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Review Article



# The effects of multi-session resistance exercise on cognitive function in healthy adults: A systematic research review and meta-analysis

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ABSTRACT

*Objectives:* Cognitive decline is a growing global concern, and lifestyle-based interventions are increasingly recognised as promising preventive strategies. This review synthesises evidence on the cognitive effects of multi-session resistance exercise in healthy adults, organising outcomes within the broad ability structure of the Cattell–Horn–Carroll (CHC) framework.

*Methods:* Following PRISMA 2020 guidelines and a PROSPERO-registered protocol, comprehensive searches of electronic databases identified studies evaluating multi-session resistance exercise interventions and cognitive outcomes in healthy adults. Study quality was assessed using RoB 2, and random-effects Generic Inverse Variance meta-analyses were conducted to account for between-study heterogeneity. Cognitive outcomes were independently classified as global cognition, executive function, working memory, processing speed, and episodic memory.

*Results:* Resistance exercise was associated with improvements in global cognition and in several domains, including executive function, working memory, and processing speed. In contrast, episodic memory retrieval showed no consistent overall benefit and demonstrated substantial variability across studies.

*Conclusions:* The findings indicate that the cognitive effects of multi-session resistance exercise are domain-specific rather than uniform across cognitive abilities. Resistance exercise appears particularly promising for supporting cognitive processes involving executive control, working memory, and rapid information processing. However, interpretation should remain cautious given heterogeneity across studies, limited evidence in some domains, and variation in intervention duration, intensity, and cognitive measurement approaches. Future research should employ larger samples and more consistent CHC-aligned outcome measures to strengthen the evidence base.

## 1. Introduction

The rise in cognitive decline is becoming an increasing issue globally, with Alzheimer's disease (AD) and other Dementias identified as the leading cause of death in the UK in 2022 (ONS, 2023). Dementia is a debilitating neurological disorder that affects approximately 15% of people worldwide (Van Schependom and D'haeseleer, 2023). As a result, there is a growing need to address this issue with the number of Dementia cases expected to rise from 982,000 in 2024–1.4 million by 2040 in the UK alone (Carnall Farrar, NHS Digital, Comas-Herrera, Wittenberg, 2024; ONS, 2023). Many neurodegenerative disorders are preceded by a period of cognitive decline, characterised by progressive alterations in brain structure and functional connectivity, which ultimately disrupt cognitive functioning (Li et al., 2020). Early stages of decline are largely asymptomatic, with little to no observable deviation from usual cognitive functioning, resulting in diseases like dementia being commonly identified only at later stage of the disease, despite substantial preclinical pathology (Jack et al., 2013; Ritchie et al., 2015). This highlights the importance of directing attention towards large-scale, preventative approaches to cognitive decline during the preclinical phase (Reuben et al., 2024). Targeting cumulative lifestyle risk factors, which contribute to pathological manifestations of cognitive decline, may contribute to the overall reduction of neurodegenerative disease burden in later life.

While pharmacological interventions have yielded promising but limited success in halting or reversing cognitive decline (Liu et al., 2023;

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Trujillo-Estrada et al., 2021), growing evidence suggests that lifestyle factors may play a crucial role in mitigating dementia risk. Non-pharmacological interventions for cognitive preservation target modifiable variables (or risk factors) which have been shown to protect against neurodegeneration. The factors shown to reduce the risk of cognitive decline include healthy dietary habits, regular physical activity and stress reduction (Angeloni et al., 2020; Dominguez et al., 2021; Franks et al., 2022; Hikichi et al., 2016). One important commonality across positive lifestyle factors is maintenance of cardiorespiratory health (Zeiher et al., 2019). Early adulthood exposure to cumulative risk factors that are harmful to cardiac health have been linked with poor cognitive function in later life (Lloyd-Jones et al., 2010). Importantly, these cardio-cognitive associations are also observed in typically ageing populations and are well established in the literature (Laitinen et al., 2015). This highlights the importance of broadening the scope of accessible cognitive preservation interventions to reduce risk factors and degree of neurodegeneration vulnerability (Xu et al., 2009). Considering the disease burden and extensive healthcare expenditure on neurodegenerative diseases World Health Organization: WHO, (2021); ONS, 2023), physical fitness-based lifestyle interventions represent a promising and scalable strategy for preserving cognitive vitality and reducing decline in later life on a global scale (Franz et al., 2021; Herold et al., 2019).

Exercise has long been established as being an essential pillar of overall physiological wellbeing (Pedersen, 2019). The World Health Organisation (WHO) strongly recommends regular physical activity to reduce the risk of cognitive decline and dementia. Exercise is one of the most evidence-supported modifiable lifestyle factors, and is central to WHO's emphasis on vascular and metabolic risk reduction more broadly (World Health Organization, 2019).

Prolonged aerobic exercise, particularly activities that enhance cardiovascular endurance, has been extensively studied and is well-established as beneficial for neural and cognitive health. Aerobic training reliably increases brain-derived neurotrophic factor (BDNF), reduces neuroinflammation, and promotes hippocampal neurogenesis, supporting improvements in memory and spatial processing (Tharmaratnam et al., 2016). Regular engagement in endurance-based activity also enhances systemic and cerebral blood flow (Valenzuela et al., 2020) and stimulates angiogenesis through upregulation of vascular endothelial growth factor (VEGF) (Ballard, 2017). These vascular and neurotrophic adaptations are widely considered to underpin the robust cognitive benefits associated with aerobic exercise, including improved executive and memory functions and reduced risk factors linked to neurodegenerative conditions such as dementia. Aerobic exercise is therefore strongly and directly associated with angiogenesis due to sustained metabolic demands and the vascular remodelling characteristic of endurance training (Kraemer and Ratamess, 2005).

In contrast, the cognitive and neurophysiological effects of resistance exercise (RE) remain comparatively underexplored. Emerging evidence suggests that multi-session RE may also induce vascular adaptations, including increased angiogenic gene expression and enhanced endothelial progenitor cell activity (Gharaat et al., 2025). Although the underlying mechanisms are less clearly defined than in aerobic exercise, recent work by Morland et al. (2017) identifies lactate as a signalling molecule capable of promoting angiogenesis via HCAR1-mediated VEGF upregulation. Given that RE elicits substantial lactate production (Kraemer and Ratamess, 2005), similar pathways may contribute to vascular and neural adaptation in resistance-based training. Despite these promising developments, the cognitive consequences of RE, and the mechanisms that support them, remain far less understood than those of aerobic exercise. This highlights a gap in the literature and the need for a systematic synthesis of current evidence. Accordingly, the present systematic research review and meta-analysis aims to evaluate the cognitive effects of multi-session resistance exercise in healthy adults. More specifically, it will novelly assess domain specific cognitive outcomes to provide clarity on what aspects of cognition are particularly sensitive to RE to help guide future directions of cognitive decline interventions.

In support of this, RE-induced plasticity has been associated with greater cognitive efficiency in MCI patients and reduced degeneration in the hippocampus in AD vulnerable at a 12-month follow up (Broadhouse et al., 2020). Thus, RE-induced neurological mechanisms may in turn protect against age-related neurodegeneration in later life (Sujkowski et al., 2022).

Whilst it is well established that aerobic exercise affords neuroprotection, the protective potential of RE remains less well understood (Chang et al., 2012). RE may be of particular benefit to individuals who suffer from physical or cardiorespiratory issues (such as chronic fatigue syndrome or asthma) and may not be able to frequently take part in aerobic exercise without risk of harm. This mode of exercise may be particularly beneficial for ageing populations, as resistance-based protocols (e.g., squats or isometric exercises) are easily adapted for home-based interventions and can be done regardless of weather conditions, and with a reduced fear of falling that can pose barriers for older adults. RE therefore provides an alternative approach in populations with greater risk of cognitive decline to preserve cognition and enhance neurobiological mechanisms (Chippendale and Lee, 2017; Landrigan et al., 2019).

