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Strengthening memory: The impact of resistance training on cognitive health in aging and cognitive impairment

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ABSTRACT

This review examines resistance training (RT) as a pathway for preserving declarative memory in later life, addressing a critical gap in the literature where RT has been largely subsumed under general physical activity despite its distinct neurobiological profile. We aimed to clarify whether RT uniquely supports declarative memory vulnerable to healthy aging, mild cognitive impairment, and early neurodegenerative pathology. We conducted a multilevel synthesis of evidence from randomized controlled trials, neuroimaging studies, electrophysiology, and molecular research examining RT effects on memory, brain structure, network connectivity, and underlying biological mechanisms. Particular attention was given to hippocampal subfields, default-mode and fronto-hippocampal networks, and exercise-responsive neurotrophic, vascular, metabolic, and inflammatory pathways. Across modalities, converging evidence indicates that RT attenuates hippocampal and precuneus atrophy, preserves white-matter integrity, strengthens functional connectivity within memory networks, and enhances neural efficiency indexed by oscillatory and event-related electrophysiological markers. Biologically, RT reliably increases insulin-like growth factor-1 and improves insulin sensitivity, endothelial function, and inflammatory balance, creating a plastic milieu that supports hippocampal resilience. Cognitive benefits are most consistent in mild cognitive impairment, with parallel improvements in mood, functional independence, and quality of life. These findings position RT as a scalable, cost-effective intervention that compares favorably with other intervention modalities. Progressive RT should be considered a core component of prevention and care strategies for cognitive aging, with implications for clinical practice, community programs, and public health policy.

Contribution/Originality: This review contributes to the existing literature by providing a multilevel synthesis of resistance training effects on declarative memory in aging. It documents converging neurobiological, neuroimaging, and electrophysiological evidence. The paper's primary contribution is demonstrating that resistance training uniquely supports hippocampal integrity and cognitive reserve beyond general physical activity.

1. INTRODUCTION

As we age, changes in memory are among the earliest cognitive shifts to emerge, often with a substantial impact on independence, identity, and overall quality of life (Barnes & Yaffe, 2011). In cases of neuropathology, such as Alzheimer's disease, memory decline is distressing and progressively debilitating (Mian et al., 2024).

Dementia is currently one of the greatest global challenges of the 21st century. More than 55 million people worldwide currently live with dementia, and this number is expected to rise to 139-153 million by 2050 (GBD 2019 Dementia Forecasting Collaborators, 2022; World Health Organization, 2023). Mild Cognitive Impairment (MCI),

affecting 12-18% of adults over 60, further emphasizes the urgency, as up to 15% progress to dementia annually (Better, 2023). Notably, the World Health Organization (2023) estimates that the economic burden of dementia exceeds one trillion USD annually, a figure predicted to double by 2030 as prevalence continues to rise in aging societies.

Dementia pharmacological treatments, which are heavily investigated, can produce short-term improvements but are limited in durability (e.g., cholinesterase inhibitors) (Birks, 2006; Livingston et al., 2020). Moreover, the treatments require advanced infrastructure and raise safety and cost concerns (e.g., lecanemab and donanemab) (Mintun et al., 2021; Van Dyck et al., 2023). Against this backdrop, lifestyle-based interventions such as exercise, particularly resistance training (RT) (e.g., lifting weights, pushing weights), stand out as cost-effective, scalable, and sustainable strategies for dementia prevention and care (e.g., (Broadhouse et al., 2020; Liu-Ambrose, Nagamatsu, Voss, Khan, & Handy, 2012).

Despite robust evidence that exercise broadly benefits late-life cognition, the specific contribution of RT to declarative memory is less clearly defined and understood (Bull et al., 2020; Colcombe & Kramer, 2003; Smith et al., 2010). In this review, we argue that RT should be recognized as a credible route to indirect cognitive support. We proceed as follows: (1) We outline how normal and pathological aging impact memory (episodic vs. semantic) and introduce the notion of cognitive reserve (e.g., STAC-r). (2) We discuss neuroscientific findings in RT interventions, highlighting hippocampal and cortical preservation, white matter integrity, functional connectivity, and electrophysiological markers of neural efficiency. (3) We reveal the biological mechanisms underlying these effects (e.g., BDNF, IGF-1). (4) We compare RT directly to other intervention modalities (e.g., aerobic exercise). (5) We consider the well-being and social benefits of RT. (6) We translate evidence into practice and discuss delivery formats of RT interventions.

2. MEMORY AGING AND RESERVE

Declarative memory refers to the conscious recollection of facts and events and is classically divided into episodic (personally experienced events situated in time and place) and semantic (general world knowledge) (Tulving, 1972).

These subsystems naturally age differently; episodic decline is more pronounced in typical aging, especially processes that depend on recollection (e.g., remembering that you met a neighbor at the bakery last Tuesday), implicating dentate gyrus/CA3 circuitry degeneration (Nyberg, Lövdén, Riklund, Lindenberger, & Bäckman, 2012; Ranganath & Ritchey, 2012; Yonelinas, 2002). Semantic memory, in turn, tends to remain comparatively stable until later life (e.g., knowledge such as the meaning of words or the capital of countries) (Nyberg et al., 2012; Salthouse, 2019; Yonelinas, 2002). Nevertheless, in pathological aging, both episodic memory (e.g., in AD and MCI) and semantic memory (e.g., in Semantic Dementia) can be compromised (Hodges & Patterson, 2007; Salmon & Bondi, 2009).

The distinction of hippocampal pattern separation (DG/CA3) motivates the intervention target. We will show in sections 2 and 3 that RT is plausibly positioned to support hippocampal function, with the potential to benefit recollection-heavy tasks that show the steepest age-related decline. This benefit relies on neural efficiency and flexible network recruitment, which define cognitive reserve and other frameworks, formalizing how lifelong enrichments could improve and sometimes reverse cognitive decline.

Cognitive reserve reframes cognitive aging as differences in adaptive efficiency rather than a uniform decline. People who have accumulated educational, occupational, and socially enriched experiences often tolerate greater neural change before symptoms appear (Barulli & Stern, 2013; Stern, 2012). The revised Scaffolding Theory of Aging and Cognition (STAC-r) model posits that positive life-course inputs, such as physical activity, strengthen scaffolding, the brain's capacity to use auxiliary networks or scaffolds to stabilize performance (Park & Reuter-Lorenz, 2009). RT functions as structured enrichment: its coordinated neuromotor practice, such as motor planning, progressive challenge like overload and periodization, and sustained effort including goal monitoring, repeatedly engages

executive control while supporting biology that enhances hippocampal plasticity and stabilizes fronto-hippocampal and default-mode control networks underpinning recollection-heavy episodic tasks (Liu-Ambrose et al., 2012).

3. NEUROSCIENTIFIC EVIDENCE FOR THE POSITIVE EFFECTS OF RESISTANCE TRAINING (RT) ON MEMORY

The link between RT and memory networks is still consolidating but increasingly convergent across modalities. In this section, we will discuss studies that used different neuroimaging and electrophysiology techniques, capturing distinct aspects of neuroplasticity and different slices of neural benefits. Many cited studies remain modest in sample sizes, protocols vary, and control conditions are heterogeneous; nonetheless, repeated observations of hippocampal and frontoparietal preservation due to RT interventions support a coherent effect.

3.1. Structure

The hippocampus and the precuneus are key nodes of declarative memory networks and are early targets of age- and dementia-related degeneration (Buckner et al., 2005; Fjell & Walhovd, 2010; Jack et al., 2010). Recent neuroimaging evidence suggests that resistance training (RT) may have a protective effect on these structures. In a 24-week nonrandomized controlled study involving older adults (≥55 years) with mild cognitive impairment, participants underwent neuropsychological assessments and magnetic resonance imaging at baseline and week 24. Those who self-selected into a supervised RT program (n=22) showed less volume loss in the left hippocampus and precuneus, while controls (n=22), who did not engage in RT but maintained habitual physical activity, exhibited significant atrophy (see Figure 1 and 2). Notably, these structural differences were accompanied by modest gains in episodic memory within the training cohort (Ribeiro et al., 2025).

