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Exercise to support learning and other cognitive functions in young adults. A review of the literature

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Abstract

Aim: To synthesize empirical evidence (2020–2026) regarding the impact of acute and chronic physical activity on cognition, academic achievement, and neurobiological mechanisms in healthy young adults.

Materials and Methods: A comprehensive synthesis of systematic reviews, meta-analyses, and original articles from the PubMed database (2020–2026) using keywords related to physical activity, exercise types (aerobic, endurance), cognition, memory, and young adults/students.

Results: Acute aerobic and resistance exercise moderately improves global cognition, specifically inhibitory control and cognitive flexibility. High-intensity protocols (HIIT, SIT) positively correlate with executive function, attention, and processing speed. Higher academic performance (GPA) is associated with physical activity, though mediated by sleep quality, stress regulation, and reduced sedentary behavior. Neurobiologically, exercise elevates BDNF and lactate concentrations (the latter predicting variance in executive tasks) and induces intensity-dependent increases in cortical oxygenation (HbO). Young adults show high sensitivity to intensity-dependent neuroplastic adaptations.

Conclusions: Physical activity is a potent non-pharmacological strategy to optimize brain health and cognitive performance. While direct academic impacts are mediated by lifestyle factors, regular high-intensity exercise drives favorable neurobiological changes and enhances executive functions critical for complex learning.

Key words: physical activity, cognitive function, neuroplasticity.

Introduction

Physical activity is widely recognized as a foundational acpect of public health, fundamentally determining human physiological and psychological well-being. Despite unequivocal evidence supporting its benefits, contemporary societies face a severe global crisis of physical inactivity. According to a comprehensive pooled analysis published in *The Lancet Global Health* by Strain et al. approximately 31.3% of the global adult population in 2022 did not meet the physical activity levels recommended by the World Health Organization (WHO). Worryingly, predictive models suggest that if current trajectories persist, the global prevalence of insufficient physical activity could escalate to 35% by 2030. This epidemiological trend is particularly pronounced among young adults (aged 18–25), a demographic undergoing critical life transitions, such as entering higher education or the workforce,that heavily promote sedentary behaviors, academic overload, and screen-based routines [1].

In the academic and clinical literature, regular physical exercise is firmly established as a potent modulator of both mental health and cognitive capabilities. Neurobiological research indicates that aerobic exercise triggers the expression of brain-derived neurotrophic factor (BDNF), a primary driver of neurogenesis and synaptic plasticity, particularly within the hippocampus [2]. Consequently, consistent movement directly enhances core cognitive processes, including working memory, sustained attention, and executive functions—skills that form the bedrock of effective academic learning [3]. Simultaneously, physical activity serves as a crucial psychological buffer against stress, anxiety, and depressive symptoms, which have shown an alarming surge among university student populations globally, frequently undermining their academic engagement [4]

Within higher education settings, the relationship between physical activity and academic performance (frequently quantified via Grade Point Average, or GPA) has become an important point of interdisciplinary investigation. Existing studies demonstrate a positive correlation, indicating that students with higher cardiorespiratory fitness consistently achieve superior academic outcomes [5]. Active individuals exhibit enhanced information-processing speeds, better cognitive flexibility, and greater resilience to psychological fatigue during rigorous evaluation periods. Furthermore, grounding these findings in self-regulation theories, physically active young adults demonstrate superior time-management skills and lower rates of procrastination, which indirectly reinforces their educational success.