Previous research has demonstrated that resistance exercise (RE) can improve performance across several cognitive domains, including attention, executive function, and working memory (Loprinzi et al., 2020; Tsukamoto et al., 2017). However, the evidence has predominantly focused on populations with diagnosed neurodegenerative conditions or cognitive impairment (Busse et al., 2008; Coelho-Junior et al., 2020), with comparatively little research synthesising domain-specific cognitive adaptations in healthy adults using a theoretically grounded framework such as the Cattell–Horn–Carroll (CHC) model (McGrew, 2008). To address this gap in the literature, the main aims of the current systematic review and meta-analysis were to: (1) determine the overall effect of resistance exercise (RE) on cognitive function in healthy adults; (2) evaluate the effects of RE across cognitive domains organised according to a CHC-informed framework, including executive function, working memory, processing speed, episodic memory and global cognition; and (3) identify which cognitive domains demonstrate the greatest responsiveness to multi-session RE interventions.

## 2. Methods

The present review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines and the Cochrane Handbook for Systematic Reviews and Interventions. The review protocol was registered with PROSPERO (CRD42024508949).

### 2.1. Search strategy

A comprehensive literature search was conducted in May 2026 across six electronic databases: MEDLINE, PubMed, Cochrane Central Register of Controlled Trials (CENTRAL), PsycINFO, Google Scholar, and EMBASE. The search strategy incorporated both controlled vocabulary (e.g., MeSH terms) and free-text keywords relevant to the review topic. Synonyms and alternative terminology were included for to improve search sensitivity. Intervention-related terms included "resistance exercise", "resistance training", "strength training", "strength exercise", "weight training", "power training", "progressive resistance training", "weightlifting", and bodybuilding. Boolean operators (AND, OR, NOT), truncation, and phrase searching were used where appropriate, and search syntax was adapted for each database. Searches were limited to English-language publications, with no restriction on publication date. An example search syntax is provided in Supplementary Materials 1.

Grey literature was included in the search to ensure comprehensive coverage of emerging and relevant evidence. Though no grey literature retrieved met the inclusion criteria. All retrieved citations were managed using EndNote, and duplicates were removed prior to the screening process. Reference lists of included studies and relevant reviews were manually screened to identify any additional eligible publications. All retrieved citations were managed using EndNote, and duplicates were removed prior to the screening process.

### 2.2. Study selection

Titles, abstracts and full-text articles were assessed against predefined eligibility criteria. Eligible study designs included randomized controlled trials, controlled clinical trials, quasi-experimental controlled studies and eligible within-subject controlled intervention studies. Participants were adults aged 18 years or older who were cognitively healthy or did not have a diagnosed neurocognitive disorder. Eligible interventions comprised multi-session resistance exercise, strength-training or weight-training protocols, including dynamic, isometric, machine-based, free-weight, elastic-band, body-weight and velocity-based exercise. Comparator conditions included non-exercise, usual-activity, wait-list, health-education, sham or low-intensity activity controls, aerobic or balance exercise, alternative resistance-training conditions and eligible pre-intervention control periods. Studies were required to report at least one validated cognitive or neuropsychological outcome assessing global cognition or a defined cognitive domain, including executive function, attention, working memory, learning and memory, processing speed, language or visuospatial processing.

Records were reviewed independently by two reviewers (GM and YS) in accordance with PRISMA guidance, with disagreements resolved through discussion and consensus. Exclusion criteria included systematic or narrative reviews, studies reporting only physiological or physical-function outcomes without an eligible cognitive measure, studies in which the independent effect of resistance exercise could not be isolated because of additional pharmacological, nutritional, cognitive-training or brain-stimulation interventions, studies recruiting participants with diagnosed dementia or other ineligible neurological conditions, and articles not published in English.

### 2.3. Coding procedure

Cognitive outcome categorisation was guided by the Cattell-Horn-Carroll (CHC) framework of cognitive abilities as a guiding taxonomy (Flanagan and Dixon, 2014). Where appropriate, outcomes were grouped according to conceptually related CHC broad abilities, including working memory (Gwm) and processing speed (Gs), while executive function, memory, and global cognition were retained as distinct domains to reflect the constructs assessed by the included studies. Measures of general cognitive performance derived from screening instruments or composite cognitive batteries were coded separately as global cognition. Classification was based on the primary cognitive construct assessed by each measure, using the test description, scoring procedures, and interpretation reported in the original study. Detailed definitions of each cognitive domain and examples of the measures assigned to them are presented in Table 1.

### 2.4. Study quality assessment

Study quality was assessed independently by two reviewers (GM and MB) using the Cochrane Risk of Bias 2 (RoB2) tool for randomised controlled trials. This tool is recommended by the Cochrane Collaboration for evaluating the methodological quality of RCTs. The RoB2 tool comprises five key assessment domains: the randomisation process, deviations from intended interventions, missing outcome data, measurement of the outcome, and selection of the reported result. Following independent assessments, discrepancies were identified, discussed and resolved through consensus. Domain-level judgements were subsequently combined to derive an overall risk of bias rating for each study.

**Table 1**
Cognitive measures were classified using the CHC framework where appropriate, with outcomes grouped according to the primary cognitive construct assessed. Where a task could measure more than one ability, classification was determined from the task procedures, delay period, scoring method, and interpretation provided in the original study. For example, short-delay match-to-sample tasks were classified as working memory, whereas versions emphasising delayed recognition or retrieval were classified as long-term storage and retrieval.

| CHC Cognitive Domain | Definition |
|---|---|
| Global Cognition | Global cognition reflects broad cognitive performance across multiple abilities. Measures typically combine scores from several cognitive domains to provide an overall estimate of cognitive functioning rather than assessing one specific ability. |
| Executive Function / Fluid Reasoning (Gf) | Executive function and fluid reasoning involve the control and coordination of goal-directed behaviour, including inhibitory control, cognitive flexibility, task switching, problem solving, and the ability to respond adaptively to novel or conflicting information. |
| Working Memory (Gwm) | Working memory refers to the capacity to temporarily maintain, update, and manipulate task-relevant information while completing an ongoing cognitive task. |
| Processing Speed (Gs) | Processing speed reflects the efficiency and rapidity with which relatively simple cognitive operations can be completed. Measures commonly emphasise response speed, visual scanning, attention, or rapid discrimination under time constraints. |
| Memory Retrieval/Episodic Memory (Glr) | Storage and retrieval refers to the ability to encode, retain, consolidate, and subsequently retrieve information over time. This domain includes episodic learning, delayed recall, and recognition memory. |

### 2.5. Data extraction

A data extraction form was developed in RevMan (Review Manager RevMan Computer program, 2024) for the present review and independently reviewed by a second reviewer to ensure comprehensive data capture. Extracted variables included exercise type, duration and protocol; cognitive domain and assessment tool; sample size, and participant demographics; outcome analysis methods and reported results. Where outcome means and standard deviations were not reported in tabular form, WebPlotDigitzer software was used to extract numerical data from graphical figures. In addition, where standard deviations were not explicitly reported, estimates were derived using reported standard errors or upper and lower confidence bounds.