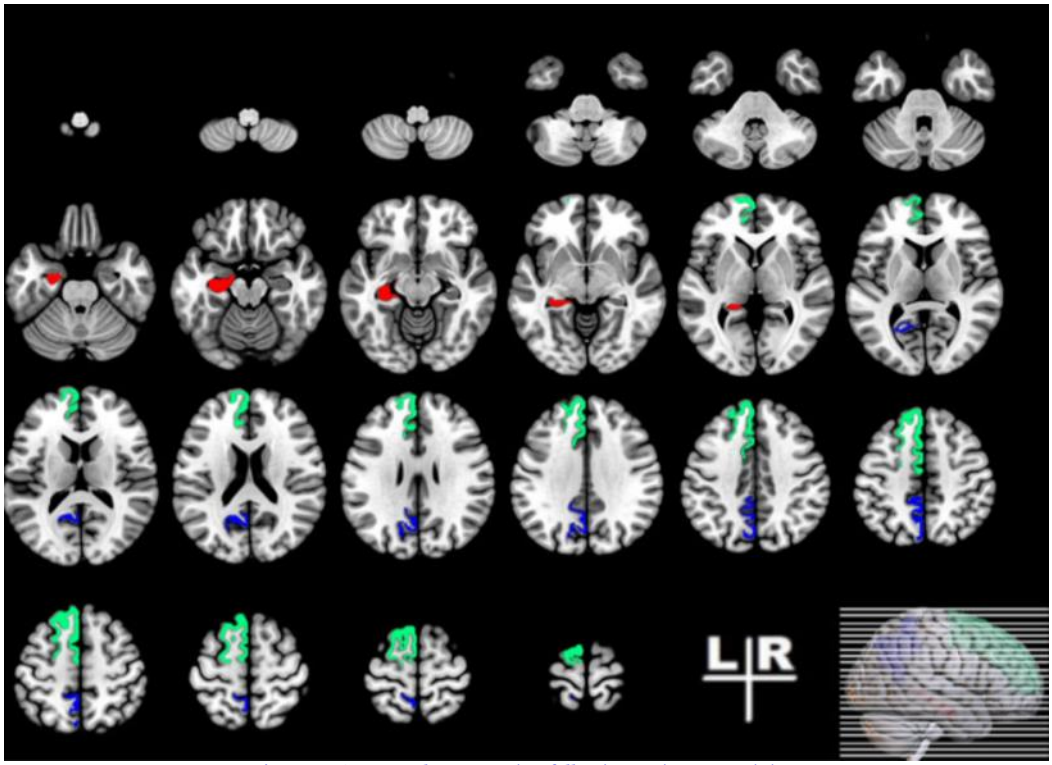

Figure 1. Structural preservation following resistance training.

Note: Structural changes observed in the Resistance Training (RT) group from Ribeiro et al. (2025). Blue: Left precuneus; Green: Superior frontal gyrus; Red: Left hippocampus. These regions illustrate areas where the RT group showed attenuated atrophy or relative preservation over 24 weeks compared to baseline. Image created with Chris Roerden's MRIcroGL Software (https://www.nitrc.org/projects/mricrogl/), reprinted from Ribeiro et al. (2025).

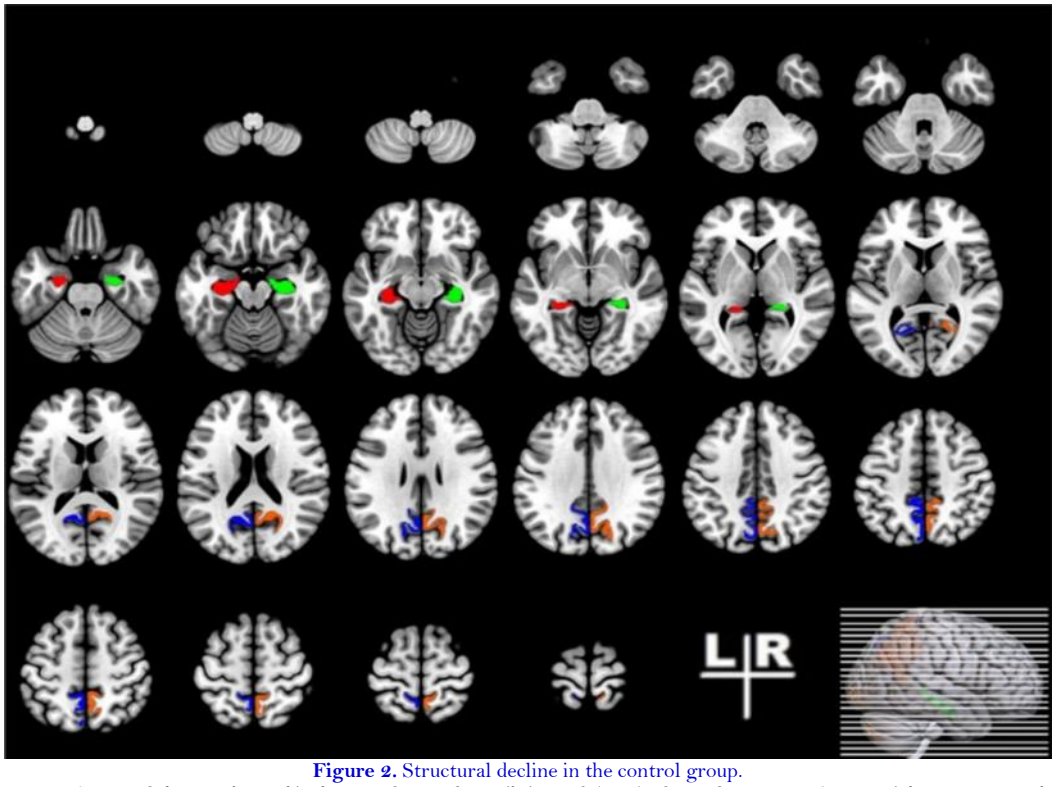

Figure 2. Structural decline in the control group.

Note: Structural changes observed in the control group from Ribeiro et al. (2025). Blue: Left precuneus; Orange: Right precuneus; Red: Left hippocampus; Green: Right hippocampus. These regions illustrate accelerated atrophy or volume decline in the absence of RT. Image created with Chris Roerden's MRIcroGL software (https://www.nitrc.org/projects/mricrogl/), reprinted from Ribeiro et al. (2025).

Although the nonrandomized design precludes definitive causal inference and does not eliminate the possibility of selection bias or residual confounding (e.g., motivation, baseline health), the pattern of findings aligns with randomized evidence showing hippocampal subfield protection and functional efficiency after progressive RT in MCI. This reinforces the biological plausibility that such training supports declarative memory networks (Broadhouse et al., 2020; Liu-Ambrose et al., 2012). In a 12-month randomized controlled trial, Liu-Ambrose et al. (2012) assigned community-dwelling older women to once-weekly RT, twice-weekly RT, or an active balance-and-tone control condition. Behavioral outcomes were assessed using a flanker response-inhibition task (also called the Eriksen Flanker Task, which is a standard test in cognitive psychology and neuroscience), complemented by functional neuroimaging. Only the twice-weekly RT group demonstrated cortical-hemodynamic changes in regions associated with response inhibition, including the anterior left middle temporal gyrus and the left anterior insula extending into the lateral orbitofrontal cortex, alongside improved flanker performance. The effects were dose-dependent, as the once-weekly condition did not yield comparable neural or behavioral change, and were interpreted as evidence of functional plasticity complementing the selective-attention benefits generally associated with aerobic training in older adults. When considered together with structural findings from Ribeiro et al. (2025) these findings support a dual account in which RT both protects memory-critical structures and enhances cortical efficiency in executive-control networks that interact with the hippocampus.

Further evidence derives from the Study of Mental Activity and Resistance Training (SMART) randomized trial, which enrolled 100 older adults with MCI (Broadhouse et al., 2020). Participants were allocated to progressive RT combined with computerized cognitive training (PRT + CCT), progressive RT with sham CCT, computerized cognitive training with sham PRT, or a double-sham condition for six months, with neuroimaging and cognitive assessments performed at baseline, post-intervention, and 18-month follow-up. The notion of sham in this case refers to a condition that mimics the structure and appearance of an intervention without containing its active or effective component. High-intensity progressive RT (~80% peak capacity) produced enduring cognitive benefits at 18 months

relative to double-sham, driven specifically by the PRT + sham arm (control group). Crucially, RT protected Alzheimer's disease-vulnerable hippocampal subfields, with elimination of atrophy in the subiculum and attenuation of atrophy in CA1 and dentate gyrus, despite cessation of training one year earlier. Thickening of the posterior cingulate cortex was observed during the training phase but was not sustained at follow-up. Resting-state fMRI revealed strengthened functional connectivity between the left hippocampus and posterior cingulate in the RT groups. Mediation analyses demonstrated that subicular preservation accounted for a significant proportion of the long-term cognitive benefit, whereas changes in post-training physical activity, cardiorespiratory fitness, or global strength did not account for hippocampal trajectories, suggesting a direct and durable neuroprotective effect of the intervention. Within their meta-analysis of exercise-induced neuroplasticity, Niemann, Godde, and Voelcker-Rehage (2020) reported that resistance training (RT) specifically enhanced functional and structural markers of neuroplasticity in several brain regions associated with memory and executive function. The included RT interventions, typically lasting 8–24 weeks, showed increased gray matter volume and functional connectivity within the hippocampus, prefrontal cortex, and parietal regions, paralleling gains in episodic and spatial memory performance. Neuroimaging results suggested that RT promoted hippocampal neurogenesis and synaptic remodeling. These molecular and structural adaptations were comparable in magnitude to those observed with aerobic training, but RT showed more consistent associations with executive and working memory improvements. The authors concluded that RT is a robust neuroplastic stimulus capable of improving both cognitive function and hippocampal integrity in healthy and clinical populations.