1. Exercise and cognitive performance in healthy young adults.

The relationship between exercise and cognitive function in young adults appears to be domain-specific rather than global. In a systematic review with multilevel meta-analysis of 12 trials including 447 healthy adults, Wilke et al. assessed the immediate effects of a single resistance exercise session on global cognition and specific cognitive domains, including inhibitory control, cognitive flexibility, working memory, and attention. Resistance exercise produced a significant moderate improvement in global cognition compared with no-exercise control conditions, with significant effects on inhibitory control and cognitive flexibility. However, the effects on working memory and attention did not reach statistical significance, and resistance exercise was not superior to aerobic exercise in any cognitive subdomain [6]. Similarly, Oberste et al. examined whether acute exercise improves set shifting, a component of executive function, the ability to switch between different cognitive sets. Their meta-analysis included 22 studies with 1,900 participants and found a small but statistically significant beneficial effect of acute exercise on subsequent set-shifting performance. The effect was slightly larger in older adults than in younger adults, while aerobic and resistance exercise produced almost identical effects, suggesting that the cognitive benefit may depend less on exercise modality and more on shared acute physiological responses to exercise [7]. Evidence regarding visuospatial working memory is less univocal. Zhu et al. analysed 21 articles including 1,595 healthy participants and 28 randomized controlled trials on physical activity and visuospatial working memory. Although physical activity had a small but significant positive effect on visuospatial working memory overall, subgroup analyses showed that the effect was evident mainly in children and older adults, whereas the effect in young adults was non-significant or nearly absent, possibly because this group already performs close to its cognitive peak [8]. Haverkamp et al. provided broad evidence by analysing controlled physical activity interventions in healthy adolescents and young individuals aged 12–30 years. Acute interventions significantly improved processing speed, attention, and inhibition, while chronic interventions significantly improved processing speed, attention, cognitive flexibility, working memory, and language skills. These findings indicate that physical activity may influence several learning-relevant cognitive domains in young populations, although the inclusion of both adolescents and young adults limits direct extrapolation to young adults alone [9]. The cognitive relevance of physical activity may also extend to reducing sedentary exposure. Chueh et al. reviewed seven studies on breaking up prolonged sitting and cognition; only three studies reported positive cognitive effects, including improvements in attention and inhibitory control in young adults after 3-minute relatively high-intensity walking breaks every 30 minutes, and improvements in attention, working memory, or cognitive flexibility in other adult populations. However, because the findings were mixed and the protocols were heterogeneous, the authors concluded that evidence for interrupting prolonged sitting as a cognitive strategy remains limited [10]

High-intensity exercise may also be relevant for cognitive performance in healthy adults. In a systematic review, Gilson et al. examined the effects of high-intensity interval training (HIIT; 70–100% VO_2max) and sprint interval training (SIT; ≥100% VO_2max) on work-related cognitive functions. The authors reported statistically significant positive effects of HIIT and SIT on several cognitive domains, including executive function, attention, memory, and processing speed. Since these functions are directly involved in task management, information processing, decision-making, and mental efficiency, the findings suggest that high-intensity exercise may contribute to improved work-related cognitive performance. Although practical implementation of HIIT or SIT in workplace settings may be challenging, the cognitive effects reported in the review are relevant to understanding exercise as a potential strategy for supporting mental performance in demanding educational or occupational contexts [11].

2. Physical activity and academic performance of students.

The association between physical activity and academic performance in students is supported by several reviews, although the strength of this relationship varies depending on population, study design, and the way academic outcomes are measured. In a systematic review and meta-analysis including 36 studies, with six studies entered into the quantitative synthesis, Trott et al. examined the association between total physical activity and academic performance in adults and found that students with higher physical activity were significantly more likely to be high academic performers than those with lower activity levels, with an odds ratio of 3.04; however, the authors judged the credibility of this evidence as low and the narrative synthesis remained mixed, with only half of the included studies reporting positive associations [12]. In university students specifically, Wunsch et al. investigated the tridirectional relationship between physical activity, stress, and academic performance; their review suggested a generally positive relation between physical activity and academic performance and a negative relation between physical activity and stress, but the meta-analysis did not demonstrate significant pooled associations and showed considerable heterogeneity, indicating that physical activity may be beneficial, but its academic effects are probably mediated by stress regulation and other contextual factors rather than acting as a simple independent predictor [13]. A more classroom-specific perspective was provided by Lynch et al., who reviewed 14 trials including almost 6000 university students and assessed classroom movement breaks and physically active learning; these interventions were feasible, increased physical activity, reduced sedentary behaviour and fatigue, improved wellbeing, and movement breaks increased focus and attention, while physically active learning had no detrimental effect on academic performance, suggesting that integrating movement into tertiary education may support learning conditions without compromising academic outcomes [14]. Original studies provide additional but not fully uniform evidence. Al Zahrani et al. conducted a cross-sectional observational study in health sciences students and reported that higher physical activity was associated with higher GPA - grade point average, lower BMI, fewer absences, and fewer academic warnings; additionally, each one-point increase in GPA was associated with an additional 629 MET(metabolic equivalents)-min/week of total physical activity, which indicates a positive link between physical activity and academic achievement, although the cross-sectional design does not allow causal interpretation [15]. In contrast, Heller et al. analysed several health behaviours simultaneously in university students and found that, when sleep, diet, sedentary behaviour, alcohol, smoking, drug use, and physical activity were considered together, only sleep and fruit and vegetable consumption were significantly associated with academic performance, while physical activity showed no correlation with academic performance; this suggests that the effect of exercise may become less apparent when other health behaviours are controlled for in the same model [16]. Meng et al. examined physical activity intervention in college students with mobile phone addiction and found that combined physical activity was effective in reducing mobile phone addiction, with emotion regulation strategies and positive coping style acting as mediating factors;