### 2.6. Meta-analytic procedure

Meta-analyses and plots were conducted using RevMan 5.3 (Cochrane Collaboration). Cognitive outcomes were pooled using a CHC-informed framework. Where appropriate, outcomes were grouped according to conceptually related CHC broad abilities, including executive function/fluid reasoning (Gf), working memory (Gwm), processing speed (Gs), and memory storage and retrieval/episodic memory (Glr); measures representing broad or composite cognitive performance were analysed separately as global cognition. For each study and cognitive domain, Hedges' g and its standard error were entered using the Generic Inverse Variance method. Pooled estimates were calculated using random-effects models, with $\tau^2$ used to estimate between-study variance.

A random-effects model was selected because variability was anticipated in participant characteristics, resistance-exercise protocols, comparator conditions, and cognitive outcome measures. This model assumes that the true intervention effect may differ across studies and incorporates both within-study uncertainty and between-study variance

into the weighting procedure. The resulting pooled estimates therefore represent the mean of a distribution of plausible intervention effects rather than a single common effect, consistent with recommendations for meta-analyses in cognitive psychology and sport science where heterogeneity is expected (Borenstein et al., 2010).

Effect sizes were expressed as Hedges' g with 95% confidence intervals. The direction of each outcome was harmonised so that positive values favoured resistance exercise and negative values favoured the comparator condition, irrespective of whether the original measure reflected accuracy, response time, or a higher test score. Statistical significance was assessed using Z tests, while heterogeneity was evaluated using Cochran's Q ($\chi^2$), $\tau^2$, and $I^2$. Funnel plots were generated for cognitive domains with sufficient studies and visually inspected for asymmetry as an indication of potential publication bias. All pooled effect estimates were derived from the random-effects models.

## 3. Results

### 3.1. Study selection and characteristics

Following full-text screening, the literature search identified 17 peer-reviewed studies that met the eligibility criteria and were included in the analysis. Data from 1270 participants were extracted across the included studies. Numerical age data were available for 1225 participants ($M$ = 67.36 ± 12.83 years) (Fig. 1).

Across the included studies, RE protocols varied considerably with respect to duration, frequency, exercise selection, and intensity. Interventions consisted of supervised multi-session programmes lasting between 8 and 24 weeks, undertaken two or three times per week. Programmes commonly incorporated both upper- and lower-body resistance exercises using free weights, resistance machines, elastic bands, or body weight. Training intensity was prescribed using a range of approaches, including percentages of 1RM (repetition maximum), velocity-based training, and self-selected loads. Comparator groups included non-exercise controls, aerobic exercise, balance training, health education, and usual care; however, only eligible comparisons were synthesised within the meta-analysis. Study characteristics are presented in Table 2. Participant attrition was reported across studies, although reasons for withdrawal were often incompletely described. Detailed attrition information is provided in Supplementary Material 2.

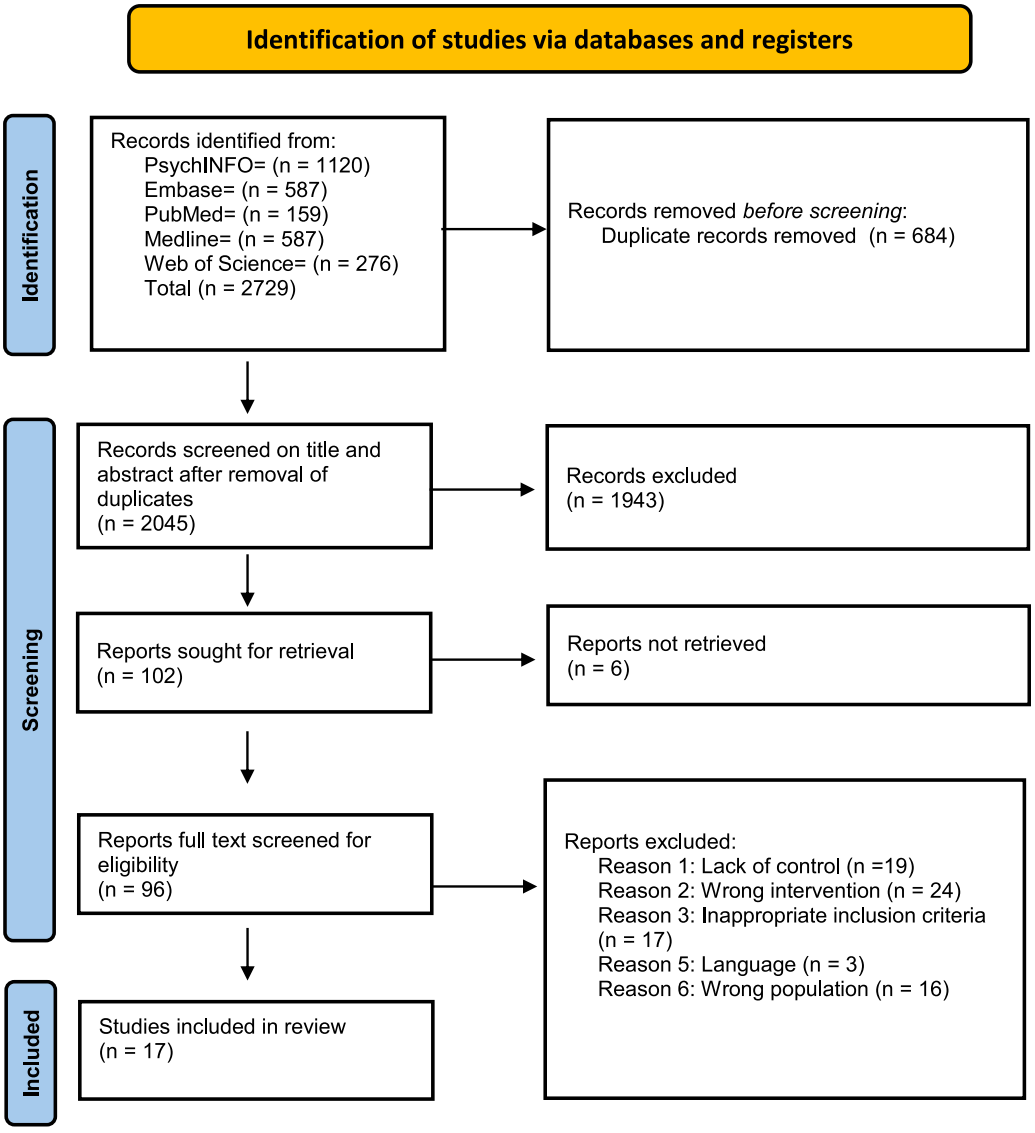



**Fig. 1.** A Study selection flow diagram (PRISMA 2020) detailing the selection process used to identify included records, including number and reason for exclusion of records at each round of screening.

**Table 2**
Characteristics of included studies. RM denotes maximum repetition, MVC denotes maximum voluntary contraction, RPE denotes rate of perceived exertion.