3.2. White Matter Integrity

Beyond gray matter, evidence suggests RT may help preserve the brain's white matter pathways, which are essential for efficient information transfer between regions involved in memory and executive functions.

In the study conducted by Ribeiro et al. (2025), participants with mild cognitive impairment who engaged in a structured RT program showed increases in fractional anisotropy (a DTI-based index of white matter integrity and organization) along with reductions in diffusivity across major tracts. Their control counterparts displayed the expected decline over the same period (see Figure 3). This pattern strongly suggests that RT can slow or partially reverse microstructural deterioration. The importance of this preservation should not be underestimated, as white matter health underpins rapid interregional communication. This connective efficiency may explain the improvements in processing speed observed in the training group.

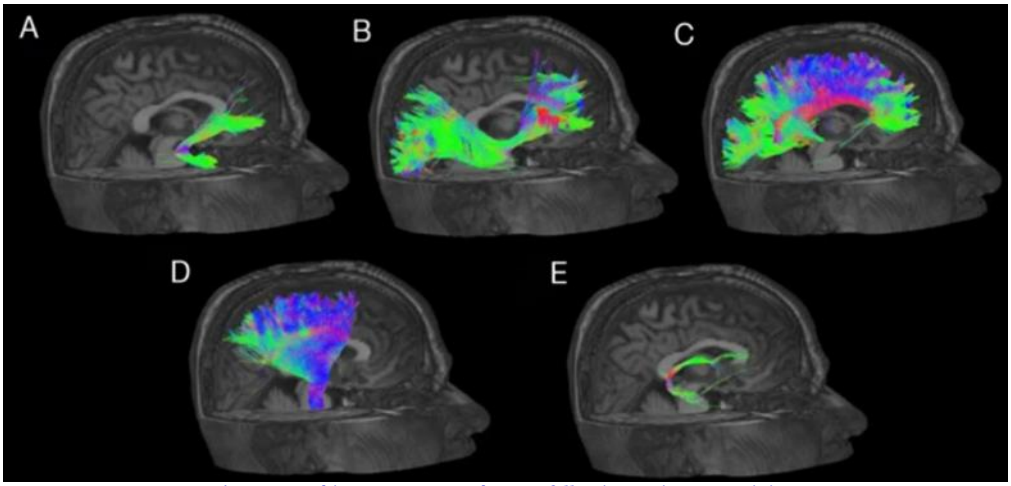

Figure 3. White-matter tract changes following resistance training.

Note: Illustration of the tracts and fascicles in which significant changes were observed after the training protocol. A Uncinate fasciculus; B inferior fronto-occipital fascicle; C corpus callosum; D corticospinal tract; E fornix. Colored following the fiber's directional tractography pattern in MRIVIEW Software, reprinted from Ribeiro et al. (2025).

Additional support comes from the work of Oh et al. (2023), who reanalyzed data from a fifty-two-week randomized controlled trial conducted in community-dwelling older women with cerebral small-vessel disease, which is strongly linked to cognitive decline, particularly in memory. In this study, participants trained twice weekly for sixty minutes following a progressive resistance protocol, and their outcomes were compared to those of an active balance-and-tone control group. White matter integrity was assessed using the T1-weighted/T2-weighted ratio, a proxy for myelin content. At the twelve-month mark, the resistance training (RT) group showed significant increases in the external capsule and in the posterior thalamic radiations, regions known to be particularly vulnerable in aging and vascular pathology. Moreover, gains in external capsule integrity correlated with improvements in peak muscle power, indicating a meaningful connection between peripheral and central adaptations. Interestingly, despite these clear structural benefits, the groups did not differ in executive outcomes on the Stroop task. However, since white matter injury is one of the most reliable predictors of cognitive decline and dementia, the preservation of tracts through RT can be viewed as a mechanistic pathway through which memory networks are indirectly supported, even without immediate cognitive improvements (Prins & Scheltens, 2015; Seiler et al., 2018).

The relevance of these findings becomes clearer when considered alongside the cross-sectional work of Seiler et al. (2018). In a large cohort of six hundred and eighty participants, tract-specific microstructural properties, derived from diffusion tensor imaging and probabilistic tractography, were examined in relation to gray matter volumes and cognition. The authors reported that five tracts, including the posterior thalamic radiations, the forceps minor and major, and the inferior fronto-occipital and longitudinal fasciculi, were particularly prone to lesion burden. Lower anisotropy within these tracts was closely associated with higher white matter hyperintensity load. Additionally, tract integrity covaried with lobar gray matter volumes, indicating a coordinated process of degeneration across tissues. When related to cognitive measures, memory performance was more strongly associated with temporal and parietal gray matter, though anisotropies in connecting tracts such as the cingulum and uncinate contributed significantly. In contrast, processing speed depended on a combination of tract integrity and lobar gray matter across several regions. The authors concluded that episodic memory is not sustained by gray matter alone but also relies on the integrity of its connective tracts, which act as the structural infrastructure of mnemonic networks.

From this perspective, the findings from RT studies that demonstrate the preservation of white matter, even in the absence of short-term behavioral effects, become especially meaningful. By maintaining the structural highways along which hippocampal and cortical regions communicate, RT may be creating the necessary conditions for declarative memory to resist decline. Tract-specific associations with gray matter volumes and cognition further emphasize that structural connectivity imposes constraints on the functional dynamics of networks, and prior work has already shown that damage to critical tracts can disrupt functional coupling among their cortical partners, whereas preserved pathways allow for greater synchrony in network activity (Hong, Kim, & Jun, 2018; Liu et al., 2023). The converging structural findings, whether concerning hippocampal subfields, the precuneus, or white matter integrity, suggest that RT provides a protective substrate for memory. Yet, structural measures alone cannot tell us how effectively these preserved regions and tracts work together in real time, since network coordination may change even when volume remains stable, and proxies such as fractional anisotropy or the T1w/T2w ratio come with interpretational limits. It is therefore essential to turn next to functional connectivity, to examine whether resistance training modifies the coordination of networks relevant for memory, particularly the interactions between the hippocampus and posterior cingulate within the default mode network and the coupling between the hippocampus and frontal control systems, in ways that resonate with reserve and scaffolding models while remaining consistent with the structural constraints identified above.

3.3. Functional Connectivity

One hundred participants diagnosed with MCI were randomly assigned to one of four conditions: a group receiving computerized cognitive training alone, a group receiving the combined intervention, and a control group

receiving what is termed a double sham. Sham RT consisted of light, non-progressive exercise movements that reproduced the social and motivational aspects of the training sessions but did not provide the intensity required to induce neuromuscular or neural adaptation; similarly, sham computerized cognitive training presented computer-based activities that lacked the level of cognitive demand necessary to engage memory and executive processes. The double sham condition, therefore, served as a placebo-like control, ensuring that any observed effects could be attributed specifically to the active components of the interventions rather than to non-specific factors such as social interaction or participant expectations. Over the course of twenty-six weeks, followed by post-training and twelve-month follow-up assessments, only the group that received progressive RT showed sustained cognitive improvements. RT enhanced functional connectivity between the hippocampus and the posterior cingulate cortex, a central hub of the default mode network, indicating that the intervention promoted more efficient and coordinated communication within systems that sustain declarative memory. Also, in parallel with other findings in the structure section, these benefits were accompanied by significant protection of hippocampal subfields, including the subiculum, CA1, and the dentate gyrus. Quantitatively, participants in the RT arm displayed two to three percent less atrophy in these regions over eighteen months compared to their sham-trained counterparts. Mediation analyses further revealed that preservation of the subiculum accounted for a substantial portion of the long-term cognitive gains. Crucially, these effects were independent of changes in cardiorespiratory fitness, overall physical activity, or whole-body strength, suggesting that high-intensity progressive resistance training confers direct neuroprotective benefits on memory-relevant structures rather than producing its effects through general health improvements.

