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Physical fitness, physical activity, exercise training and cognitive function in older adults

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Abstract  Cognitive impairment is a major health and social issue. Over the past decade many studies have reported that engaging in physical activity and exercise training, and a higher level of physical fitness, can postpone the onset of age-associated cognitive decline or reduce its impact. In this review, therefore, we focused on the association between physical fitness, physical activity, exercise training and cognitive function in older adults. It is assumed that physical fitness, including cardiorespiratory fitness, muscle strength, walking ability, balance, reaction time and flexibility are associated with cognitive function. When considering potential determinants of age-associated cognitive decline, active lifestyles are often considered as protective. In recent years, some regular forms of exercise, including resistance training, have been reported as providing potentially useful psychological benefits. More recently, several potential mechanisms that may underlie the association between physical activity or exercise training and reduced risk of cognitive decline have been revealed.

Keywords: physical fitness, physical activity, exercise training, cognitive function, older adults

Introduction

Although cognitive decline is only one aspect of growing old, it is the most costly in terms of the financial, personal and societal burdens incurred. Moreover, cognitive decline can lead to dementia, illness and death1). Information processing begins to slow in our 30s2) and can explain a large proportion of age-associated decline in all affected cognitive domains. Within the range defined as ‘normal cognitive aging,’ i.e. cognitive changes which would not meet the criteria for dementia or any of the varieties of ‘mild cognitive impairment,’ people differ extremely in the degree to which their brains decline with age3).

On the other hand, some studies reported that engaging in physical activity and exercise training, and maintaining an overall higher level of physical fitness can postpone the onset of age-associated cognitive decline, or reduce the impact of it4). However, the mechanisms by which this may work, and to what extent physical activity, training and fitness can be effective are still ambiguous. Therefore, our challenge for improving the well-being of older people is to identify the individual differences and mechanisms of age-associated cognitive decline and, most importantly, to understand the association between cognitive function and physical activity, training and fitness. Therefore, the purpose of this review is to discuss the association between physical fitness, physical activity, exercise training and cognitive function in older adults.

Relationship between cognitive function and physical fitness

According to a review article published recently4), there is an association between baseline physical fitness and cognitive function. This relationship also depends on how physical and cognitive functions are measured. For instance, grip strength is associated with mental state, while walking speed is correlated with changes in fluid cognition. Lower cognitive function was associated with poor physical performance in gait speed, standing balance and chair stand tests5). Even subjects with only mild cognitive impairment had more balance and gait problems than cognitively normal subjects6); and impaired equilibrium and limb coordination were clinically categorized in a series of patients suffering from mild cognitive impairment and mild Alzheimer’s disease (AD)7). Therefore, poor physical fitness coexists with cognitive impairment. Overall, staying alert and physically fit is important to staying healthy while aging and maintaining functional independence.

In another study of 2893 older adults by Rosano et al.8),

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there was a significant correlation between poor physical performance in gait speed, balance and lower extremity muscle strength and poor performance in cognitive function. There is evidence that changes in physical and cognitive functioning are associated, but these associations are not strong enough or consistent enough to provide conclusive evidence for “common cause” aging. Not all declines occurred together, and not all measures had equal impact.

There are different aspects or categories of physical fitness as follows:

**Cardiorespiratory fitness.** The cardiovascular fitness hypothesis suggests that cardiovascular (aerobic) fitness is a physiological mediator that explains the various mental health benefits of physical activity. As applied to cognitive performance, this hypothesis suggests that the gains in cardiovascular fitness achieved through regular participation in physical activity improve cognitive performance. Netz et al., in a study on 38 older adults aged 65.3 - 85.3 years, reported that the moderately-fit group achieved significantly better global cognitive scores; and a significant correlation was found between peak VO2 and attention, executive function and global cognitive score. The trend for superior cognitive scores in the moderate-fitness group, compared to the low-fitness group, was unequivocal in terms of both accuracy and reaction time. These results show that maintaining a higher level of cardiovascular fitness may help protect against cognitive deterioration, even at an advanced age. Overall, the data are insufficient to prove that the improvements in cognitive function, which can be attributed to physical exercise, are due to improvements in cardiovascular fitness, although the temporal association suggests that this might be the case. Larger studies are needed to confirm whether aerobic training is necessary or whether the same can be achieved with any type of physical exercise.