| First author, year | N | Age (years) | % Female | RE protocol (Set no. X Rep no: Duration) | Control group | RM/ MVC % |
|---|---|---|---|---|---|---|
| Castillo Quezada et al. 2021 | 113 | 69.39 ± 6.48 | 100% | Progressive resistance training: 3 sessions per week; 12 weeks | Non-exercise control | Progressive 1-RM |
| Cherup et al. 2018 | 30 | 70.3 ± 7.3 | 73.33% | High-velocity resistance circuit: 3 sessions per week; 12 weeks | Non-exercise control | High-velocity RT |
| Claußen et al. 2025 | 83 | 70.5 ± 4.5 | 64.8% | Metastable resistance training: 2 sessions per week; 10 weeks | Traditional resistance training and balance training | Progressive free-weight RT |
| Coetsee and Terblanche, (2017) | 67 | 62.45 ± 5.34 | 63.41% | 3 × 10 reps of upper and lower body resistance exercises: 3 sessions per week; 16 weeks | Non-exercise control | 100% 10-RM |
| Cunha et al. 2023 | 61 | 69.75 ± 4.68 | 100% | 3 × 8–12 reps of 8 exercises: 3 sessions per week; 12 weeks | Non-exercise control | 8–12 RM |
| Duarte Martins et al. 2025 | 79 | 70.3 ± 5.1 | 69.9 | High-speed resistance training: 3 sessions per week; 16 weeks | Usual activity control | Velocity-based training |
| Fernandez-Gamez et al. 2025 | 90 | 71.75 ± 3.96 | 57.8% | Elastic-band resistance exercise: 180 min per week; 24 weeks | Usual activity control | Elastic resistance |
| Huang et al. 2025 | 63 | 21.63 ± 1.68 | 50% | Resistance exercise: 3 sessions per week; 8 weeks | Non-exercise control | Progressive RT |
| Iuliano et al. 2015 | 80 | 66.96 ± 11.73 | 60% | High-intensity resistance training: 3 sessions per week; 12 weeks | Non-exercise control | High-intensity RT |
| Ikudome et al. 2017 | 170 | 67.2 ± 5.5 | 71.2% | 5 body-mass RE exercises | Usual lifestyle continuation | Body-mass |
| Kaseb et al. 2026 | 45 | ≥ 60 years | 0% | Resistance training ± blood flow restriction: 2 sessions per week; 8 weeks | Non-exercise control | 70–80% 1-RM (<40% with BFR) |
| Kimura et al. 2010 | 119 | 74.3 ± 5.5 | 58.8% | Progressive resistance training: 2 sessions per week; 12 weeks | Health education | Progressive RT |
| Kujawski et al. (2022) | 55 | 64.6 ± 4 | 92.59% | 4 × 15/12/10/10 reps of 6 exercises: 2 sessions per week; 3 months | Sitting calisthenic balance programme | Self-chosen weight |
| Liu-Ambrose et al. 2008 | 74 | 82.2 ± 6.25 | 69.5% | Home-based resistance and balance training: 6 months | Guideline falls prevention care | Body-weight resistance |
| Macauley et al. 2021 | 20 | 69.1 ± 5.8 | 70% | 3 sessions per week of periodised strength training: 12 weeks | Control pre-exercise period | 85–90% 1-RM |
| Smolarek et al. 2016 | 37 | 65.87 ± 5.69 | 100% | 3 × 10 reps of 10 exercises: 3 sessions per week; 12 weeks | Non-exercise control | 60–70% 1-RM |
| Timmons et al. 2018 | 84 | 69.3 ± 3.5 | 46.43% | Resistance training: 3 sessions per week; 12 weeks | Non-exercise control | 60–65% 1-RM |

### 3.2. Quality assessment

Of the 17 included studies, 14 were rated as low risk of bias, 2 raised some concerns, and 1 was rated as high risk. A summary of the quality assessment results is provided below (Fig. 2). The main area of methodological concern identified in the quality assessment was the randomisation process, chiefly the methods used as a control. For example, one study used a stretching control – some concerns were raised over the level of potential physiological arousal the control may cause. Blinding was also identified as a concern in one study, where multiple participants withdrew after realising they had been assigned to the control condition (full quality assessment details are available in supplementary material 3).

### 3.3. Data analysis

#### 3.3.1. Quantitative synthesis

Random-effects Generic Inverse Variance (GIV) meta-analyses were conducted to evaluate the effects of resistance exercise on cognition. Standardised effect sizes (Hedges' g) and their corresponding standard errors were analysed using RevMan 5.3 review software, allowing studies reporting either post-intervention values or change scores to be synthesised within a common analytical framework. Cognitive outcomes were organised using the CHC framework as a guiding taxonomy. CHC domains Visual Processing and Verbal Fluency did not feature in the reported domain-wise analysis due to insufficient data across the included studies. When appropriate, in studies in which multiple outcome data was reported within the same cognitive domain, representative outcomes were selected and categorized into the corresponding outcome domain.

#### 3.3.2. Global cognition

In global cognition, resistance exercise demonstrated a moderate and statistically significant positive effect on overall cognitive performance compared with the control conditions ($g = 0.76$, 95% CI [0.32, 1.21], $Z = 3.38$, $p < .001$). Substantial heterogeneity was observed across studies ($\chi^2(7) = 20.48$, $p = .005$, $I^2 = 68\%$), suggesting considerable variability in effect estimates that may reflect differences in intervention

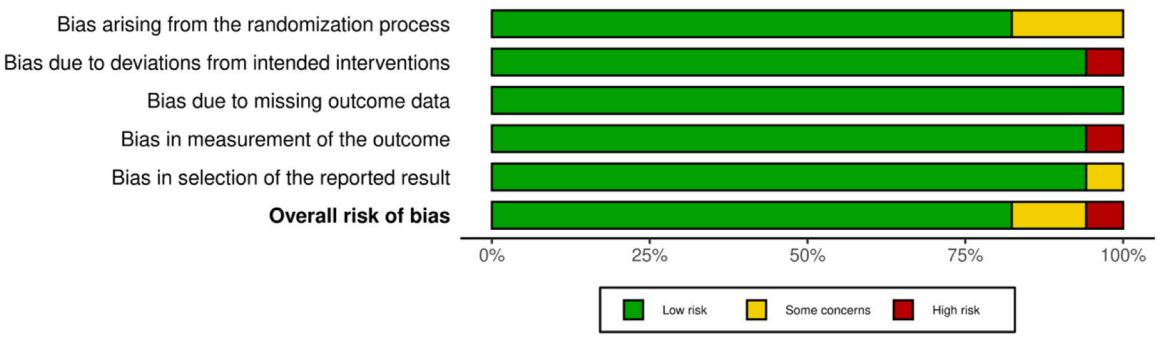



**Fig. 2.** Quality assessment risk of bias ratings shown as a percentage (%) across each of the 5 assessment domains with overall bias shown in the first row.

characteristics, participant populations, and cognitive assessments. Overall, the pooled analysis favoured resistance exercise over the comparator conditions (Fig. 3).

### 3.3.3. Executive function

Executive function was represented by measures of cognitive flexibility, inhibitory control and problem solving, including the Trail Making Test Part B, Stroop Colour–Word Test and Wisconsin Card Sorting Test. A random-effects Generic Inverse Variance meta-analysis demonstrated a small but statistically significant benefit of resistance exercise compared with the control conditions ($g = 0.29$, 95% CI [0.14, 0.44], $Z = 3.83$, $p < .001$). Between-study heterogeneity was moderate ($\chi^2(25) = 49.13$, $p = .003$, $I^2 = 50\%$), indicating moderate variability in effect estimates across studies. Despite differences in intervention characteristics and cognitive assessments, the pooled effect favoured resistance exercise (Fig. 4).

### 3.3.4. Working memory

Working memory was represented by measures such as Digit Span and Letter–Number Sequencing. A random-effects Generic Inverse Variance meta-analysis demonstrated a small but statistically significant benefit of resistance exercise compared with the control conditions ($g = 0.37$, 95% CI [0.19, 0.55], $Z = 3.99$, $p < .001$). Between-study heterogeneity was low ($\chi^2(10) = 8.63$, $p = .57$, $I^2 = 12\%$), indicating little variability in effect estimates across studies. Despite differences in intervention characteristics and cognitive assessments, the pooled effect favoured resistance exercise (Fig. 5).

