Review paper

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Mind over Matter: Flexing cognitive muscles through exercise, training, and dieting to combat age-related cognitive decline

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Abstract
Cognitive decline is a natural consequence of aging; regardless of health status. Symptomatic of cognitive decline with age is a general decay in a variety of areas, such as executive function, processing, language, fine motor skills, and various types of memory. This is termed age-related cognitive decline. There have been many attempts at slowing down or reversing the effects of age related cognitive and physical decline. Some of the different approaches reviewed in this paper include increased physical activity, eating a particular diet, and/or cognitive training. The brain has a lifelong capacity for plasticity and adaptation, which implies that 'reversal' approaches should be able to at least partially restore cognitive functioning, memory and therefore, the quality of life in healthy older adults. Even after age related natural brain decline, specifically designed strategies should be able to (re)train the brain and reverse cognitive decline. Results from studies addressing each of these strategies are reviewed and discussed. The studies provide insight and evidence as to how cognitive training, exercise, and dieting/nutrition are all promising non pharmaceutical and implementable ways to improve overall cognition and prevent neurodegenerative diseases in healthy older people. The analysis presented in this paper also recommends that the legacy variable of 'linear age' be replaced by the quantifiable variable of 'cognitive age' in any future studies which correct for age, so as to arrive at true age independent results.

Keywords
Aging, Cognitive decline, Exercise, Nutrition, Cognitive training, Neuroplasticity, Mediterranean diet, Yoga, Tai chi, Aerobic exercise

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Introduction

Although no one wants to get older, aging is an inevitable development. Aging results in a decline in physical health, mental health, and cognitive health. There is yet no way to reverse aging. It is estimated that in 2023, every 1 in 6 persons will be over the age of 60 (1). This large increase in elderly population is accompanied by age-related cognitive decline, which can be characterized by a deterioration in the attributes of thinking, memory, language and judgement, among others. Cognitive decline has become a leading cause of mental disability in the elderly. It is estimated that 55 million people currently live with dementia, and 10 million people are diagnosed yearly, causing it to be the 7th leading cause of death in the world (2). Though not all age-related cognitive decline leads to dementia, the process of cognitive decline increases the propensity for neurodegenerative diseases and mental disorders.

While there is, again, no cure for aging, there are many ways to protect against cognitive decline and its related diseases. As the number of elderly individuals grow, so does the need to determine how to delay cognitive decline. This topic of delaying and/or decreasing age-related cognitive decline has attracted interest of late, and there has been much research done which focuses on taking advantage of the plasticity of the brain and its ability to adapt. Recent advances in medical imaging techniques have helped to show that the brain does, indeed, have lifelong plasticity, even in the case of extremely advanced age and dwindling physical health, though plasticity at this stage is significantly decreased than that in younger, healthier individuals (3,4). The goal is to increase plasticity in those with advanced age using a number of possible techniques.

Overview

This review will evaluate some of the popular approaches towards the issue of age-related cognitive decline and the most promising ways to increase neuroplasticity. Many daily activities, such as physical exercise and brain stimulation are thought to increase brain plasticity, and adherence to a healthy diet may also decrease or slow cognitive decline. This review will present a discussion of studies and clinical trials of each method, emphasizing their results and efficacy. Finally, there will also be a discussion of the ways to apply the results of this paper to elderly persons who are at risk of cognitive decline.

Cognitive training

Cognitive training, which usually takes the form of a stimulating activity designed to target one or more specific cognitive functions, (5,6) is one of the potential ways to decrease cognitive decline. From video games to solving crosswords, cognitive training includes a broad range of activities (7). Despite the many different types of cognitive training, studies show that most forms of cognitive stimulation are associated with increased brain plasticity and a resulting improvement in various executive functions (8).