**Muscle strength.** Several recent cross-sectional studies have shown associations between muscle strength and physical fitness and disability. A number of prospective studies have described the association of handgrip strength and health decline in the elderly, predominantly describing its association with functional disability and mortality. A limited number of studies examine the association between muscle strength and cognition. Taekema et al., reported that poor handgrip strength predicts accelerated dependency in activities of daily living (ADL) and cognitive decline in the oldest old. In another study by Christensen et al., weaker handgrip strength was associated with greater variability in memory change in a sample of 426 elderly community dwellers over 3.5 years. These results were also supported by another study in which older Mexican-Americans with poor cognition had steeper declines in handgrip muscle strength over 7 years than those with good cognition, independent of other demographic and health factors. Therefore, measuring handgrip strength, which is easy to apply in clinical geriatric practice, can help identify those oldest old patients at risk for future decline. Independent of muscle mass, poor physical function and muscle strength coexisted with cognitive impairment. Therefore, it is likely, that the functional decline seen in dementia may be directly related to factors that result in cognitive impairment, independent of coexisting sarcopenia.

Overall, reduced muscle strength may be an early marker of a generalized decrease in nervous system processing that occurs with aging, and is reflected in cognitive function. In a study by Boyle et al., greater muscle strength at baseline was associated with about a 43% decrease in the risk of AD. Increased muscle strength was associated with a slower rate of decline in global cognitive function. Finally, muscle strength was associated with a decreased risk of mild cognitive impairment (MCI), the precursor to AD. These results show that greater muscle strength is associated with a decreased risk of developing AD and MCI, and suggest that a common pathogenesis may underlie loss of strength and cognition in aging. These results are in keeping with a previous study, which reported that declining strength in old age is associated with an increased risk of AD.

**Walking ability.** In this review, we have considered different aspects of walking ability, such as gait pattern, gait speed and community settings. Changes in cognitive function contribute to changes in variability and stability of the gait pattern seen as a progressive decrease in step length and an increase in cadence. Walking under fairly demanding dual-task conditions could, therefore, be helpful when screening individuals with gait impairments and those at risk for falling, as this appears to unmask gait impairments that can provoke falls. Deshpande et al. stated that compared to usual gait speed, adding a neuromuscular, but not a cognitive, challenge while walking may provide a more sensitive predictor of accelerated cognitive decline over time. In their study, fast gait speed, rather than usual gait speed, or gait speed in a ‘walking-while-talking’ condition, was an independent predictor of accelerated decline on Mini-Mental State Examination (MMSE) results over a 3-year period. This suggests that measuring fast gait speed in older persons may help identify those at high risk of cognitive decline.

Although results from longitudinal studies on the association between gait speed and subsequent cognitive decline have varied, cognitive decline and dementia are strongly associated with a higher risk of subsequently developing a slow gait speed. As a case in point, one study on 488 elderly adults, conducted over a 7-year period, reported that, for every unit of decline in cognition score, walking speed decreased 0.07 units. Another study on 85 adults aged 65 and older, over a 3-year period, reported that slow gait speed was associated with a higher risk of
subsequent cognitive decline. By contrast, another study on 1,193 adults aged 70 and older, over a 2-year period\(^{29}\), did not find a significant association between gait speed and cognitive change.

