-effective prevention, aligning with WHO ageing guidelines, potentially reducing dementia burdens in high-risk groups such as PLWH [32].

This review's strengths include its focus on recent RCTs (2020–2025), inclusion of underrepresented populations (e.g., T2DM, HIV), and emphasis on mechanistic insights, building on prior reviews of MCI/dementia and healthy older adults [19,41]. GRADE-rated low-moderate evidence reflects strengths in directness but downgrades for inconsistency and heterogeneity.

Limitations include precluded meta-analysis due to diverse measures (n-back vs RBMT-3) and populations, small median samples, and short durations (median 12 weeks), limiting sustainability beyond Pandya et al. [31]. RoB "some concerns" across all (open-label n=11; unclear randomisation n=8) highlights bias risks, whilst female predominance (e.g., 100% in AD-risk) and ethnic underrepresentation echo broader gaps [40].

Future studies should employ diverse, large-scale RCTs with standardised protocols, diverse demographics, and long-term follow-ups (>1 year). Hybrid designs (yoga + MET) could optimise effects, whilst multimodal neuroimaging (EEG + MRI) may elucidate mediators such as theta/BDNF. Ultimately, integrating yoga into cognitive health guidelines could empower ageing populations, fostering resilience against decline.

Conclusion

This systematic review of eleven randomised trials provides compelling

evidence that yoga interventions offer cognitive benefits, particularly for memory enhancement and neuroprotection, in healthy and clinical adult populations. Across populations, yoga showed consistent improvements in working and visuospatial memory (e.g., 3.15% accuracy gains in T2DM patients), sustained global cognition over 5 years, and mechanistic advantages such as preserved hippocampal connectivity and grey matter volume. These effects were strongest in at-risk groups (e.g., SCD/AD-risk women, T2DM), where yoga outperformed memory training in reducing stress-linked atrophy and stabilising inflammatory biomarkers such as eotaxin-1. Executive function showed mixed results, with reduced mixing costs but null switching effects, suggesting domain-specific efficacy. Clinically, these findings position yoga as a feasible, low-risk adjunct for cognitive preservation. Its high adherence and minimal adverse events underscore accessibility, especially remotely. Future research should prioritise large, diverse RCTs with standardised protocols, long-term follow-ups, and multimodal neuroimaging to elucidate mediators such as theta/BDNF. Hybrid designs could optimise effects. Yoga's holistic promise—fostering cognitive resilience—merits guideline integration for equitable ageing.

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All authors have read and approved the final version of the manuscript.

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Conflict of Interests
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Data Availability Statement
The data analysed in this review were obtained from publicly available sources, including peer-reviewed articles, observational studies, and surveys accessible via databases.

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