Puzzles have been used for a long time as cognitive training tools, and the impact of puzzles has been supported by results from multiple studies. In a study conducted by Li et al. (9) focused on cognitive reasoning and processing by using various puzzles, 70 healthy participants between the ages of 65-75 were recruited, split into multi-domain, single-domain, and control groups. The multi-domain group focused on memory, reasoning, and problem solving, while the single-domain group targeted exclusively reasoning. The study used time-domain entropy and functional entropy to quantify neuronal activity. Entropy can be used to measure the degree of uncertainty in a probability distribution. Both types of entropy improved with training, and there were correlations between changes in entropy observed for regions such as the hippocampus and improvements of cognitive performance. More studies have assessed the effect of puzzles on global visuospatial cognition (10,11), as measured by pre test and post test scores on eight visuospatial cognitive ability attributes. Most show a positive effect.

Often more popular than general cognitive training, is computerized cognitive training, especially now, in the technology age. Video games, computerized tasks, and virtual reality are all forms of computerized cognitive training that have the potential to increase neuroplasticity. Research shows that computerized training has a positive impact on brain health (12-17). Computerized training significantly improved older adults' scores on the Repeatable Battery for Neuropsychological Status (RBANS) Auditory Memory/Attention test, demonstrating that they improved in the subset measures of memory and attention (12). The RBANS is a screening test that examines attention, language, visuospatial abilities, and memory (18). Computerized cognitive training also resulted in an improvement in trained tasks such as the Pearson's Cogmed Working Memory trained task and in untrained tasks that depend on working memory and processing speed (13). The Cogmed trained tasks measure attention and working memory (14). Significant improvement was also seen in the performance of five neuropsychological tests, Trail Making Test Part A and Part B, Digit Symbol, Controlled Oral Word Association Test and Semantic Fluency. Computerized cognitive training has also been shown to improve mental health, specifically in reducing anxiety, as shown through a decrease in anxiety symptoms (15), and scoring lower on the GAI (Geriatric Anxiety Inventory) after training (16).

The studies discussed above typically comprised of smaller sample sizes. Ball et al. conducted a study with nearly 3000 healthy elderly aged individuals between 65 and 94 years (a three decadal age difference). The participants were enrolled into 6 field sites across the United States in 4 groups (19). After normalizing for age, gender, education level, and marriage status, subjects were randomly assigned to four groups, each undergoing a different form of training (memory training, reasoning training, speed-of-processing training and no-training (control)). Over 5-6 weeks, interventions were conducted in small group settings in ten 60–75-minute periods. The Speed of processing training was the most successful, with 87% of speed-of-training participants demonstrating measurable cognitive improvement. Several follow up studies were performed (20,21), to determine the effect of the treatments after five and ten years. Willis and others (20) concluded that, after five years, various cognitive training treatments maintained their intended effects on cognitive abilities such as memory, reasoning, and speed of processing. With additional training after 11 and 35 months, the results showed additional improvement. In a similar study conducted by Rebok et al. (21), however, it was found that after ten years, memory training effects were no longer maintained, except for effects obtained from reasoning and speed of processing interventions. Therefore, the duration of the effects of cognitive training are, as yet, undetermined, although anecdotal evidence argues for long-term lasting decelerating effects of cognitive training on age-related cognitive decline.

The overall findings of these studies are that cognitive training, both general and computerized, can decrease age-related cognitive decline. Cognitive training often targets one specific cognitive domain, typically memory, attention, processing speed, and/or language.

Physical training and exercise

There are many studies that demonstrate how exercise and physical training benefit and protect the human mind in multiple ways (22-28). Some studies also demonstrated a positive correlation between brain plasticity and physical training (29,30). Other than brain health, exercise is also a way to maintain physical health, and maintaining good physical status has been known to lower the probability of contracting metabolic disease, diabetes (31), cancer (32), and various cardiovascular diseases (33). This results in increased general well-being.

Low impact exercises such as walking, Pilates, Yoga and Tai chi are likely the most elderly-friendly exercises, because they do not require strenuous physical effort and yet provide meaningful cardiovascular priming. Not only are they safer, but they also provide positive cognitive benefits.

Tai chi is a form of Chinese martial art that involves slow, gentle movements. Tai chi also controls breathing and state of mind, along with balance, thereby demonstrating its benefit on many parts of the human body. Supporting this notion, a meta-analysis by Wayne et al. (34) involving twenty studies and a total of 2553 participants found that in cognitively healthy elderly adults, tai chi showed potential to enhance executive functioning. Similarly, Liu et al. (35), compared 33 studies with a total of 1808 participants. Improved scores were found on the Montreal Cognitive Assessment Scale, Mini-Mental State Exam (MMSE), and Trail Making Test Part-B cognitive function tests.