A possible explanation for these conflicting results is the difference in sample size and years of follow-up between the studies. A larger number of subjects over a longer follow-up period could test this explanation, as in the 7-year study of 2070 older Mexican-American adults. This study found that a slow 8-foot walk time without cognitive impairment at baseline was an independent predictor of MMSE score decline\(^{30}\). Duff et al.\(^{31}\) also found that global cognition was related to walking speed. Furthermore, Prohaska et al.\(^{32}\) reported that the community setting where people walk and the intensity of walking within their neighborhood were significantly associated with cognitive status. Older adults with lower Mental Alternation Test (MAT) scores were more likely to walk in indoor shopping malls rather than in parks, whereas, those with higher cognitive function scores on the MMSE were less likely to walk in indoor gyms.

**Balance, reaction time, flexibility.** Until now, studies that investigated the correlation between physical fitness and human brain function have focused on one facet of physical fitness, namely, cardiovascular fitness\(^{33}\). However, fitness is a multi-faceted concept that not only includes physical (i.e. cardiovascular fitness and muscular strength), but also motor fitness indexed by components such as flexibility, reaction time and balance. In a study with 72 participants aged 62 - 79 years, both physical fitness, as indexed by cardiovascular fitness and muscular strength, and motor fitness, which included movement speed, balance, motor coordination and flexibility, were strongly associated with cognitive functioning. Additionally, functional brain imaging data revealed that physical and motor fitness were differentially related to cognitive processes\(^{34}\). These results are consistent with another study indicating that agility and balance are associated with cognitive functions in elderly patients with AD\(^{35}\).

There have been a limited number of studies that have investigated the transfer of cognitive intervention training to physical outcome measures in older adults. A recent study by Li et al.\(^{36}\), showed that after five sessions of cognitive dual-task training, the training group had significant improvements in body sway during single-support balance and improvements in center of gravity alignment during double-support dynamic balance, while the control group had no appreciable improvements. Therefore, cognitive training can be a beneficial intervention and particularly suitable for individuals with mobility and balance restrictions. In a study of reaction time by Kvelde et al.\(^{37}\), self-reported depressed mood was related to slowed performance on a choice stepping reaction time task, and the relationship was explained by underlying physiological and cognitive impairments.

**Relationship between cognitive function and physical activity**

When considering potential determinants of age-associated cognitive decline, active lifestyles are often considered protective\(^{38}\). Age-associated cognitive decline is apparently delayed or reduced in more physically active individuals\(^{39}\). In other words, physical activity need not be strenuous; individuals may experience less cognitive decline in later life by walking more\(^{38,39}\). However, further investigation is warranted, especially to examine if there are critical periods in life when physical activity needs to be initiated and maintained, and what type of physical activity (e.g. aerobic versus anaerobic) might result in the greatest benefits\(^{39}\). Not all studies report an association between physical activity and cognitive function, perhaps due to different physical activity measurements, the validity of the cognitive assessments, length of follow-up in old age, and the timing and duration of the physical activity itself\(^{38}\). Over all, cognition and functional performance are significant contributors to independence in older adults. Individuals who have greater leg power, shorter reaction time, faster processing speed, better memory and greater functional performance tend to have higher physical function and remain independent\(^{39}\).

**Leisure time.** Leisure-time activities are activities that individuals engage in for enjoyment or well being that are independent of work or the activities of daily living. Verghese et al. (2003)\(^{41}\) examined the relationship between leisure-time activities and the risk of dementia in a prospective cohort of 469 subjects older than 75 years of age who resided in the Bronx, a borough of New York City, and did not have dementia at base line. The authors performed Cox proportional-hazards analysis and reported that the leisure-time activities of reading (HR: 0.65, 95% CI: 0.43 - 0.97), playing board games (HR: 0.26, 95% CI: 0.17 - 0.57), playing musical instruments (HR: 0.31, 95% CI: 0.11 - 0.90), and dancing (HR: 0.24, 95% CI: 0.06 - 0.99) were associated with a reduced risk of dementia. They suggested that the results of their study could also apply to patients with AD and vascular dementia. In particular, they believed that intellectual activities were effective. Leung et al. (2011)\(^{42}\) reported that a higher level of participation in intellectual activities by Hong Kong elderly Chinese, as measured by total hours per week, was significantly associated with a lower incidence of global cognitive decline (OR: 0.97, 95% CI: 0.94 - 0.99). Iwasa et al. (2012)\(^{43}\), in a study with Japanese subjects, showed that, after 5 years, non participation in a hobby was associated with cognitive decline (OR: 1.87, 95% CI: 1.16 - 3.02).