Evidence from other imaging modalities converges on this interpretation. In the study conducted by Nagamatsu, Handy, Hsu, Voss, and Liu-Ambrose (2012), six months of progressive RT were associated with altered hemodynamic responses during an associative memory paradigm. In particular, increased activity was reported in the right lingual gyrus, the occipital-fusiform gyrus, and the right frontal pole. Importantly, changes in the lingual gyrus were positively correlated with gains in memory performance, indicating a functional link between cortical plasticity and behavioral improvements.

Resting-state analyses in individuals with mild cognitive impairment support previous findings. Suo et al. (2016) observed that six months of resistance training caused both decreases and increases in functional connectivity. Reductions were noted between the posterior cingulate and the inferior temporal lobe, as well as between the bilateral hippocampi and the right inferior temporal lobe. Increases were observed between the hippocampi and the right middle frontal lobe. Although these reorganization patterns were not directly correlated with neuropsychological test performance, they were associated with overall cognitive improvements, indicating that the intervention promoted compensatory network-level adaptations. Structural results from the same trial showed increased gray matter in the posterior cingulate and reductions in white-matter hyperintensities, reinforcing the idea that resistance training induces neuroprotective changes in regions heavily involved in Alzheimer's disease.

Concluding, the imaging evidence indicates that progressive RT is capable of both preserving Alzheimer-vulnerable brain structures and tightening the coupling between memory hubs such as the hippocampus and posterior cingulate. These neural changes translate into durable cognitive benefits in mild cognitive impairment. Nevertheless, what such imaging measures cannot capture is whether RT also improves the rapid, moment-to-moment efficiency of neural operations that underlie encoding and retrieval.

This leads naturally to the next line of inquiry: whether resistance training can influence fast electrical signatures of neural efficiency, specifically oscillatory activity in the alpha and theta frequency ranges and event-related potentials that index stimulus evaluation and cognitive control.

3.4. Neurophysiological Indicators of Neuroefficiency

In a 12-week randomized trial of older adults with MCI, twice-weekly elastic-band RT at approximately 15RM (~65% 1-RM) shifted resting EEG toward a more efficient profile: theta power decreased at the left frontal site (F3;

$p < .05$), and alpha power increased at the left temporal site (T3; $p < .05$). Healthy exercisers showed theta decreases at parietal sites (P3/P4; $p < .05/.01$). The MCI-RT group also improved on Digit Span Backward ($p < .05$), while broader episodic measures remained unchanged over twelve weeks (Hong et al., 2018).

Because MCI typically features excess slow-wave (delta/theta) activity and reduced alpha activity, these shifts are consistent with partial normalization of cortical rhythms that can lower control costs during encoding and retrieval, even before large behavioral gains emerge (Meghdadi et al., 2021). Alpha efficiency, also (posterior/temporal), is associated with better mnemonic processing and reduced neural noise. In MCI, small RT-related alpha/theta normalizations suggest improved conditions for episodic encoding and retrieval, even if short tests show modest change (Hong et al., 2018).

Complementing spectral power, event-related potentials capture the speed and allocation of attention as information is processed. A systematic review of 14 studies in older adults found that physical exercise, especially aerobic or RT, is associated with larger P3 amplitudes and shorter P3 latencies, classic signatures of faster stimulus evaluation and more efficient attentional allocation (Pedroso et al., 2017).

In an amnestic MCI trial directly comparing resistance versus aerobic exercise over 16 weeks, both modalities increased P3 amplitude during task switching (latency unchanged), alongside divergent patterns in neurotrophins and inflammatory cytokines, suggesting distinct, modality-specific routes to a shared efficiency signal (Tsai, Pai, Ukropec, & Ukropcová, 2019).

In sum, alpha/theta normalization at rest and P3 enhancement during active processing outline a plausible control-to-memory bridge: by making attentional updating less costly, RT can improve the conditions under which episodic encoding and retrieval take place.

Finally, acute studies show that these efficiency effects can appear within a single session. In a crossover randomized trial, one bout of multi-joint barbell resistance training (back squat, press, deadlift; approximately 75% 1-RM, 3×5) shortened Stroop reaction time and reduced frontocentral N2b (an anterior cingulate conflict marker) compared with stretching, without compromising accuracy, consistent with lower control demand for equivalent performance (Lin, Hsieh, Chueh, Huang, & Hung, 2021).

While N2b indexes control rather than memory per se, more efficient conflict monitoring is relevant for effortful remembering (e.g., source monitoring), dovetailing with a reserve/CRUNCH interpretation in which RT reduces the energetic cost of cognitive operations. RT is linked to more efficient electrical dynamics (resting alpha/theta, P3, N2b). These signals complement structural or fMRI findings by showing that the preserved/retuned substrate can be coordinated more efficiently in real time.

In effect, the evidence indicates that RT fosters neuroprotection on multiple fronts, preserving the volume of gray matter regions critical for memory, improving the efficiency of functional networks, and maintaining the integrity of white matter tracts that support information transfer and neural dynamics (including task-related activity, resting-state connectivity, oscillatory power, and ERP components). These results further highlight the capacity of resistance exercise to drive neuroplastic adaptations in perceptual-mnemonic areas, fronto-hippocampal pathways, and electrophysiological indices of cognitive control in older adults and individuals with MCI (Hong et al., 2018; Nagamatsu et al., 2012; Suo et al., 2016; Tsai et al., 2019).

3.4.1. Summary. Neuroscientific Evidence for the Positive Effects of Resistance Training (RT) on Memory

- RT attenuates hippocampal and precuneus atrophy in aging and mild cognitive impairment.
- Protects Alzheimer's-vulnerable subfields (CA1, DG, subiculum) and maintains cortical thickness.
- Enhances white-matter integrity (↑ FA; ↓ diffusivity) in tracts linked to memory and control.
- Strengthens hippocampus–PCC and hippocampus–PFC functional connectivity.
- Improves neural efficiency: ↑ alpha, ↓ theta, ↑ P3 amplitude, ↓ N2b, supporting attentional and encoding processes.

4. BIOLOGICAL EVIDENCE FOR THE POSITIVE EFFECTS OF RESISTANCE TRAINING (RT) ON MEMORY

This section explores the routes through which RT could reach hippocampal and default-mode systems, focusing on exercise-responsive biological mechanisms that create a plastic environment conducive to memory.

4.1. Neurotrophic Factors

Evidence indicates that exercise can reliably increase peripheral BDNF concentrations. In Parkinson's disease, a systematic review of sixteen trials involving approximately three hundred seventy participants reported significant post-exercise increases in BDNF, with a moderate-to-large pooled effect size (Hedges' $g \approx 0.70$, 95% CI 0.03–1.38) (Paterno, Polsinelli, & Federico, 2024). Higher training intensity was associated with larger increases, whereas no systematic differences emerged between exercise modalities (aerobic, resistance, balance, multimodal). The substantial heterogeneity across studies ($I^2 \approx 76\%$) underscores that the robustness of BDNF as an exercise biomarker is shaped by both interindividual variability and methodological constraints. BDNF is highly assay-sensitive and platelet-dependent because variations in pre-analytic handling, such as clotting time or centrifugation speed, can materially alter measured outcomes and may themselves be influenced by exercise (Castillo-Navarrete, Guzmán-Castillo, Bustos, & Rojas, 2023; Gejl et al., 2014; Serra-Millàs, 2016).

Beyond the Parkinson's literature, meta-analyses in mixed adult samples show a reliable acute increase in BDNF after exercise, whereas resting training-level increases are smaller, more heterogeneous, and sometimes stronger after aerobic compared to resistance training (RT) programs (Dinoff et al., 2016; Szuhany, Bugatti, & Otto, 2015). This suggests that, although BDNF is consistently exercise-responsive, its behavior is not modality-specific.

By contrast, insulin-like growth factor-1 (IGF-1) responses to RT appear more stable and reproducible in late life. Meta-analyses of randomized trials consistently report significant serum IGF-1 increases, particularly in programs lasting twelve to sixteen weeks, with effects most pronounced in cohorts above sixty years of age and, in some analyses, in women (Amiri, Fathei, & Mosaferi Ziaaldini, 2021; Jiang et al., 2020). Mechanistically, IGF-1 is of particular interest because it crosses the blood–brain barrier via a saturable transport system, offering a plausible route for peripheral increases to influence central processes such as dendritic complexity, synaptogenesis, and angiogenesis (Pan & Kastin, 2000).