Another form of low impact exercise is Yoga. Yoga is a type of exercise that includes physical, mental, and spiritual attributes. It originated in ancient India (36). It has been shown to play a key role in strengthening memory, awareness, and learning (37). Hishikawa et al. (38) tested a total of 385 subjects who participated in a 12-month exercise program. They found that Yoga, when included with other exercises improved the mean scores obtained on multiple tests of cognitive function, as well as improving physical functionality. Gothe et al. (39) reviewed 11 studies that sought to determine the effects of Yoga on brain structures, and after assessment using MRI, fMRI, and SPECT, concluded that Yoga demonstrated a positive effect on the function of the hippocampus, amygdala, prefrontal cortex, and cingulate cortex.

Aerobic exercise has been shown to have a positive impact on cognitive health (40,41). This form of exercise works the cardiovascular system; the heart rate and breathing rate increase during aerobic activities. Aerobic exercise includes activities like jogging, swimming, or cycling (42). The Centers for Disease Control and Prevention (CDC) recommend 150 minutes of moderately intense aerobic activity per week for adults 65 and above to stay healthy (43).

Dustman et al. (44) studied the effects of an aerobic exercise program, including strength and flexibility exercises, versus subjects who did not exercise. It was found that aerobic exercise increased cerebral metabolic activity, with participants scoring better on neuropsychological tests than their control cohort counterparts. Miyazaki et al. (45) studied 88 cognitively healthy older adults, placing them into a walking, dance, or control group. Both the walking and dance programs improved neurological functions of participants, with dance training being even more effective.

Aerobic exercise has also been shown to promote brain plasticity in older adults. Colmenares and others studied the effect of aerobic exercises, including walking and dancing interventions, on white matter in healthy older adults (46). They measured the differences using MRI imaging, and found that there were positive changes in the late-myelinating regions. Myelination is the forming of a myelin sheath around a nerve, which allows for improved conduction and cognitive function (47). The hippocampus and amygdala are included in the late-myelinating regions.

While aerobic exercise is helpful for improving circulation, resistance training is another beneficial type of exercise that focuses on building and strengthening muscles (48). There are, however, less studies that sought to determine the effects of resistance training on older adults, likely because this king of training is too strenuous for the elderly. Resistance training has been studied for its potential benefits towards cognitive processing (49) and memory (50). For example, in a 12-month randomized controlled trial, Liu-Ambrose and others (49) studied 155 elderly women who either resistance trained once a week, twice a week, or balance and tone trained in the control group. Compared to the control group, the resistance training groups improved their performance on the Stroop Test, demonstrating improved cognitive processing and selective attention. Coelho et al. (50) studied the effects of resistance training along with combined resistance and power training on 45 healthy older women. They found that resistance training and combined training both resulted in overall improvements in cognitive function and short-term memory. However, these studies only followed women and it is unclear if the same benefits could be accrued by men.

For more conclusive studies that support the benefit of resistance training, some reviews and meta-analyses were also found in the literature. Cheng and colleagues (51) performed a meta-analysis on 257 studies and found that resistance exercise did have a beneficial effect on brain function, and could delay cognitive degradation attributes such as memory and attention decline. In another systematic review, Herold et al. (52) analyzed 18 studies, finding evidence that resistance exercises and training showed improvements in executive functions, and led to lower white matter atrophy. Similarly, Li et al. (53) compared 12 articles, and found that resistance training had positive effects on executive function, but did not significantly affect memory and attention. They did, however, state that further studies were needed to assess the development and application of resistance training. A systematic review and meta-analysis by Falck and others (54) that included 48 studies found that exercise induced a positive effect on cognitive function. The overall conclusion was that resistance training may improve executive functions of the brain in healthy older people.