although this study did not primarily measure GPA, it suggests that exercise may improve academic functioning indirectly by reducing maladaptive phone use and strengthening self-regulatory resources relevant to learning [17]. Similarly, Li et al. used a randomized fMRI design in individuals with internet gaming disorder and showed that progressive moderate aerobic exercise reduced IGD symptoms and craving and altered neural synchrony and functional connectivity in reward and control networks; because IGD is associated with impaired academic and social functioning, these findings support a possible neurobehavioural pathway through which aerobic exercise may improve study-related functioning, even though academic performance was not the primary endpoint [18]. Recent adolescent-focused reviews also suggest that physical activity and cardiopulmonary fitness are generally associated with better academic or executive outcomes, particularly attention, working memory, and inhibitory control, but the authors emphasize variability across studies and the need for stronger longitudinal and experimental designs [19, 20] Taken together, the current evidence suggests that physical activity may support academic performance in students, but this relationship is likely to be dictated by other, indirect factors such through multiple pathways, including reduced fatigue, better stress regulation, lower problematic screen use, and healthier body composition and improving cognitive functions, while its independent association with GPA remains heterogeneous across studies.

3. Neurobiological impact of exercise on the brain

The neurobiological effects of exercise on the brain appear to involve several partly overlapping mechanisms, including changes in functional connectivity, neuroplasticity markers, neurotrophin release, lactate metabolism, and cortical oxygenation. Moore et al. reviewed studies examining the interrelationship between exercise, functional connectivity, and cognition in healthy adults. Seven studies assessed the relationship between functional connectivity and cognitive performance across multiple brain regions in the context of exercise. Their findings suggest that exercise-related cognitive effects may be partly mediated by changes in large-scale functional connectivity, although the available evidence remains limited by the small number and heterogeneity of studies [21]. Hortobágyi et al. provided broader evidence on exercise-induced neuroplasticity by analysing 50 studies with 60 intervemtion arms and 2,283 participants, including healthy young adults, healthy older adults, and neurological patients. Overall, both low-intensity exercise and high-intensity exercise improved markers of neuroplasticity, such as: brain activation, neurochemical markers, motor and cognitive function. Importantly, exercise intensity scaled with neuroplasticity only in healthy young adults, while exercise-induced neuroplasticity changes were associated with motor rather than cognitive outcomes. These results suggest that young healthy individuals may be particularly responsive to intensity-dependent neuroplastic adaptations, although such changes cannot be directly equated with cognitive improvement [22]. Another mechanism concerns brain-derived neurotrophic factor. Fernández-Rodríguez et al. conducted a systematic review and meta-analysis on the immediate effects of high-intensity exercise on BDNF in healthy young adults, including 22 studies with 552 individuals aged 20–31 years. High-intensity exercise increased BDNF compared with non-exercise conditions and light-intensity exercise, but not clearly compared with moderate-intensity exercise. These findings indicate that high-intensity exercise may acutely enhance circulating BDNF in young adults, supporting its potential role in exercise-induced neuroplasticity and brain health [23]. Lactate may also be relevant as a metabolic signal linking intense exercise with cognition. Jacob et al. reviewed 226 study entries including 2,560 healthy adults with a mean age of 24.1 ± 4.7 years and examined how HIIT (high intensity interval training) protocol parameters influenced blood lactate levels and post-exercise cognition. They found that relatively low work-interval volume, longer recovery intervals, and medium total session volume elicited peak lactate levels; lactate levels immediately after HIIT explained 14–17% of the variance in Stroop interference performance 30 minutes after exercise. This suggests that lactate response after HIIT may be connected with executive processes such as inhibitory control and selective attention, which are important for learning and complex cognitive work [24]. Endurance training has also been discussed in relation to BDNF and inflammatory markers. Evidence on endurance training, BDNF, and inflammation in healthy individuals and Parkinson's disease, describing endurance exercise as a stimulus that may modulate neurotrophic support and inflammatory pathways relevant to neuroprotection [25]. Lammers et al. examined whether whole-body exercise acutely or shortly after completion changes cortical oxygenated hemoglobin concentration (HbO) in healthy adults, using fNIRS (functional near infrared spectroscopy) as an indicator of cortical activity. The review included studies in which healthy adults performed different forms of whole-body exercise, mainly walking, cycling, or coordination tasks, lasting 5–60 minutes and ranging from low to vigorous intensity. In the quantitative analysis, 29 studies were included. The main outcome was the difference in cortical HbO concentration during or shortly after exercise compared with baseline. Exercise produced a significant moderate acute increase in cortical HbO during exercise compared with baseline. The effect was intensity-dependent: low-intensity exercise produced a smaller increase ($g = 0.24$), moderate-intensity exercise a larger increase ($g = 0.64$), and vigorous-intensity exercise the strongest increase ($g = 0.92$; $p < 0.001$). The effect was not significantly modified by brain region, exercise type, exercise duration, or sex. Short-term post-exercise effects showed only a trend toward increased HbO after exercise compared with baseline. These findings suggest that whole-body exercise acutely increases cortical oxygenation, particularly at higher intensities, which may reflect increased cortical activation and oxygen delivery during exercise. Therefore, cortical oxygenation represents a plausible physiological mechanism through which exercise may temporarily support brain activity relevant to cognition, although the evidence is stronger for changes during exercise than for sustained post-exercise effects [26]. The current literature suggests that exercise influences the brain through both molecular and systems-level mechanisms: high-intensity exercise may acutely increase BDNF, HIIT-induced lactate may be associated with executive cognitive performance, exercise intensity may modulate neuroplasticity particularly in healthy young adults, and exercise may alter functional connectivity and cortical oxygenation. These mechanisms provide biological plausibility for the cognitive and learning-related effects of exercise, although the strength of evidence differs across mechanisms and not all neurobiological changes translate directly into measurable cognitive improvement.