### 3.3.5. Processing speed

Processing speed was assessed using reaction time measures and validated tests of psychomotor speed. A random-effects Generic Inverse Variance meta-analysis demonstrated a small but statistically significant benefit of resistance exercise compared with the control conditions ($g = 0.27$, 95% CI [0.15, 0.39], $Z = 4.54$, $p < .001$). Between-study heterogeneity was low ($\chi^2(23) = 24.63$, $p = .37$, $I^2 = 7\%$), indicating little variability in effect estimates across studies. Despite differences in intervention characteristics and cognitive assessments, the pooled effect favoured resistance exercise (Fig. 6).

### 3.3.6. Episodic memory

Episodic memory retrieval was assessed using episodic and delayed recall measures. A random-effects Generic Inverse Variance meta-analysis demonstrated no statistically significant benefit of resistance exercise compared with the control conditions ($g = -0.19$, 95% CI [−0.73, 0.34], $Z = 0.71$, $p = .48$). Between-study heterogeneity was considerable ($\chi^2(7) = 33.33$, $p < .001$, $I^2 = 83\%$), indicating substantial variability in effect estimates across studies. Despite differences in intervention characteristics and cognitive assessments, the pooled effect did not significantly favour either resistance exercise or the control conditions (Fig. 7).

## 3.4. Funnel plots

Funnel plots were used to assess the symmetry of effect sizes for global cognition, executive function, working memory, processing speed, and memory retrieval and to evaluate the potential presence of publication bias (Fig. 8). Overall, the studies were distributed around the pooled effect sizes with no marked evidence of asymmetry across most cognitive domains. Executive function, working memory, and processing speed demonstrated relatively symmetrical distributions. The global cognition funnel plot showed slightly greater dispersion. Finally, the episodic memory retrieval plot (Fig. 8) displayed mild visual asymmetry, largely reflecting a small number of studies with more extreme effect sizes. Across all domains, larger effect sizes were not consistently associated with smaller study sizes, suggesting that substantial publication bias was unlikely. The minor asymmetry observed is more likely attributable to between-study heterogeneity than to publication bias.

## 4. Discussion

This systematic review and meta-analysis examined the impact of RE on cognitive abilities in healthy adults. Organising outcomes using a CHC-informed framework indicated that the cognitive effects of RE varied across domains rather than appearing uniformly across all cognitive outcomes. Executive function, working memory, processing speed, and global cognition generally favoured RE. In contrast, findings for long-term episodic memory retrieval varied considerably across

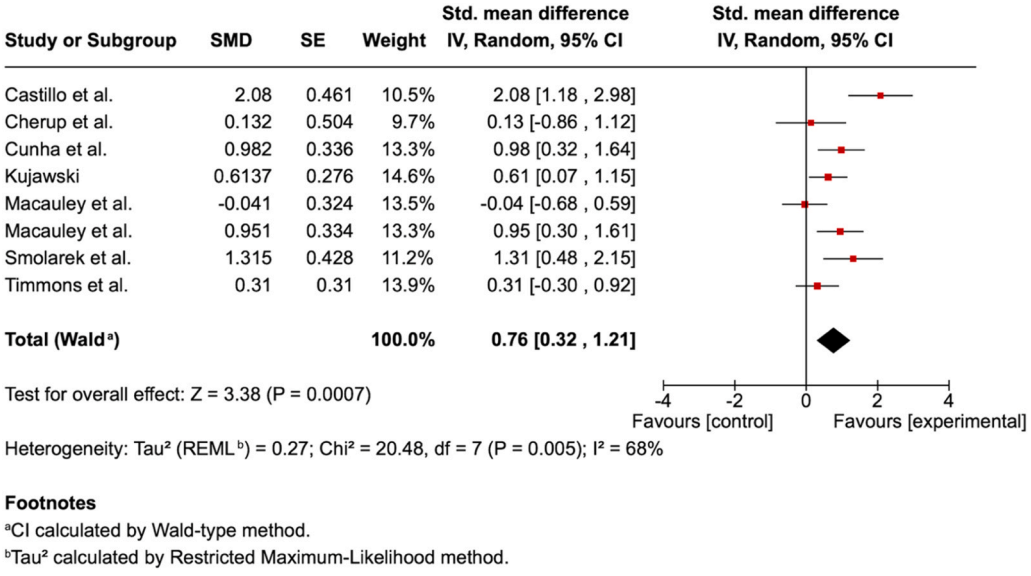



**Fig. 3.** The forest plot presents standardised mean differences for the effect of resistance exercise on global cognitive performance compared with control conditions. Squares represent individual study effect estimates, with square size proportional to the weight assigned to each estimate. Horizontal lines represent 95% confidence intervals, and the diamond represents the pooled effect estimate and its 95% confidence interval. Positive effect estimates favour resistance exercise, whereas negative estimates favour the control condition.

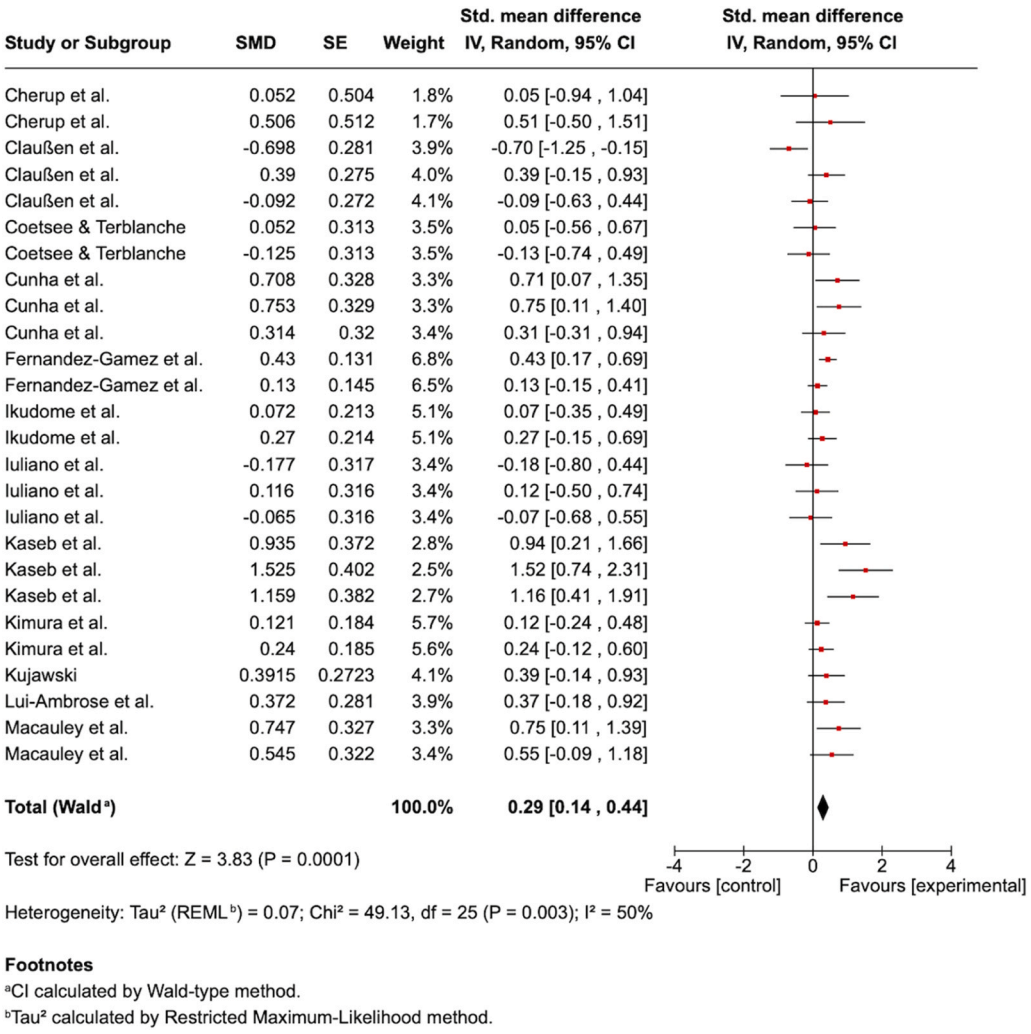



**Fig. 4.** The forest plot presents standardised mean differences for the effect of resistance exercise on executive function compared with control conditions. Squares represent individual study effect estimates, with square size proportional to the weight assigned to each estimate. Horizontal lines represent 95% confidence intervals, and the diamond represents the pooled effect estimate and its 95% confidence interval. Positive effect estimates favour resistance exercise, whereas negative estimates favour the control condition.

studies, limiting confidence that RE produces a reliable benefit in this domain. Taken together, the results suggest that RE may be particularly relevant to cognitive processes involving executive control, the active maintenance of information, and efficient information processing, and are consistent with existing reviews examining the efficacy of RE protocols (Chang et al., 2012; Landrigan et al., 2019).