Other than simply seeking to determine how different exercises benefit cognitive health in healthy older adults, it is also important to determine which type of exercise and how much exercise has the most positive effect. Gallardo-Gomez et al. (55) reviewed the optimal amount (dose) and type of exercise to improve cognitive function in older adults. After examining 44 studies, they concluded that there was no minimal dose of exercise for beneficial effect, and that low doses of exercise; especially resistance training; still improved cognition in older adults.

Combining physical exercise with cognitive training is another potential treatment for improving cognition in healthy older adults. There are many studies either comparing one of the treatments or both (56,57). Brinke et al. (58) studied the effects of cognitive training with and without physical training on cognition, and found that though there were no significant differences in memory, the exercise and cognitive training group's results improved significantly in the Stroop test and others designed to assess physical and neurological health levels. Castaño and colleagues (59) studied 30 healthy older adults and their responses to either resistance training or to resistance training plus cognitive training. It was found that improvements in cognitive function were only observed after both resistance training and cognitive training, which contradicted many other studies that found cognitive increases solely with resistance training.

Physical training, both aerobic and resistance exercises have been shown to improve cognitive and/or executive functions. Exercise is particularly beneficial due to the fact that it focuses on both cognitive health, as well as physical health. Regardless of the neurological benefits, a regular exercise regimen is recommended for people of all ages for its general health benefits (60-62).

Nutrition

A dietary and nutritional approach toward decreasing age-related cognitive decline is also important. Whether consuming a plant-based diet or a different intake ratio of proteins, fats and carbohydrates, there are many different foods and nutrients that hold potential (63-66). Additionally, there is a correlation between obesity and cognitive decline in later life (67). The incidence and onset of obesity and metabolic disease can be decreased and prolonged respectively by eating a healthy diet.

The Mediterranean diet (MeDi) has been shown to reduce the risk of cardiovascular diseases, cancer, and diabetes, and is associated with improvement in health status (68-70). It has recently been linked to better cognitive function as well (71). It consists of many plant-based foods and healthy fats, including vegetables, fruits, fish, whole grains, and olive oil, and does not contain a significant amount of red meat (72). Loughrey and colleagues (73) reviewed and analyzed the impact of the MeDi on cognitive function in healthy older adults using 15 studies with over 40,000 participants. Evidence suggested that the MeDi had a significantly beneficial effect on global cognition, and less significant but still beneficial effects on memory, and executive function. A similar meta-analysis by Coelho-Júnior et al. (74) investigated 19 studies assessing the impact of the MeDi on healthy older adults, finding that it was associated with both physical and mental benefits. Similar to the study by Loughrey et al., favorable scores on the Mini Mental State Examination provided evidence that the connection between global cognition and MeDi was strong. Titova and others (75) obtained data from 194 healthy individuals who kept diaries of their food intake for one week. They found that MeDi, which consists of a very low intake of meat, was linked to a greater brain volume and to a better performance on the seven minute screen (7MS) test, which is used to determine if a person is developing dementia (76). Qin et al. (77) studied how the dietary patterns of Chinese elderly individuals affected cognitive decline, concluding that an adapted MeDi or a wheat-based diverse diet reduced the rates of cognitive decline in the older Chinese population (difference in mean standardized unit [SU] change/year $\beta=0.042$).

However, studies have also found negative results regarding the effectiveness of the MeDi. Cherbuin et al. (78) assessed 1528 individuals who followed the MeDi, and found that adherence to the diet was not protective against cognitive decline in older individuals, and that excessive caloric intake could lead to cognitive diseases like Mild Cognitive Impairment (MCI) or dementia. Due to studies that report conflicting results, the effectiveness of the MeDi diet is on cognition in healthy older individuals cannot be conclusively determined. Anecdotal data, however, do argue for a cognitive benefit.