Discussion

The synthesis of current research underscores that the relationship between exercise and cognition in healthy young adults is fundamentally domain-specific. While global cognitive improvements are observable, the most robust effects are concentrated in executive functions, particularly inhibitory control and cognitive flexibility. This aligns with the neurobiological evidence regarding the activation of the prefrontal cortex and increased cortical oxygenation (HbO)during physical activity.

A critical nuance identified in the literature is the "ceiling effect" often observed in the young adult demographic. Unlike children or older adults, who show broad gains in areas like visuospatial working memory, young adults typically operate at their cognitive peak. This may explain why certain interventions yield non-significant results in this group; their baseline performance leaves less "room" for measurable improvement compared to developing or declining populations.

Furthermore, the data suggests that exercise intensity is a primary driver of neurobiological change in this age group. The significant correlation between lactate levels post-HIIT and executive performance, alongside the intensity-dependent release of BDNF, suggests that vigorous activity may be necessary to trigger meaningful neuroplastic adaptations.

Regarding academic performance, the evidence remains heterogeneous. While a positive correlation between physical activity and GPA exists, it is likely not a direct causal link. Instead, exercise appears to function as a catalyst for a healthier lifestyle matrix, improving academic outcomes indirectly by regulating stress, enhancing sleep quality, and mitigating maladaptive behaviors such as excessive screen time or sedentary fatigue.

Conclusions

In conclusion, physical activity serves as a powerful, low-cost intervention for optimizing cognitive health in young adults. To maximize cognitive gains, particularly in demanding educational or professional settings, the following should be considered:

Intensity. High-intensity protocols (HIIT/SIT) appear more effective than low-intensity activities for acutely boosting executive functions and neurotrophic factors like BDNF.

Targeted Benefits. Exercise should be viewed as a tool for enhancing specific "learning-relevant" domains, such as focus and inhibitory control, rather than a universal "iq booster."

Indirect Academic Impact. The benefits of exercise on GPA are likely mediated by improved mental health and better self-regulatory resources.

Practical Integration. Short, high-intensity movement breaks are a feasible strategy for reducing the negative cognitive impact of prolonged sedentary behavior in classroom or office environments.

While the physiological mechanisms ranging from lactate signaling to increased functional connectivity are increasingly understood, future research should focus on longitudinal designs to determine the long-term sustainability of these cognitive enhancements in the young adult population.

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