The pattern of findings suggests that the cognitive effects of RE may depend on the processes assessed and the sensitivity of the measures used. The absence of a consistent benefit for episodic memory retrieval may reflect differences in memory tasks, intervention characteristics, and the comparatively limited evidence available for this domain. More broadly, variation between domains indicates that RE does not influence all aspects of cognition to the same extent. The improvements observed in executive function and working memory may partly reflect the cognitive demands of RE, including sustained attention, action monitoring, the maintenance of task goals, and the coordination of movement sequences, alongside physiological adaptations associated with exercise. The present review indicates that RE-induced cognitive changes are not uniform across cognitive domains, supporting the value of a theoretically informed framework for synthesising cognitive outcomes.

The domain-specific improvements observed following RE are broadly congruent with existing research reporting cognitive benefits in neurotypical (Yu et al., 2021) and clinically impaired populations (Huang et al., 2022). RE has also been associated with broader functional benefits, including increased overall activity levels, reduced fear of falling, and a lower incidence of falls (Wang et al., 2022), greater independent task completion, leading to an increased sense of confidence to engage in social interaction (Bergland et al., 2018). Both engagement in exercise and cognitive functioning are known lifestyle factors that are associated with reductions in dementia risk (Hikichi et al., 2016). This suggests a potential interaction whereby RE enhances both day-to-day activity and independence, while also exerting direct effects on cognition via vascular and neurophysiological adaptations. These cognitive effects may also be reinforced by indirect or secondary benefits of RE, including improvements in mental well-being and opportunities for social enrichment (Hämmig, 2019).

RE also induces changes to blood pressure and dynamic cerebral autoregulation (dCA) that is the process by which cerebral blood flow is regulated in reaction to fluctuations in blood pressure (Smail et al., 2023). However, the cognitive effects of these changes remain debated and further research is needed to determine whether dCA fluctuations pose a risk for overperfusion-related complications or represent an opportunity for cerebrovascular adaptation (Carr and Ainslie, 2020; Perry and Lucas, 2021). Thomas et al. (2021) suggests that RE-induced increases in blood pressure result in adaptations to the cerebral vasculature which maintain typical perfusion, while intracranial pulsatility

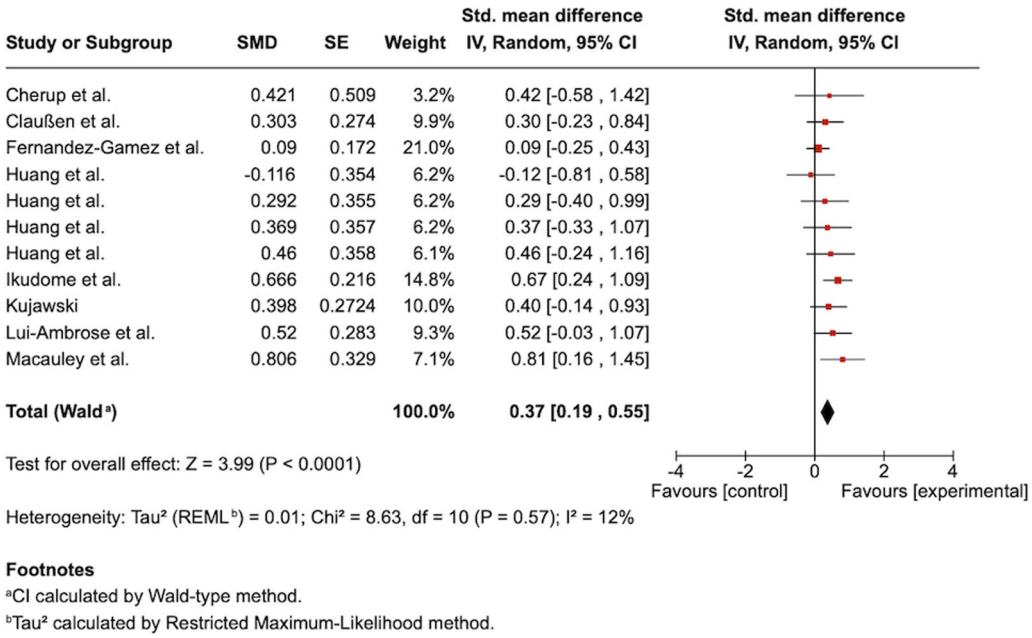



**Fig. 5.** The forest plot presents standardised mean differences for the effect of resistance exercise on working memory compared with control conditions. Squares represent individual study effect estimates, with square size proportional to the weight assigned to each estimate. Horizontal lines represent 95% confidence intervals, and the diamond represents the pooled effect estimate and its 95% confidence interval. Positive effect estimates favour resistance exercise, whereas negative estimates favour the control condition.

index decreases and cerebrovascular resistance index increases. This demonstrates the ability of the brain to autoregulate following exercise-induced haemodynamic fluctuations, a mechanism which may be crucial for preserving neural efficiency in later life. As a result, future research may seek to determine whether RE-induced changes in blood pressure and dCA represent a physiological challenge that risks over-perfusion or a stimulus that promotes beneficial cerebrovascular adaptation. However, this will likely require mechanistic, longitudinal, and multimodal studies that link haemodynamic responses to structural vascular changes and cognitive outcomes directly.

Inversely, in a meta-analysis of 270 randomised controlled trials (RCTs) assessing the effect of different exercise modes on resting blood pressure identified isometric RE as having the most potent antihypertensive effects, producing the greatest reductions in both systolic and diastolic blood pressure (Edwards et al., 2023). Considering the adverse effects that high blood pressure poses to cognitive performance in mid and later life, further research examining the effect of different resistance exercise protocols on cognitive performance is essential (Forte and Casagrande, 2020). It is also theorised that cognitive effects resulting from changes to neurobiological mechanisms are bolstered by cognitive demands required to complete RE (e.g. focus during lifting free-weights). This results in a form of attentional priming which may also improve vigilance capacity (Smit et al., 2005; Sanabria et al., 2019). This is supported by Tsuk et al. (2019), who found that an acute session of RE improved both attention and executive function, whereas an aerobic exercise session improved executive function only. The present review similarly identified benefits across executive function and processing speed, suggesting that the cognitive demands of RE may contribute to attentional control and more efficient information processing. This further emphasises the need to determine how characteristics of RE, including session duration and cognitive demands, influence the optimisation of domain-specific cognitive benefits.