**Work-related activity.** There are a few studies that examined the relationship between cognitive function and work-related physical activity. Kröger et al. (2008) fo-
cused on work complexity in a 10-year population study with the Canadian Study of Health and Aging\(^4\) which revealed that highly complex work with people or things gave the participant a 28 - 64% reduced risk of dementia. In a study on the elderly in Sydney, Australia, Suo et al. (2012) found that higher total lifetime experiences are linked with increased grey matter volume in the hippocampus, and supervisory and managerial experience in midlife was the dominant contributor to this effect. In a 2-3 year follow-up study, they also found that the rate of hippocampal atrophy in late-life, in those who had more than 10 years of high level supervisory experience in midlife, was five times slower than the hippocampal atrophy of those with no midlife supervisory experience\(^4\). Rovio et al. (2007) researched the relationship between work-related physical activity (occupational or commuting physical activity) and cognitive disease in North Karelia. This study showed that, although people with a low level of commuting physical activity significantly reduced their risk for AD (approximately 60% compared to moderately active work), high commuting physical activity also reduced AD; but there was no consistent relationship between AD and commuting physical activity. The authors did not find this type of physical activity to be sufficient to protect against dementia and AD as people aged\(^4\). Type of work-related physical activity appears to be more important than the amount. Hippocampal volume change might explain this mechanism.

**Activities of daily life (ADL) and instrumental activities of daily life (IADL).** Many previous studies reported a relationship between ADL, IADL and cognitive function. McGuire et al. (2006) performed a 2-year follow-up study on 4,077 community-dwelling civilian men and women who were least 70 years old. They revealed that people with the lowest level of cognition had 1.5 times greater ADL and IADL disability than those who were disability-free. Furthermore, cognitive functioning was not predictive of individual ADL, but was predictive of some IADLs such as preparing meals, shopping for groceries, managing money, telephone use, light housework and managing medications, but not heavy housework\(^5\). Also, Fauth et al. (2012) performed Cox regression analysis for 8 years, in a longitudinal study in northern Utah, and reported that ADL disability increased the risk of dementia by 83% (HR: 1.83, 95% CI: 1.48 - 2.27)\(^4\). Furthermore, once individuals begin to suffer from ADL and IADL disabilities, they experience a faster cognitive decline as displayed in Fig. 1\(^5\). Some studies focused on mild cognitive impairment (MCI) and said that older people with MCI had difficulty performing their IADLs\(^6\). Azuchi’s longitudinal study on Japanese community-dwelling elderly persons, aged 65 years and older, found a significantly greater risk (a factor increase of 2.4 - 9.4) among individuals with MCI of losing their ability to perform ADL and IADL compared to those with intact cognition\(^6\).

**Effects of social community.** Social relations, including social networks, social integration and social engagement greatly impact cognitive decline and dementia. Fratiglioni et al. (2000)\(^5\) performed a 3-year follow-up examination on individuals with good cognition aged 75 years or