Other than adhering to a specific diet, studies also sought to determine the effects of specific foods. A review by Rajaram et al. (79) identified some of the common plant foods in plant-based dietary patterns, and determined how each of these foods affected different cognitive domains. They first addressed studies of polyphenol-rich fruit juices, such as orange, grape, and pomegranate. Polyphenols are a type of plant compound that have many health benefits and are prominent in fruits (80). Fruit juices appeared to improve global or domain-specific cognitive functions. They also compared studies that sought to determine different dietary patterns and how they affected the brain. These dietary patterns included vegetable-fruit based diets, higher calorie diets and wheat-based diets, among others. Overall, studies showed that red meat, butter, fried foods, and sweets tended to hasten the onset or accelerate cognitive decline, whereas plant foods rich in antioxidant nutrients protected the brain and improved global cognition. Cocoa is also a food rich in polyphenol, and is often studied for its effects on cognition. Rajaram et al. found that longer exposure to cocoa improved cognition in older adults. Similarly, coffee and tea are also both good sources of polyphenols. Chronic intake of coffee and tea seemed to lower the risk of cognitive disorders. Finally, tree nuts and legumes are also rich in polyphenols. Elderly individuals who consumed high amounts of nuts had better overall cognitive performance. A more specific study that focused on walnuts found that consuming walnuts frequently led to faster reflex reaction times and better recall test scores. The conclusion in this review was that foods richest in polyphenols exhibited the most beneficial effects on cognitive function, though how the dose, subclasses of polyphenols, and synergism between plant foods affected cognitive functions was less clear.

The WHO and CDC recommend eating a varied but preponderantly plant and fiber based diet to keep healthy and prevent chronic non communicable metabolic diseases and obesity (81,82). Some foods have a beneficial effect on cognitive health as well, particularly foods with high levels of polyphenols. These foods should be consumed more frequently, since they have been shown to improve age-related cognitive decline.

Comparing diet and exercise

Studies have also been performed to determine the effect of both diet and exercise together on cognitive decline in elderly participants. Imaoka et al.'s 2019 study (83) compared the influence of exercise alone and exercise + diet using a two-way ANOVA test. Using a p-value of 0.05, the test determined that there was a significant difference between the two cohorts on the Trail Making Test (TMT), gait speed, and grip strength. They concluded that a combination of exercise and dieting was effective in improving the tested attributes of cognitive function.

To determine the exact effect of diet and exercise on cognition, the Centers for Disease Control and Prevention (CDC) created the National Health and Nutrition Examination Survey (NHANES), which used questionnaires to collect data on various health related variables, including cognitive functioning, diet and nutrition, and physical activity. Using a linear regression model, the exact relationship between diet and nutrition with cognitive health was found. Results showed that the average level of physical activity each day (none, moderate, heavy) had a moderate, but non-significant effect on cognitive functioning ($p=0.067$) in the single model and a non-significant effect ($p=0.12$) in the multivariate model. However, eating dark green vegetables was significantly correlated to the cognitive functioning score in both the single and multivariate models, with p-values of 0.005 and 0.008 respectively. The NHANES data taken together with Imaoka's study (83) suggests that diet may have a stronger effect on cognitive functioning than does exercise (Table 1).

Table 1. Effect of diet and nutrition on cognitive functioning

Model	Single Model		Multivariate Model	
	Estimate	p-value	Estimate	p-value
Avg level of physical activity each day	1.69	0.067	1.45	0.116
# times/month eat dark green vegetables	0.128	0.005	0.121	0.008

Discussion

Based on the studies in this review, cognitive training, physical training, and eating a specific diet/food, have beneficial effects on the brain, and may be an effective and non-pharmaceutical way to delay or decelerate age-related cognitive decline. Additionally, as dementia and mild cognitive impairment become more common, prevention becomes increasingly important. Engaging in some form of physical activity or cognitive training daily is beneficial, and it should be recommended for both cognitively healthy as well as unhealthy older adults (84). However, there is a paucity of studies which compare the strategies to decrease cognitive decline, hence it is difficult to conclude which of those strategies is most effective. Knowing this could be advantageous, since it would rank order interventions in the order most worth pursuing. This highlights a need for future studies to better understand the extent of how helpful cognitive training, exercise, and dieting are - especially when compared to one another – in delaying or decelerating age related cognitive decline.