A strict evidentiary standard requires demonstrating that peripheral changes in IGF-1 or BDNF correlate with central brain levels and result in measurable memory outcomes. Preclinical resistance training studies help bridge this gap. In rodent models, ladder-climbing protocols mimicking progressive resistance exercise improve hippocampus-dependent memory and increase hippocampal IGF-1 and BDNF signaling, along with elevated synaptic protein expression, even when peripheral serum signals vary (Cassilhas et al., 2012). These findings suggest that local engagement of trophic factors in hippocampal circuits may be more critical for cognitive outcomes than systemic levels alone.

A cautious but consistent interpretation suggests that RT selectively and reliably elevates IGF-1 in late life and may activate local BDNF signaling within memory circuits. Resting peripheral BDNF responses tend to be smaller, more heterogeneous, and more sensitive to assay and handling choices. This pattern supports a model where RT contributes to neuroplasticity mainly through IGF-1-anchored pathways, while BDNF functions as an exercise-wide co-signal that depends on intensity and methodological factors, rather than being exclusively linked to resistance modalities.

4.2. Systemic and Cerebral Vascular Adaptations

Evidence from meta-analyses shows that resistance training (RT) increases brachial artery flow-mediated dilation, reflecting enhanced endothelial responsiveness and blood flow regulation (Silva, Menêses, Parmenter, Ritti-Dias, & Farah, 2021). However, methodological differences, such as flow-mediated dilation procedures and shear rate

normalization, contribute to heterogeneity. In older adults, the evidence is weaker: randomized trials show consistent vascular improvements with aerobic or combined exercise, whereas RT alone yields smaller and less reliable effects, likely due to limited study power (Da Silva Rodrigues et al., 2025).

At the microvascular level, progressive RT promotes skeletal muscle capillarization, improving oxygen and nutrient delivery (McIntosh, Anglin, Robinson, Beck, & Roberts, 2024). Macrovascular adaptations include increases in conduit artery diameter and limb blood flow that partially reverse with detraining, underscoring the dose dependence of vascular remodeling (Stebbings, Morse, McMahon, & Onambele, 2013). Circuit-based, low- to moderate-intensity RT may also reduce arterial stiffness and blood pressure in older adults (Hu & Liu, 2025; Zhang, Zhang, Ye, & Korivi, 2021).

These systemic adaptations likely help stabilize cerebral perfusion, though direct evidence remains limited. In late life, aerobic and combined training show clearer cerebral blood flow benefits than RT alone. For example, 12 weeks of supervised training normalized elevated perfusion in prefrontal and insular regions and improved verbal fluency and working memory (Alfini, Weiss, Nielson, Verber, & Smith, 2019) while other studies suggest regional rather than global cerebral blood flow changes with fitness gains (Feron et al., 2024).

4.3. Improved Insulin Sensitivity and Metabolism

A meta-analysis of randomized controlled trials lasting over 12 weeks found that resistance training (RT) significantly reduced insulin resistance (HOMA-IR; $g \approx -0.25$) and glycated hemoglobin ($g \approx -0.51$), with stronger effects in longer or more intensive programs (Jiahao, Li, & Lu, 2021). These metabolic improvements are highly relevant to brain function, as chronic insulin resistance disrupts synaptic stability and neuronal energy balance. By improving glucose regulation, RT helps maintain the energetic support necessary for memory processes.

Recent evidence extends these effects to the brain level. In older adults with prediabetes, 12 weeks of moderate-to-high intensity training increased insulin-responsive proteins such as Akt within neuronal extracellular vesicles, indicating enhanced central insulin sensitivity (Malin et al., 2025; Malin & Erdbrügger, 2024). Brown et al. (2022) showed in mice that even a single bout of exercise facilitated insulin transport across the blood-brain barrier and increased vascular binding, providing evidence that acute exercise can improve central insulin delivery and potentially support hippocampal glucose utilization.

4.4. Inflammation and Oxidative Stress

Chronic low-grade inflammation, or inflammaging, is a hallmark of aging and a major driver of neurodegeneration. Elevated cytokines such as interleukin-6 (IL-6), tumor necrosis factor-alpha (TNF-α), and C-reactive protein create a biochemical environment that disrupts synaptic stability, weakens plasticity, and increases dementia risk (Franceschi, Garagnani, Parini, Giuliani, & Santoro, 2018). Over time, this persistent immune activation accelerates cognitive decline, an effect that resistance training (RT) appears to counteract.

Inflammation interacts closely with oxidative stress, forming a pathway that progressively damages memory systems. Pro-inflammatory cascades increase microglial reactivity, while excessive reactive oxygen species (ROS) impair mitochondrial function and cellular repair (Bacanoiu, Danoiu, Rusu, & Marin, 2023; Simioni et al., 2018). RT interrupts these processes: in Alzheimer's models, resistance protocols reduced cortical and hippocampal cytokine levels, dampened microglial activity, and restored mitochondrial efficiency (Liu et al., 2022). In older adults, 12–24 weeks of RT lowered systemic IL-6 and TNF-α and, in some studies, increased anti-inflammatory IL-10 (Sellami, Bragazzi, Aboghaba, & Elrayess, 2021).

RT also modulates oxidative balance. Although it acutely generates ROS, repeated bouts enhance antioxidant capacity. A 12-week unilateral RT study in older adults showed increased CuZnSOD and catalase activity in trained limbs, reflecting adaptive upregulation of endogenous defenses (Parise, Phillips, Kaczor, & Tarnopolsky, 2005; Powers, Sollanek, Wiggs, Demirel, & Smuder, 2014).

Together, these anti-inflammatory and antioxidant adaptations extend to the central nervous system, reducing neuroinflammation, restoring mitochondrial efficiency, and maintaining hippocampal energy homeostasis.

Resistance training (RT) engages multiple biological systems that support memory and cognitive health. At the molecular level, RT reliably elevates IGF-1 and can stimulate local BDNF signaling within hippocampal circuits, creating conditions that favor synaptic plasticity, dendritic growth, and neurogenesis. These neurotrophic effects provide a plausible link between peripheral exercise adaptations and central memory processes (Cassilhas et al., 2012; Cassilhas et al., 2007).

RT also produces vascular adaptations, including improved endothelial responsiveness, enhanced capillarization, and greater arterial elasticity, which help stabilize cerebral blood flow and maintain oxygen and nutrient delivery to memory-related regions (Hu & Liu, 2025; Silva et al., 2021; Zhang et al., 2021). Parallel metabolic improvements, such as reduced insulin resistance and glycated hemoglobin, restore glucose control and support neuronal energy balance, thereby preserving the metabolic foundation of cognitive function (Jiahao et al., 2021; Malin & Erdbrügger, 2024).

Finally, RT attenuates chronic inflammation and oxidative stress, lowering circulating pro-inflammatory cytokines and upregulating antioxidant defenses. These adaptations protect mitochondrial function and synaptic integrity, reducing processes that contribute to age-related cognitive decline (Parise et al., 2005; Powers et al., 2014; Sellami et al., 2021).