![Fig. 1](image-url) Change in cognitive function among nondisabled and those disabled at fourth year of observation. (A) Activities of daily living (ADL) disability. (B) Instrumental activities of daily living (IADL) disability. Vertical line shows standardized score of cognitive function test battery. [Rajan KB et al., 2012]
greater living in Stockholm (Sweden). They looked at the effect of these three types of social relations on the development of dementia. They also assessed the combined effect of their structural and qualitative features and created an index summarizing their different components. Being single and living alone emerged as the strongest determinant of dementia, almost doubling the disease risk, and having children with frequent but unsatisfying contact was related to an increased incidence of dementia (OR: 2.0, 95%CI: 1.2 - 3.4). The relationship between availability of relatives/friends and development of dementia was not modified by frequency of contact or feelings of satisfaction. Moreover, they showed a clear pattern: individuals with a moderate, limited or poor social network were at increased risk of dementia when compared to those with an extensive social environment. The relative risk for a poor or limited social network compared with an extensive or moderate social network was 1.6 (95% CI: 1.2 - 2.1). Zunzunegui et al. (2003) analyzed data from a longitudinal study of community-dwelling older men and women over age 65. They found that those with poor social networks, little social integration and social engagement are at high risk of cognitive decline, and the nature of the social relationships associated with maintaining cognitive function differ by gender in older adults. This study indicated that the frequency of visual contact with relatives and their social integration are positively associated with cognitive function in both men and women. However, engagement with friends is also significantly associated with good cognitive function in women. Karp et al. (2006) focused on mental, physical and social activities, and indicated that all three activities are related to risk of dementia (Relative risk, 0.71, 0.68, 0.61, respectively). They suggested that a broad spectrum of activities containing more than one of the components is more beneficial than engaging in only one type of activity.

Effects of exercise training on cognitive function

Endurance training. Regular participation in moderately intense physical activity increases the heart’s ability to deliver oxygen to the working muscles and is indicative of an increase in cardiovascular fitness. These gains in cardiovascular fitness are thought to be associated with changes in underlying physiological mechanisms such as cerebral structure, cerebral blood flow and brain-derived neurotrophic factor (BDNF), which are themselves associated with cognitive performance. In a study on the relationship between aerobic fitness and cognitive function, moderately-fit older adults achieved significantly better results on the global cognitive score, and a significant correlation was found between peak VO2 and attention, executive function and global cognitive score. The trend for superior cognitive scores in the moderate-fitness group compared to the low-fitness group was unequivocal, both in terms of accuracy and reaction time. One of the reasons for the difference in cognitive scores between these two groups is the cognitive deficits associated with reduced pulmonary function.

Nagamatsu et al. (2013) conducted a 26-week single-blinded randomized trial for women in Vancouver to determine if verbal memory, verbal learning and spatial memory performance, at the end of the trial, might be associated with physical performance measures. In this study, the aerobic exercise group improved in verbal and spatial memory performance. Predovan et al. (2012) targeted sedentary older adults (i.e., a lack of or irregular physical activity) to determine if the benefits of aerobic exercise extend to different executive processes measured by using a modified version of the Stroop task. They showed that subjects who participated in 3 months of aerobic training improved their inhibition/switching Stroop test performance compared to the control group (Control group change: 133 sec to 135 sec; Training group change: 136 sec to 126 sec). Smith et al. (2010) performed a meta-analytic study and revealed that aerobic exercise improves attention, processing speed, executive function and memory, but not working memory (Fig. 2-5).

Resistance training. In recent years, strength training has been reported as a potentially useful exercise to facilitate independence in daily life and to prevent falls in weak, elderly individuals. Accordingly, interesting findings from several studies have shown that strength training might also have psychological aspects. Liu-Ambrose et al. (2010) performed a 52-week resistance training intervention in a randomized control trial (RCT) with community-dwelling women aged 65 - 75 years. They tested the effect of resistance training on cognitive function by looking at executive function (Stroop test), set shifting (Trail making test) and working memory (Verbal digit span). They reported that resistance-training (RT) groups significantly improved their performance on the Stroop test compared with those in the balance and tone (BAT) group (RT group: 45.0 to 40.9 vs. BAT group: 44.0 to 43.8). Cassilhas et al. (2007) also performed a resistance training intervention with a RCT and revealed that the Moderate and High load groups scored higher than the control group on short-term memory (Digit-span forward score change: 0.51 and 0.50 vs. -0.47), visual modality of short-term memory (Corsi’s block-tapping task backward score change: 0.97 and 0.95 vs. 0.00) and long-term episodic memory (Rey-Osterrieth complex figure immediate recall: 8.38 and 8.31 vs. 5.17). Attention improved only in the High load group (Toulouse-Pieron concentration test errors change: -4.85 vs. 5.52).