Age could be a potential confounding factor in the studies discussed. Though each of these studies were targeted toward healthy older adults, the age range was not the same for every single one. Comparing a 65 year old with an 80 year old would lead to inaccurate results, demonstrating that perhaps further research is needed to compare the effects of different interventions on different age groups. One way to do this could be to look at the individual data and compare subjects older or younger than a certain age. For example, in the study by Li et al. (11), the mean age of participants in the cognitive training group was 70.54 years with a standard deviation of 3.23 years, whereas the mean age of participants in the control group was 68.59 ± 3.24. As humans age, brain volume begins to decrease at a faster rate, leading to declines in cognitive ability (85). According to studies investigating the age-related changes in brain volume (86,87), around the age of 35, brain volume loss is ~ 0.2%, which then becomes ~ 0.5% at age 60. After age 60, this percentage greatly increases, reaching ~ 2.1% at age 70. Li et al.'s study claimed that functional entropy increased significantly less in the cognitive training group (p=0.047) compared to the control group, demonstrating a clear benefit of cognitive training. However, even though the linear ages in the different groups were not statistically different, their cognitive abilities could have been. Using the linear relationship, $y= 0.16X - 9.1$, where y = cognitive ability score and X=age, the cognitive ranges of the two groups were calculated as (1.356 to 2.3928) and (1.6696 to 2.7032) (86,87). This means that the actual functional entropy (corrected for cognitive age) was not significantly different between the two groups ($p>0.05$). This underscores the important point that studies performed on geriatric populations should normalize for 'cognitive age' rather than the conventional norm of only accounting for 'linear age'." This was, however, not adjusted for in the Li study, and if done so, the p-value could become insignificant. Another example of age being a potential confounding variable in the literature can be shown in a study by Imaoka et al. (83), which sought to determine the effect of combined exercise and nutrition support compared to exercise alone on cognitive function in older adults. The study found that on the TMT-A (trail making test), there was a significant difference in scores of those in the exercise + nutrition group versus those in the exercise alone group. The trail making test reflects many cognitive processes such as attention, flexibility, visual search etc. However, the study did not account for the fact that there was a mean age difference of 2 linear years between the groups. The mean age of those in the exercise + nutrition group was 74.4, compared to a mean age of 76.3 in the exercise group. This could account for the significant difference in TMT-A scores, and if adjusted for 'cognitive age', could make the data either non-significant or much less significant.

Another potential confounding variable in the studies could be not adjusting for socio-economic status and/or education. Since many of these studies used mental examinations such as the Stroop Color-Word Test to determine the effect of treatments, it is possible that those with more years of education scored better than those with less. For example, in a study on resistance training and executive functions by Liu-Ambrose et al. (49) the Stroop Test was used to measure outcome. However, the baseline characteristics of trial participants showed that the BAT group (control group), had a mean of 19 people with university degrees while the 2x RT group (double resistance training group) had a mean of 22 people with university degrees. The study concluded that the resistance group significantly improved their performance on the Stroop Test, with $p \leq 0.03$. However the difference in education among these groups was not accounted for. A 2006 study on the Stroop Color-Word Test (88) sought to determine the influence of age, sex, and education on scores. The study found that executive function decline was more pronounced in individuals with a low level of education, supporting the idea that normalizing for level of education could change the results.

To find out the exact effect of age, sex, education, and income (socio-economic status) on age related cognitive decline, the data from the NHANES surveys was used again. The surveys included data on both demographic and cognitive functioning in adults 60+. Using a regression model, the demographic data and cognitive functioning data were concatenated, allowing the determination of the exact effect that each demographic had on cognition.

Results showed that age, gender, and education level (<9th grade, 9th-11th grade, high school graduate, some college, and college grad or above) each significantly affected the cognitive functioning score both in the single model and as a covariate in the multivariate model (Table 2). On the other hand, annual family income was not correlated to the cognitive functioning score in either model.