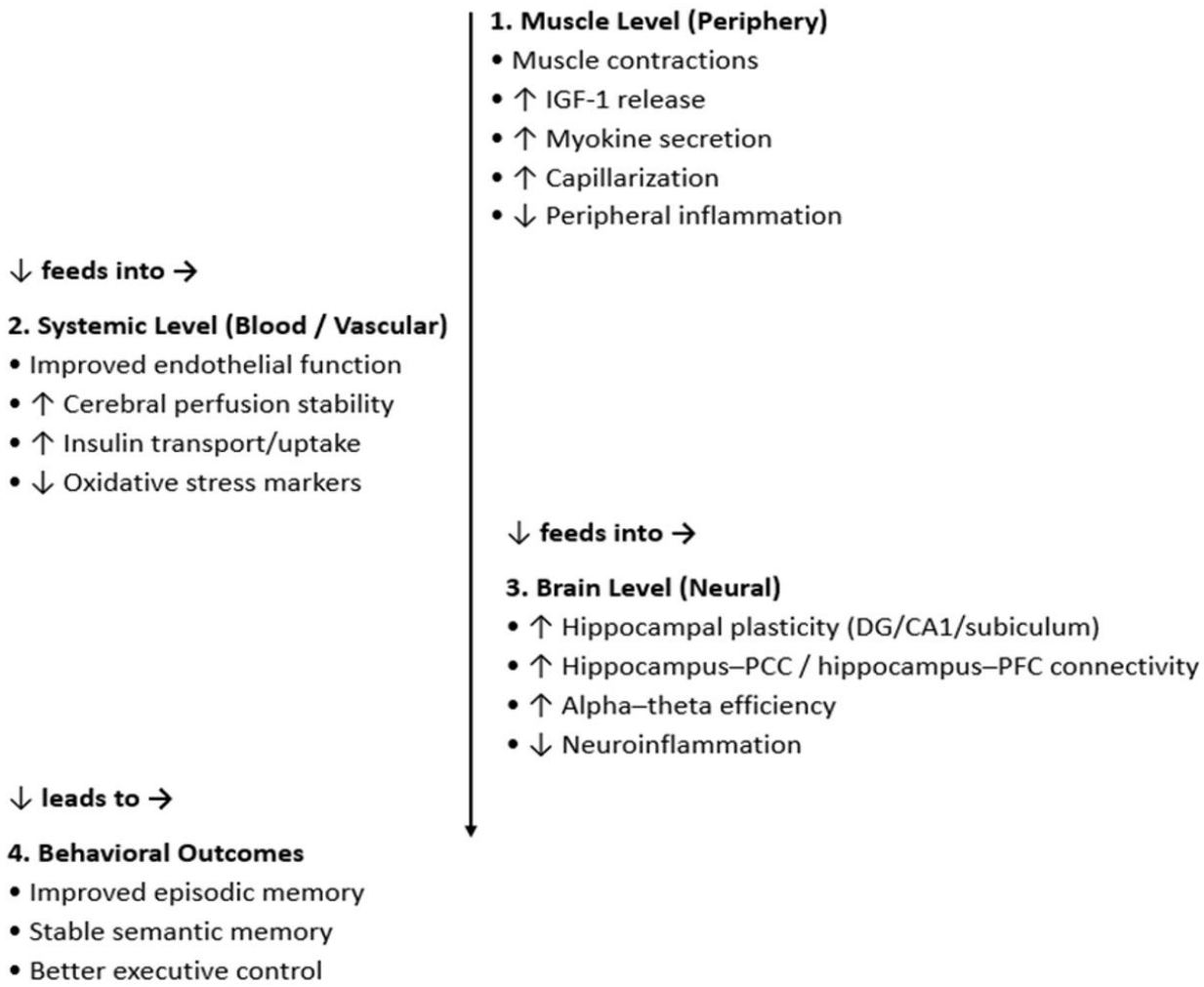

Figure 4. The Muscle–Brain Axis linking resistance training to declarative memory in aging.

Note: Schematic illustration of the muscle–brain axis through which resistance training promotes declarative-memory resilience in aging. Peripheral muscular signals (e.g., IGF-1, myokines) interact with systemic vascular and metabolic pathways to enhance hippocampal plasticity, stabilize network connectivity, and support episodic and semantic memory.

Together, these converging mechanisms, neurotrophic, vascular, metabolic, and anti-inflammatory, create a plastic and metabolically stable neural environment that supports hippocampal structure, network connectivity, and cognitive resilience (see Figure 4). While some variability exists across age, sex, and exercise parameters, the overall evidence positions RT as a multisystem intervention that promotes brain health and may reduce dementia risk by preserving the biological foundations of memory. This integrative perspective aligns with models of cognitive reserve and the scaffolding theory of aging and cognition, where neuromotor complexity and progressive overload of RT act as catalysts for reserve building and compensatory scaffolding.

4.4.1. Summary. Biological Evidence for the Positive Effects of Resistance Training (RT) on Memory

- Neurotrophic: RT increases IGF-1 reliably; BDNF increases are heterogeneous but support synaptic plasticity.
- Vascular: RT improves endothelial function, arterial flexibility, and muscle capillarization; stabilizes cerebral perfusion indirectly.
- Metabolic: RT improves insulin sensitivity peripherally and centrally (neuronal EVs), enhancing glucose availability for memory circuits.
- Inflammatory/Redox: RT reduces IL-6/TNF-α and boosts antioxidant defenses, mitigating neuroinflammation and oxidative stress.
- Mechanisms converge on hippocampal protection, network efficiency, and declarative memory resilience.

5. COMPARING RESISTANCE TRAINING (RT) TO OTHER INTERVENTION MODALITIES

5.1. Pharmacological Interventions

Pharmacological interventions denote the use of medications to prevent, slow, or alleviate cognitive decline by targeting specific neurochemical pathways. In AD and other age-related impairments, cholinesterase inhibitors regulate glutamatergic transmission and reduce excitotoxic stress (Birks, 2006). This strategy offers modest and often transient cognitive benefits in MCI and AD, but it has not reliably prevented progression or reversion from MCI to dementia (Birks, 2006). Recent developments in anti-amyloid biologics like lecanemab and donanemab show promise for slowing progression over approximately 18 months in highly selected early Alzheimer's populations. However, their use is limited by the need for infusion infrastructure, serial MRI and biomarker monitoring, and risks such as amyloid-related imaging abnormalities (Fink et al., 2018; Mintun et al., 2021; Van Dyck et al., 2023).

When considering the relative strength of pharmacology versus exercise, the evidence is thin but suggestive. Ströhle et al. (2015) conducted a meta-analysis of drug and exercise trials in AD and MCI, finding a small pooled cognitive benefit for pharmacological treatments (SMCR ≈ 0.23) and a more robust effect for exercise interventions in AD (SMCR ≈ 0.83) and a modest benefit in MCI. However, the authors emphasize that there is a lack of well-powered, head-to-head trials directly comparing drugs and exercise (Ströhle et al., 2015). Most comparisons are indirect, placing effect sizes from separate trials side by side, which raises challenges of confounding (differences in sample, duration, and intensity). It is, however, true that reviews of physical activity and cognition often propose that pharmacological approaches are inherently narrower, targeting one receptor or pathway, whereas exercise can engage multiple systems simultaneously (vascular, metabolic, neurotrophic, and inflammatory). Yet, this advantage remains theoretical, as few trials have tested it head-to-head (e.g., Meng, Lin, and Tzeng (2020)).

Future studies should directly compare RT with standard pharmacology to clarify efficacy and safety. Meanwhile, in clinical practice, RT can be framed as a complementary intervention: combining it with disease-modifying drugs in eligible individuals may broaden outcomes (cognition, mood, strength, mobility) while remaining the most scalable, accessible option for many who will not receive or choose against high-cost biologics. This positioning aligns with public health imperatives for equitable, high-value dementia prevention and care (Livingston et al., 2020; Ngandu et al., 2015).

5.2. Cognitive Training

Cognitive training involves structured practice on standardized tasks aimed at enhancing specific cognitive domains. It is usually delivered through computer-based exercises or paper-and-pencil activities targeting functions such as memory, attention, or reasoning, including tasks like linking items to a mental route or span tasks (Lampit, Hallock, & Valenzuela, 2014).

Evidence shows that cognitive training reliably enhances the trained domains, most often working memory, processing speed, and aspects of executive control. However, its transfer to global cognition and everyday function is usually modest and domain-specific (Ball et al., 2002). In contrast, RT produces broader, multidomain gains: beyond improvements in executive function and memory, trials and reviews document parallel benefits in mood, quality of life, physical function, and independence, outcomes that align more closely with the real-world priorities of older adults and those with MCI (Khodadad, Mirzazadeh, & Saatchian, 2023). Mechanistically, RT engages neuromuscular, vascular, and neurotrophic pathways (e.g., IGF-1/BDNF signaling, hippocampal and prefrontal plasticity) that plausibly support far transfer to cognition and daily function, an effect CT alone has struggled to demonstrate consistently at scale.

Although the literature remains sparse, a few randomized trials provide insights into how cognitive training, RT, and their combination compare. (Aminirakan, Losekamm, & Wollesen, 2024) tested all three, CT alone, RT alone, and CT + RT, in older adults over 12 weeks. Their findings showed modest effect sizes (roughly $d \approx 0.25$) for combined training over control on certain cognitive and mobility outcomes, suggesting the hybrid approach may outperform single modalities (Aminirakan et al., 2024). In a smaller but telling trial, Wang, Zhang, Wang, Zhang, and Song (2024) compared "instability resistance + cognitive training" against instability resistance alone in elderly women (n=36). The combined intervention resulted in significantly better performance on tests such as Trail Making and Digit Symbol Substitution, along with improvements in dual-task function, indicating that adding cognitive training to resistance training can enhance cognitive gains (Wang et al., 2024).