Chang and Etnier (2009) studied the dose-response relationship between resistance exercise intensity and cognitive performance. When their subjects trained at intensities of 40%, 70% and 100% of their 10 repetition maximum load, there was a weak but significant linear
Fig. 2  Effect of aerobic exercise on attention and processing speed (n = 24). Individuals randomized to aerobic exercise treatment exhibited improved attention and processing speed relative to controls (g = .158 [95% CI: .055 to .260], P = .003). Each study is denoted with a circle, with larger sample sizes corresponding to larger marks. [Smith PJ et al., 2010]

Fig. 3  Effect of aerobic exercise on executive function (n = 19). Individuals randomized to aerobic exercise treatment exhibited improved executive function (g = .123 [95% CI: .021 to .225], P = .018). Each study is denoted with a circle, with larger sample sizes corresponding to larger marks. [Smith PJ et al., 2010]
Fig. 4  Effect of aerobic exercise on memory (n = 16). Individuals randomized to aerobic exercise treatment exhibited improved memory relative to controls (g = .128 [95% CI: .015 - .241], P = .026). Each study is denoted with a circle, with larger sample sizes corresponding to larger marks. [Smith PJ et al., 2010]

Fig. 5  Effect of aerobic exercise on working memory (n = 12). Individuals randomized to aerobic exercise treatment did not exhibit significant improvements in working memory relative to controls (g = .032 [95% CI: -.103 to .166], P = .642). Each study is denoted with a circle, with larger sample sizes corresponding to larger marks. [Smith PJ et al., 2010]
or quadratic trend effect of exercise intensity on information processing speed tested under various Stroop test conditions ($R^2=0.11 - 0.19$). Those results indicate that resistance training can benefit speed of information processing, executive functions and memory function. Furthermore, the dose-response effect on cognitive function may be relative to exercise intensity.

**Other trainings.** Multiple exercises have been tried in older adults to improve cognitive function or prevent dementia. Alkin et al. (2007)\(^70\) applied individual, language-enriched physical fitness interventions (aerobic, resistance and balance training) to 24 mild- to moderate-stage Alzheimer’s patients. Changes in global functioning and neuropsychological test performance were tracked and compared to those of a similar group of untreated patients from the Consortium for the Establishment of a Registry for Alzheimer’s Disease. Rikli & Edwards (1991)\(^71\) provided low-impact aerobic exercise and general calisthenics 3 times per week over 3 years for 31 female volunteers aged 57 - 85. Cognitive function improved in the exercise group as measured by simple (Exercise group: 287 ms to 274 ms vs. Control group: 285 ms to 291 ms) and choice (Exercise group: 352 ms to 318 ms vs. Control group: 380 ms to 392 ms) reaction times. This suggests that exercise is effective in reversing or at least slowing down certain age-related declines in motor performance and speed of cognitive processing.

An RCT conducted by Williams et al. (1997)\(^72\) showed that mixed aerobic and resistance training programs over 12 months could improve reaction time (275 ms to 271 ms) and memory span (15.21 to 16.25) when compared with control subjects. Compared to groups who received other training, those who received 6 months of Tai-Chi exercise improved and maintained cognitive function with regard to attention, concentration and mental tracking as assessed by a Backward Digit-span test\(^73\).