Moving forward, further assessing the influence of RE on distinct neural mechanisms will also offer more depth regarding how exercise interacts with brain dynamics and neuroplasticity. Benefits were evident across executive function, working memory, processing speed, and global cognition, whereas episodic memory showed no clear improvement and considerable variation between studies. This pattern indicates that RE may influence several interacting cognitive systems rather than a single performance component. RE-related changes in white matter integrity and neurotransmitter release may support more efficient information processing (Gong et al., 2024), while improved cerebral perfusion may facilitate neuronal activation and executive control (Yan, Wang, 2025). Nevertheless, the inconsistent findings for memory outcomes suggest that neurophysiological adaptations may not translate uniformly across cognitive domains, underscoring the need for mechanistic studies that combine theoretically informed cognitive classifications with direct measures of brain function.

Further important areas for future consideration are that of RE type, intensity, duration, and frequency. Despite awareness of the importance of this, the present number of studies was too small to yield meaningful meta-analytic data of this capacity. Existing data suggests that both acute RE and multi-session protocols over the course of months provide evidence for improving cognitive abilities (Chang et al., 2012). However, future research should directly compare and assess whether certain protocols are more beneficial in acute settings, while others may provide more beneficial effects in a multi-session context. For example, high MVC (maximum voluntary contraction) protocols may pose a greater risk of musculoskeletal injury over longer durations (Govindasamy et al., 2025), which may have a harmful effect on cognition in older adult populations by way of reduced mobility, social engagement, and dependence on others (Fragala et al., 2019). Future investigations involving longitudinal RE interventions should also consider progressive overload (Broadhouse et al., 2020). If exercise protocols remain stable in their physiological demands, then the individual is likely to experience a reduction in difficulty as they become accustomed to the task. This may result in a form of exercise-based ceiling effect, wherein the intervention demands are not taxing enough to influence cognitive markers. This is supported by Olson et al. (2023) who found low-intensity exercise to have minimal impact on cognition directly when compared to non-exercise controls. Future research could further this by comparing the cognitive outcomes of an exercise intervention focused on progressive overload with a static protocol in which exercise difficulty is stable. Findings would allow for insights into the optimal long-term approach

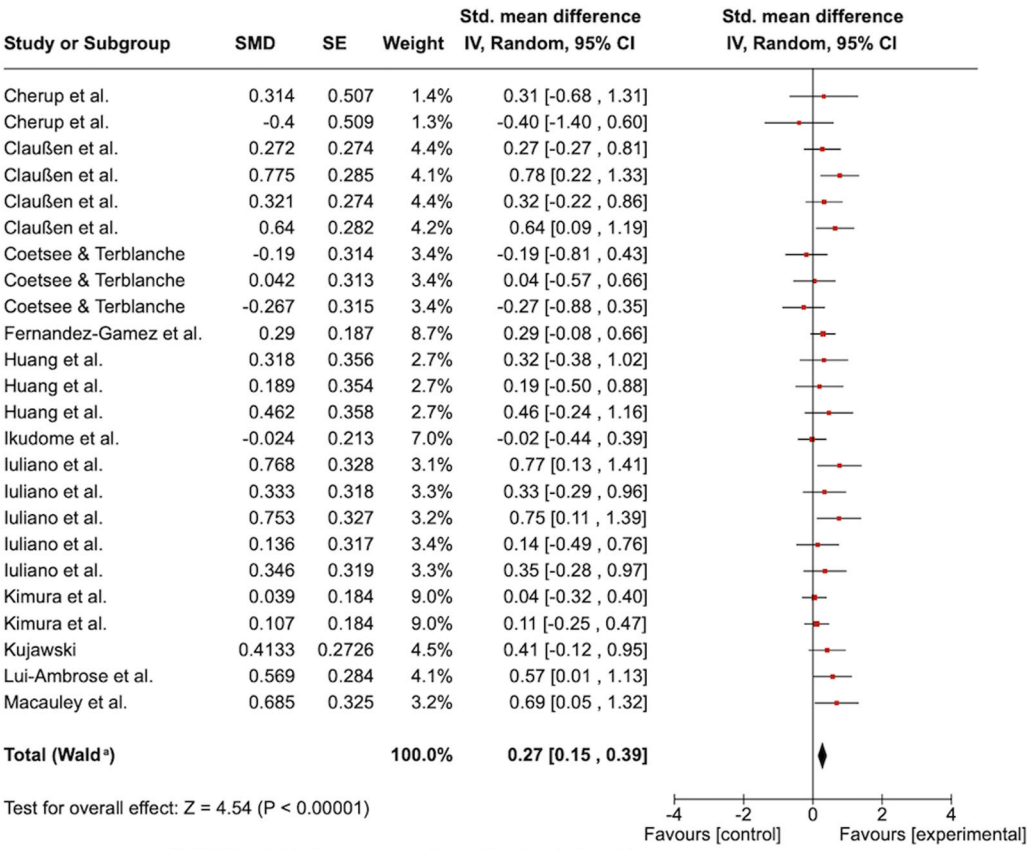



**Fig. 6.** The forest plot presents standardised mean differences for the effect of resistance exercise on processing speed compared with control conditions. Squares represent individual study effect estimates, with square size proportional to the weight assigned to each estimate. Horizontal lines represent 95% confidence intervals, and the diamond represents the pooled effect estimate and its 95% confidence interval. Positive effect estimates favour resistance exercise, whereas negative estimates favour the control condition.

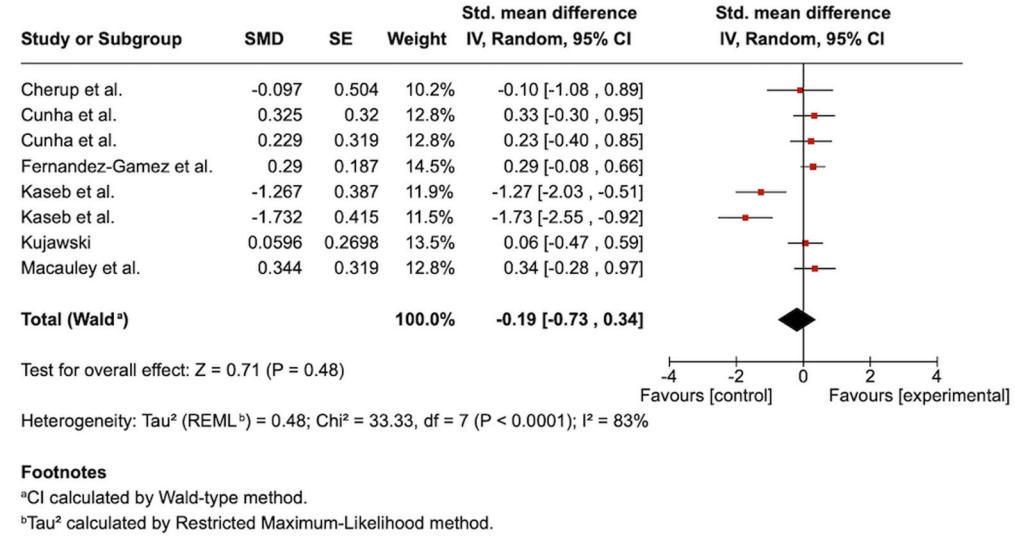



**Fig. 7.** The forest plot presents standardised mean differences for the effect of resistance exercise on episodic memory compared with control conditions. Squares represent individual study effect estimates, with square size proportional to the weight assigned to each estimate. Horizontal lines represent 95% confidence intervals, and the diamond represents the pooled effect estimate and its 95% confidence interval. Positive effect estimates favour resistance exercise, whereas negative estimates favour the control condition.