Cognitive training (CT) produces domain-specific gains (e.g., processing speed, working memory), but the transfer to global cognition and daily function is typically smaller than with exercise, particularly RT, which simultaneously enhances strength, mobility, and mood (Ball et al., 2002; Coelho-Junior et al., 2022; Khodadad et al., 2023). Combining RT with CT is a promising strategy, with protocols grounded in guided plasticity facilitation that posit synergistic effects when physiological plasticity (via RT) is coupled with task-specific cognitive challenge (Aminirakan et al., 2024; Ball et al., 2002; Khodadad et al., 2023; Ngandu et al., 2015). The FINGER trial exemplifies this integration, embedding RT within a multidomain program that also included diet, cognitive training, and vascular risk monitoring, resulting in significant improvements in global cognition (Ngandu et al., 2015). RT appears particularly essential when the intervention goals include not only cognition but also strength, mobility, independence in activities of daily living, and mood regulation, or when individuals present with insulin resistance, sarcopenia, or elevated inflammatory burden. In such cases, RT addresses mechanisms unlikely to be fully engaged by aerobic training alone. Moreover, there is growing interest in pairing resistance sessions with post-exercise cognitive tasks to exploit periods of heightened plasticity and maximize transfer effects (Coelho-Junior et al., 2022; Liu-Ambrose et al., 2012).

5.3. Other Exercise Interventions

Overall, RT emerges as a strong and versatile intervention for cognitive health, effective both on its own and within multimodal programs. Meta-analytic evidence suggests that concurrent aerobic and RT are particularly effective for global cognition, yielding a small-to-moderate effect (Hedges' $g = 0.32$, 95% CI [0.17, 0.46]), with the strongest gains observed when programs are delivered in circuit formats three to four times per week (Zhang, Fang, & Wang, 2025). Nonetheless, network meta-analyses have consistently ranked RT as one of the most effective single modalities for improving cognition in both MCI and dementia populations, with especially strong effects on executive

functions and episodic memory (Huang et al., 2022). Li et al. (2022) found that RT significantly improved attention and executive functions in older adults with mild cognitive impairment (MCI), whereas aerobic training showed no clear advantage over control conditions. Similarly, Krootnark, Chaikeeree, Saengsirisuwan, and Boonsinsukh (2024) demonstrated that low-intensity home-based RT produced comparable gains to aerobic training in global cognition and executive function, with aerobic training showing only a slight advantage for inhibitory control tasks. These findings suggest that both modalities are effective, but RT may confer unique benefits through mechanisms beyond cardiorespiratory fitness, including neuromuscular adaptations and neurotrophic modulation (Broadhouse et al., 2020).

RT benefits are concentrated in protocols that employ progressive loading at approximately sixty to eighty percent of one repetition maximum, performed at least twice per week, with multijoint movements and supervised progression (Coelho-Junior et al., 2022; Liu-Ambrose et al., 2012). Aerobic training benefits scale with the accumulation of one hundred fifty to three hundred minutes per week of moderate intensity or seventy-five to one hundred fifty minutes per week of vigorous intensity, sustained for at least six months, in line with the recommendations of the World Health Organization (Bull et al., 2020; Smith et al., 2010).

In fact, all major exercise modalities outperform non-exercise controls for cognition in older adults with MCI or dementia, but RT often exhibits larger or at least comparable effects. In the largest network meta-analysis to date (71 RCTs; over 5,600 participants) Huang et al. (2022) reported that RT produced the largest standardized mean differences (SMDs) among single modalities for global cognition (SMD = 1.05; 95% CI 0.56–1.54), executive function (SMD = 0.85; 95% CI 0.21–1.49), and memory (SMD = 0.32; 95% CI 0.01–0.63). Subgroup analyses suggest that multicomponent programs (aerobic + RT ± balance) may be slightly superior in early stages (MCI) for global cognition and executive function, while RT retains unique benefits for memory and remains effective in dementia (Huang et al., 2022).

In a network meta-analysis by Han, Zhang, Zhang, Li, and Wu (2025) that included 58 RCTs and 4,349 older adult participants, five exercise modalities, resistance training, aerobic exercise, mind-body exercise, multicomponent exercise, and HIIT, were compared regarding global and domain-specific cognition in healthy aging. The results showed that resistance training produced the greatest improvements in global cognition (SMD = 0.55) and inhibitory control, especially with 45-minute sessions twice weekly for 12 weeks. Mind-body exercise (e.g., Tai Chi, yoga) was most effective for executive function, notably task-switching (SMD = -0.58) and working memory (SMD = 2.45), with high-frequency, moderate-duration protocols. Aerobic exercise best enhanced memory (SMD = 0.42). Subgroup analyses indicated the largest benefits occurred with high-frequency (≥3 sessions/week), mid-term interventions (12–24 weeks), 45–60 minute sessions, in participants aged 65–75 years, and in Asian populations. The authors conclude that exercise provides domain-specific cognitive benefits, supporting tailored prescriptions: resistance training for global cognition, mind–body exercise for executive function, and aerobic exercise for memory. Direct comparative evidence from a low-intensity, home-based RCT in individuals with MCI showed that RT and aerobic training yielded similar improvements in global cognition and executive function, with aerobic exercise showing only a slight advantage on an inhibitory control task (Krootnark et al., 2024).

In sum, all exercise modalities benefit cognition, but RT often produces the largest gains in executive and global cognition. RT engages endocrine and neuromuscular pathways not targeted by other training modalities. We treat RT as a non-substitutable pillar in a multimodal program.

5.3.1. Summary. Comparing Resistance Training (RT) to Other Intervention Modalities

- Compared with pharmacological treatments, which yield modest and population-restricted cognitive benefits, resistance training shows broader and often larger effects while remaining safer, more scalable, and suitable as a complementary strategy.

- Resistance training supports broader improvements in global cognition, mood, and functional independence through multimodal biological mechanisms, whereas cognitive training produces largely domain-specific gains with limited transfer.
- Although all exercise modalities benefit cognition, resistance training consistently ranks among the most effective interventions for global cognition and executive function, engaging neuromuscular and neurotrophic pathways not fully targeted by other exercise modalities.

6. EFFECTIVE RESISTANCE TRAINING (RT) DOSE

Evidence indicates that intensities below approximately 50% 1-RM do not consistently elevate systemic IGF-1 or engage the neuromuscular stress needed to trigger hippocampal IGF-1 transport, a pathway linked to dentate-gyrus plasticity and episodic memory improvements in aging and mild cognitive impairment (MCI) (Broadhouse et al., 2020; Vints et al., 2024). Higher-intensity RT protocols that effectively elevate IGF-1 and related myokines (e.g., BDNF, irisin) have been shown to promote hippocampal neurogenesis and neurovascular health (Gao, Zhang, Liu, Chen, & Wang, 2024).

Moreover, only loads that induce substantial motor-unit recruitment and metabolic challenge reliably improve insulin sensitivity, an important determinant of hippocampal glucose uptake and a strong metabolic predictor of cognitive decline in prediabetes and MCI (Dhahbi et al., 2025). Neurovascular adaptations, including improved endothelial function, shear-stress–mediated nitric oxide release, and stabilization of cerebral perfusion, also appear to be dose-dependent phenomena that require sufficient mechanical and metabolic stimulation, responses that low-load RT seldom elicits. This aligns with evidence showing that moderate-to-high intensity RT enhances both cerebral blood flow and prefrontal perfusion in older adults (Dhahbi et al., 2025).

Electrophysiological and structural findings further suggest that cortical responsivity and hippocampal integrity respond preferentially to higher RT intensities. Significant gains in cortical thickness in the parahippocampal and entorhinal regions, as well as improvements in inhibitory control, have been observed following 12 weeks of RT in older adults at high risk for MCI (Kušleikienė et al., 2025). Similarly, RT protects hippocampal and precuneus volumes, enhances white matter integrity, and improves episodic memory performance in MCI (Ribeiro et al., 2025). Acute resistance bouts at moderate-to-high intensity transiently elevate serum IGF-1 and VEGF while improving P3 amplitude, an electrophysiological marker of neural efficiency, further supporting a threshold-dependent mechanism of neuroactivation (Tsai et al., 2019).

Table 1. Evidence-based resistance training protocol for older adults and clinical groups.