**Mechanisms of effects of exercise training on cognitive function**

According to one review article\(^74\), there are several potential mechanisms that may underlie the association between physical activity and reduced risk of cognitive decline and dementia. Physical activity may reduce vascular risk, obesity, or levels of inflammatory markers, all of which are interrelated. In addition, reducing these factors has been associated with reduced risk of cognitive decline and dementia. Physical activity may also directly lead to enhanced neuronal health and function minimizing the clinical effect of neuronal loss that may occur early in the dementia process. The existence of plausible biological mechanisms provides further evidence supporting a causal association between physical activity and reduced risk of cognitive decline and dementia in older adults (Fig. 6).

**Endurance training.** The finding that aerobic exercise improves memory is consistent with several animal studies that show physical activity increases BDNF in the hippocampus and other body parts. BDNF in the lumbar spinal cord and the hippocampus increased in rats performing aerobic exercise. Russo-Neustadt et al. (2004)\(^75\) studied BDNF in the hippocampus and showed that short-term exercise significantly elevated full-length BDNF levels in all hippocampal areas (144% - 252%). Gomez-Pinilla et al. (2002)\(^76\) evaluated the possibility that exercise induces an integrated response of BDNF in an animal model study. This study revealed that the BDNF mRNA level in rats’ spinal cords (142%) and soleus muscles (175%) increased after running on wheels for 7 days. A

![Fig. 6](image-url) Potential mechanisms that may underlie the association between physical activity and reduced risk of cognitive decline and dementia in older adults.
few studies on humans also looked at BDNF levels. Griffin et al. (2011)\(^7\) investigated possible causal links between increased availability of the growth factors BDNF and IGF-1 and enhancements in cognitive function. They showed that memory function improved and BDNF increased significantly after 5 weeks of acute exercise. These results provide evidence for a link between acute exercise and cognitive function. Acute exercise has been shown to increase serum BDNF and selectively improve medial temporal lobe dependent memory. Hence, BDNF is a proposed mediator of the cognitive enhancements described, possibly through its reported role in mechanisms underlying synaptic plasticity.

**Resistance training.** Strength training may improve neurocognitive function by increasing insulin growth factor (IGF), which has been noted as a mediator of the exercise and neurocognition relationship. Ding et al. (2006)\(^8\) showed that rats that performed wheel exercise with a load significantly increased IGF-1 mRNA levels in the hippocampus (138 ± 13%) above sedentary control levels, suggesting that interfaces with the BDNF system mediates exercise-induced synaptic and cognitive plasticity. Similarly, resistance training in humans increased IGF-I levels. Borst et al. (2001)\(^9\) studied the longitudinal relationship between changes in IGF-I and increases in strength that occur as a result of intensive resistance training in previously sedentary persons aged 25-50. Furthermore, they also assessed the impact of training volume on IGF-I and found that resistance training was associated with increased strength and a significant increase, but not a dose-response effect, on circulating IGF-I (1-set group: 20.5%, 3-set group: 18.5%). Hameed et al. (2003)\(^10\) observed a 68% increase of IGF-Ia in 70 - 82 year-old male subjects with strength training.

**Other mechanisms.** Another mechanism by which exercise may slow dementia is by decreasing amyloid load. Adlard et al. (2005)\(^11\), using an animal model, showed that 5 months of voluntary exercise decreased extracellular amyloid-β (Aβ) plaques in the frontal cortex (38%), in the cortex at the level of the hippocampus (53%), and in the hippocampus (40%). The mechanism appears to be mediated by a change in the processing of the amyloid precursor protein (APP) after short-term exercise, because 1 month of activity decreased the proteolytic fragments of APP for α-C-terminal fragment (α-CTF). A human model was used to assess whether exercise moderates the effects of apolipoprotein E (apoE) in normal, middle-aged and older adults\(^12\). There was a significant Exercise Group × apoE status interaction suggesting that a physically active lifestyle may reduce brain amyloid level.

**Conclusion**

The data are not always sufficient for showing the evidence whether cognitive function could be improved through regular exercise and a physically active lifestyle in older adults. Although several potential mechanisms, that may underlie the association between physical activity or exercise training and reduced risk of cognitive decline, have been revealed, larger studies are still required to confirm these findings.

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