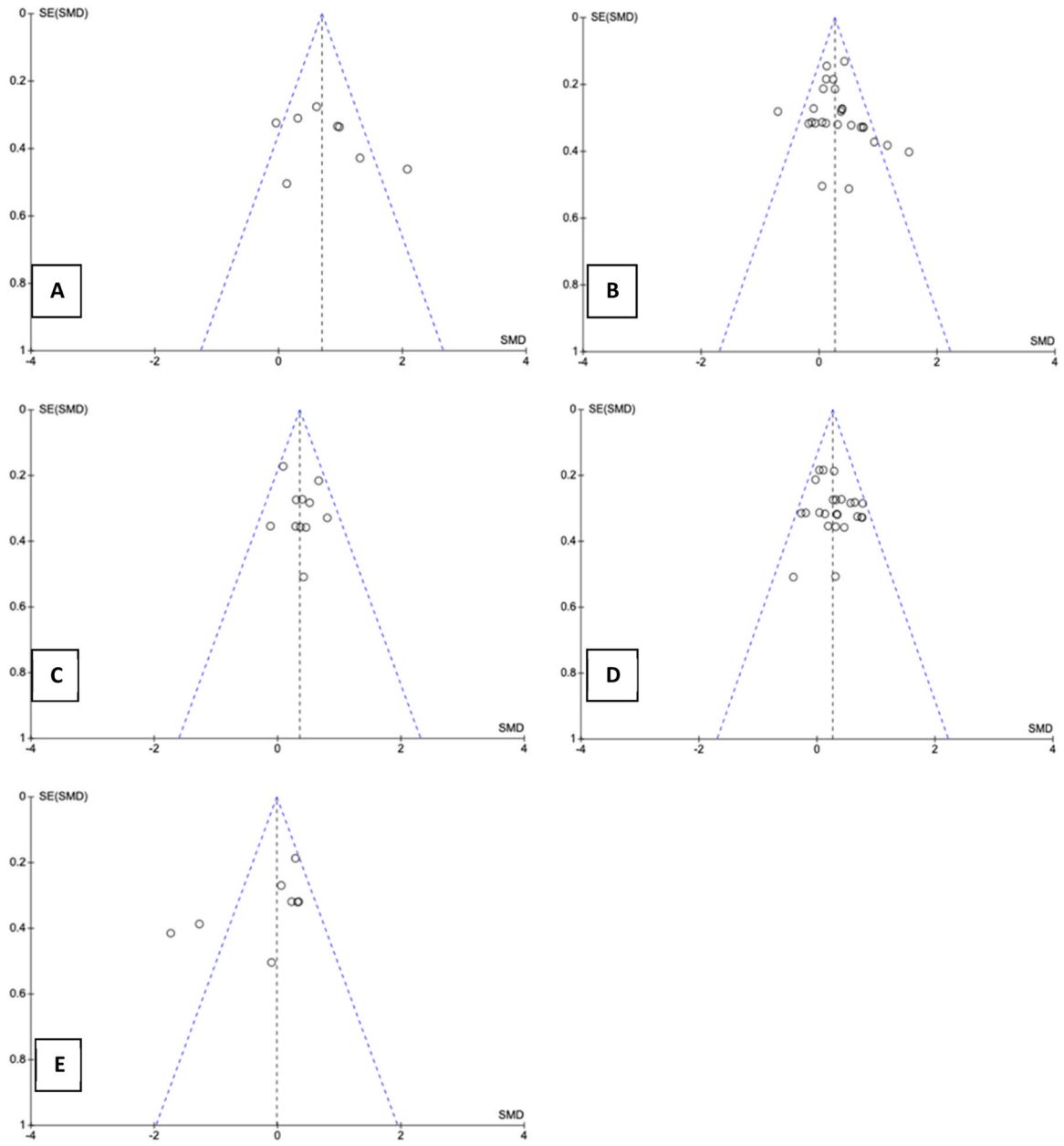



**Fig. 8.** Funnel plots assessing study effect sizes against standard error for global cognition (Plot A), executive function (Plot B), working memory (Plot C), processing speed (Plot D), and episodic memory retrieval (Plot E). Each point represents data from an included study. The central dashed line indicates the pooled effect estimate, while the blue dashed lines represent the expected 95% confidence limits under the assumption of no publication bias.

to RE when enhancing or preserving cognition is a central goal. Future investigations may also seek to understand the mechanisms underlying cognitive improvement more directly. Monitoring changes in cerebral blood flow and vascular adaptations would help clarify the physiological processes mediating cognitive gains. Neuroimaging techniques such as near-infrared spectroscopy (fNIRS) may be applied during exercise and cognitive testing to assess the cerebrovascular impact of exercise (Shen et al., 2024). Since aerobic and resistance training is known to induce angiogenesis and improve neurovascular coupling, including neurophysiological measures could reveal whether vascular remodelling is contributing to observed improvements in cognition.

### 4.1. Limitations

Despite these largely promising findings, results should be interpreted with caution because the consistency of effects differed across cognitive domains, with especially marked between-study variability in episodic memory and global cognition. Despite this, most studies included in the present review employed multiple measures within a given cognitive domain. The inclusion of several tests for the same domain may help mitigate publication bias by reducing the likelihood of statistical malpractices such as p-hacking and selective reporting. This approach promotes transparency and enables a more comprehensive and reliable meta-analysis. Variability in the cognitive measures used across studies may have contributed to the observed heterogeneity. Some of the measures of cognition included in this review were compiled from screening tools to identify for cognitive impairment, such as the MoCA and NIH Toolbox Cognition Battery (Kringle et al., 2023; Nasreddine et al., 2005). These measures provide a composite score representing multiple domains giving an overview of cognitive abilities. Because composite score aggregates performance across multiple tests, they tend to provide a stable estimate of overall executive functioning.

However, in doing so, variance in scores for different subtests within the battery are removed and thus can also hide within-subject differences across domains (Jonaitis et al., 2019).

The use of composite scores can make comparisons between clinical screening tools and laboratory-based, single measures of a cognitive domain (e.g. Trial making test) challenging. It is possible that the variance in measurement sensitivity between composite tests and single measures may have contributed to higher heterogeneity. Furthermore, some cognitive domains were only featured in a small portion of the included studies, significantly hindering statistical power in these circumstances and as such this data should be interpreted with caution. Participant attrition was evident across most studies. Understanding barriers to RE is important to ensure accessibility and equity in future interventions to target individuals particularly at risk of neurodegenerative diseases. Stated reasons for attrition are summarised in supplementary materials 2. An additional consideration concerns the nature and suitability of control conditions employed across studies. Control groups varied considerably, ranging from passive sitting to low-intensity stretching or balance activities, which may differ in their physiological and cognitive engagement. Active controls that elicit mild arousal or attentional demands may attenuate observed intervention effects, whereas passive controls may inflate effect sizes. Future research would benefit from greater standardisation and clearer justification of control conditions to improve interpretability and comparability across studies.

### 4.2. Conclusions

This review and meta-analysis demonstrated that resistance training exerts measurable effects on cognition in neurologically healthy adults. Benefits were observed for global cognition and several cognitive domains organised using a CHC-informed framework, including executive function, working memory, and processing speed, whereas episodic memory outcomes showed no clear overall improvement. The pattern of findings suggests that RE may support both broad cognitive performance and specific higher-order processes involved in executive control, the temporary maintenance and manipulation of information, and efficient information processing. These findings highlight the potential value of incorporating RE into lifestyle-based approaches to preserve and improve cognitive functioning across adulthood, including through relatively short intervention periods. Between-study heterogeneity and a modest number of included studies highlight the importance of continued investigation using larger sample sizes before established recommendations can be made at a societal level. Future large-scale studies should further investigate the neurophysiological mechanisms underpinning exercise-induced cognitive change and determine how specific exercise protocols and durations may be optimised to maximise these effects.

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## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.arr.2026.103277.

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