Parameter	Evidence-based recommendation	Example evidence
Frequency	2–3 sessions/week on non-consecutive days	Cassilhas et al. (2007)
Session duration	45–60 min per session (including warm-up & cool-down)	Nagamatsu et al. (2012)
Program length	≥12 weeks; stronger effects with 24–52 weeks	Liu-Ambrose et al. (2012)
Intensity	Start at ~50–60% 1RM, progress toward 70–80% 1RM (RPE 13–16)	Cassilhas et al. (2007); Monteiro-Junior et al. (2022)
Volume	2–3 sets of 8–12 reps per exercise	Cassilhas et al. (2007)
Exercises	6–10 multi-joint exercises: e.g., leg press/squat, chest press, row, hip hinge, overhead press	Uc et al. (2014); Schrank and Rymer (2023)
Progression	Increase load 5–10% when 12 reps become easy; structured progression every 3–4 weeks	Monteiro-Junior et al. (2022)
Supervision	Strongly recommended in the first 4–6 weeks or throughout clinical cases (PD, MCI).	Liu-Ambrose et al. (2012); Uc et al. (2014)
Cognitive & brain outcomes	Improvements in executive function, memory, cortical function, and hippocampal integrity.	Nagamatsu et al. (2012); Liu-Ambrose et al. (2012)
Clinical applicability	Effective and safe in older adults with MCI, PD, and prediabetes	Liu-Ambrose et al. (2012); Malin and Erdbrügger (2024)

Finally, in frail or sarcopenic adults, low-load RT improves functional outcomes but often fails to reverse physiological risk factors such as inflammation, insulin resistance, and microvascular impairment that accelerate hippocampal atrophy and cognitive decline (Vints et al., 2024). These findings suggest that the effective RT dose for cognitive benefit extends beyond muscular strength; it must activate endocrine, metabolic, and vascular pathways that support hippocampal plasticity and cognitive resilience. See Table 1 for a suggested evidence-based RT training protocol for older adults and clinical groups.

7. DISCUSSION

This chapter asked a simple question: Does resistance training support declarative memory in aging and cognitive impairment, and through which pathways? The evidence is consistent. RT results in gains in memory and executive control, with preservation of hippocampal and frontal structures, as well as vascular and metabolic improvements that make these behavioral effects biologically plausible rather than incidental (Huang et al., 2022; Nagamatsu et al., 2012). Furthermore, these cognitive improvements coincide with better mood, strength, mobility, and daily function, positioning RT as a multidomain intervention rather than a narrow cognitive technique (e.g., Gordon et al. (2018))

A coherent reading of the evidence follows the chain from molecules to networks to behavior. Progressive load improves insulin sensitivity and shifts inflammatory tone toward balance, reducing metabolic and immune stressors that weigh on hippocampal and default-mode systems in late life (e.g., (Jiahao et al., 2021; Malin & Erdbrügger, 2024)). In parallel, training supports endothelial function, capillarization, and arterial flexibility, conditions that stabilize perfusion in memory circuits (Hu & Liu, 2025; McIntosh et al., 2024; Silva et al., 2021; Zhang et al., 2021). Imaging and electrophysiology echo these biological shifts, with reports of strengthened fronto-hippocampal communication and more efficient cortical dynamics that align with improved attention and encoding efficiency (Alfini et al., 2019; Feron et al., 2024). No single pathway is sufficient; rather, metabolic support, calmer inflammation, steadier blood flow, and neural efficiency act together to nudge memory systems toward resilience.

Theoretical models help organize this picture. Cognitive Reserve and the Scaffolding Theory of Aging and Cognition frame RT as neural enrichment that builds reserve through repeated motor-cognitive challenges while supporting compensatory recruitment when primary circuits falter (Park & Reuter-Lorenz, 2009; Reuter-Lorenz & Park, 2014). By improving neural efficiency and vascular and metabolic support, training can shift the load–capacity balance so compensation remains effective at lower energetic costs (Cabeza, 2002; Reuter-Lorenz & Cappell, 2008). In short, RT can raise the ceiling for compensation while lowering the price of everyday cognition.

Caution remains essential. Protocols vary in frequency, intensity relative to one repetition maximum, supervision, and exercise selection; outcomes range from isolated tests to composites; comparators differ; samples are often modest; follow-ups are short; and frailer or multimorbid adults are frequently excluded (Coelho-Junior et al., 2022; Huang et al., 2022). Biomarker findings are not uniform across sex or baseline health, and causal mediation linking specific physiological changes to cognitive gains still needs rigorous testing (Malin & Erdbrügger, 2024). Direct head-to-head trials that isolate the unique contribution of RT relative to aerobic or multicomponent programs are scarce, although network meta-analyses consistently rank resistance training among the strongest single modalities for global cognition and executive function, with domain-specific strengths also evident for aerobic and mind–body formats (Han et al., 2025; Huang et al., 2022).

Additional considerations include sex-specific and hormonal influences, which may partly explain heterogeneity in neural and metabolic responses to training (Landen et al., 2023). Estrogen and testosterone appear to modulate neuroplasticity and BDNF sensitivity, suggesting the need for stratification by sex and hormonal profile. Determining the minimal effective dose and optimal intensity for cognitive benefit remains a priority, as most studies use moderate-to-high loads without systematically testing dose-response effects (Coelho-Junior et al., 2022; Northey, Cherbuin, Pumpa, Smee, & Rattray, 2018). Finally, resistance training interacts with other lifestyle factors, such as

nutrition and sleep, which together influence cognitive outcomes. Multimodal approaches, including the Finnish Geriatric Intervention Study (FINGER), demonstrate that combining exercise with dietary and cognitive interventions yields synergistic benefits (Kivipelto et al., 2020; Ngandu et al., 2015).

Integration is preferable to substitution. Combining RT with other intervention modalities tends to broaden transfer; early comparative trials suggest that pairing resistance sessions with cognitive training yields additive advantages on set-shifting, processing speed, and dual-task outcomes, consistent with guided plasticity facilitation (Aminirakan et al., 2024; Ngandu et al., 2015; Wang et al., 2024). Circuit-style or multicomponent formats delivered three to four times weekly show small to moderate effects on global cognition and translate well to community settings (Zhang et al., 2025).

Practice implications follow from what is strongest. Progressive, supervised programs at moderate to high relative intensity about two to three times per week are feasible and safe for many older adults when appropriately screened, with reliable benefits to strength and function and probable gains in memory and executive domains (Coelho-Junior et al., 2022).

From a public health and policy perspective, RT is a high-value option. It targets outcomes that matter to patients and caregivers, including memory, attention, mood, mobility, and everyday function, while remaining scalable in primary care, senior centers, and municipal facilities (Livingston et al., 2020; Ngandu et al., 2015). Aligning reimbursement and workforce development with international recommendations on muscle-strengthening activity would accelerate adoption in settings where access to high-cost biologics is limited (Livingston et al., 2020).

The scientific path forward is clear. Progress will depend on harmonized protocols, biomarker batteries that span imaging, electrophysiology, and blood, stratification by genetic and metabolic risk, and pragmatic trials that test delivery at scale across diverse settings. Longitudinal cohorts are needed to determine whether RT delays incident dementia or institutionalization, and health-economic analyses should quantify cost offsets from delayed disability and reduced caregiver burden (Livingston et al., 2020).

Clinicians can prescribe progressive, supervised programs tailored to capacity and comorbidity; communities can deliver accessible group formats; policymakers can support access through reimbursement, workforce training, and age-friendly infrastructure (Livingston et al., 2020; Ngandu et al., 2015). Remaining uncertainties, such as optimal dose and progression, durability, mediating mechanisms in diverse populations, and best practices for equitable scale-up, are solvable with coordinated research and implementation. To establish resistance training as a cornerstone of cognitive health, future studies should adopt harmonized, multisite trial designs that clarify optimal frequency, intensity, and duration. Integrative approaches combining neuroimaging, electrophysiology, and molecular markers can illuminate causal mechanisms linking muscular adaptation to neural plasticity. Identifying moderators like genetics, sex, baseline fitness, and psychosocial context will refine precision-based prescriptions. Testing multimodal interventions that pair resistance training with cognitive or lifestyle programs may reveal synergistic effects. Additionally, pragmatic and globally inclusive trials with low-cost, culturally adaptable delivery models and long-term follow-up are necessary to ensure sustainable, equitable translation of benefits into public health practice. In an era where pharmacological advances are meaningful but partial, and societal costs of cognitive decline rise, resistance training stands out as a low-cost, high-reach, evidence-informed tool that strengthens the body, protects the brain, and sustains independence (Livingston et al., 2020). Elevating it to a front-line strategy for healthy cognitive aging is both scientifically defensible and practically urgent.

8. CONCLUSIONS

This chapter argues that resistance training functions as a multidomain cognitive health intervention with particular relevance for declarative memory. It promotes hippocampal and network-level plasticity, steadies perfusion, supports white-matter integrity, normalizes cortical dynamics, improves insulin sensitivity, and dampens chronic inflammation, while strengthening mood, self-efficacy, mobility, and social connectedness (Nagamatsu et al., 2012;

Silva et al., 2021). The practical message is straightforward. Resistance training deserves a central place in prevention and care pathways for older adults, including those with mild cognitive impairment.

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