Table 2. Demographic data correlation with cognitive functioning

Model	Single Model		Multivariate Model	
	Estimate	p-value	Estimate	p-value
Age (years)	-0.89	<0.0001	-0.79	<0.0001
Gender (female vs male)	5.66	<0.0001	5.19	<0.0001
Education Level	6.44	<0.0001	6.14	<0.0001
Annual Family Income	0.02	0.769	-0.05	0.249

Though all of the studies only included healthy older adults as subjects, many also stated that there was not a comprehensive test to check participants for dementia or Mild Cognitive Impairment (MCI); rather, only a quick survey without any extensive screening was administered to participants. Many also allowed participants to self report. This could have led to inaccuracies because the effects of cognitive treatments would be very different on a healthy brain versus on a brain already in cognitive decline. For example, those with MCI, a condition where one might have worsened memory but no readily observable changes in overall behavior, might not even be aware of, or understand their symptoms. Moreira et al., found that participants with MCI scored lower on the Mini Mental State Examination (MMSE) than those with healthy cognition (89). Therefore, more conclusive screening for age-related cognitive diseases is needed, prior to inclusion, to provide accurate results.

It is important to remember that the goal of any intervention(s) is to improve the lives and cognition of older adults who may have MCI and dementia, which means it is important to think about how easy these interventions are to implement and/or the ease of acceptance and/or adoption by the participants. A 2013 study found that a diet with more fruits, vegetables, and nuts, cost an average of $1.50 more per day than a diet with more processed foods and meat (90). This may not be affordable for some elderly individuals who are retired and living on social security benefits and/or on food stamps. Furthermore, many nursing homes do not necessarily have the best meal plans that include foods that are cognitively beneficial.

Most of the studies concluded that temporally inconsistent cognitive or physical training did not have the same positive benefits that consistent training did. This means that someone using these interventions to decrease cognitive decline would need to remember to engage consistently on a day-to-day basis.

Considering that many elderly individuals have some memory impairment and/or MCI, they may train intermittently and/or inconsistently. This may reduce the efficacy of the intervention. However, there are easy tasks that have been shown to improve cognition that are also simple to perform and do not need to be formally remembered. Taking a walk and solving crossword or jigsaw puzzles every day are cheap, easy ways to train both cognitively and physically and can be incorporated into the daily routine of elderly individuals without much effort.

Follow-up studies are also essential. Though the few studies that did follow ups after the initial study found that regularly engaging in the interventions, typically continued to be beneficial, most studies did not explicitly test this. Without knowing how long the effect of an intervention lasted and whether the participant followed the intervention regularly, there is no way to determine whether the intervention made a significant difference to age related cognition decline. Even simple follow-ups such as sending a survey or calling the people involved in the study would be beneficial, though thorough retesting is the best way to determine the length of effectiveness in treatments. The ideal solution would be to design comprehensive longitudinal studies that address the factors and interventions in age related cognitive decline.

Conclusion

Though not overwhelmingly consensual, the balance of studies suggests that cognitive training, physical exercise and an appropriate healthy diet; each by themselves, and together, were able to significantly reduce or prevent age-related cognitive decline in healthy older individuals. Studies suggested that while there seemed to be no lower limit on how much (or little) physical exercise or cognitive training may be beneficial, the consistency with which these interventions were practiced significantly affected how long their effects lasted in delaying or decelerating age related cognitive decline. These daily interventions could be as simple as solving a crossword puzzle, taking a walk and eating a healthy diet composed of vegetables and fiber. Age, gender and education level were identified as confounding factors in the studies. The former was not corrected for in many studies due to a continued mistaken assumption in the literature of the existence of near uniform cognition levels among cohorts of 'elderly individuals'. However, this paper found that accurate incorporation of decadal cognition levels changed the conclusion of several studies. It is hence recommended that the legacy variable of 'linear age' be replaced by the quantifiable variable of 'cognitive age' in any future studies which correct for age, so as to arrive at true age independent results. Some studies also did not formally test participants for cognitive function prior to inclusion, therefore any differences in cognition pre and post study were unreliable. Uniform testing criteria need to be adopted for inclusion of healthy elderly individuals in studies that test age related cognitive decline. There is a paucity in the literature of comprehensive longitudinal studies that address the factors (individually and when combined) and interventions in age related cognitive decline. Such studies will build consensus among the scientific and medical community on the most effective non-pharmacological ways to prevent and/or slow age related cognitive decline so as to enable the elderly population to enjoy a better quality of life.

References

1. Ageing and health. World Health Organization, 2022, https://www.who.int/news-room/fact-sheets/detail/ageingandhealth#:~:text=At%20this%20time%20the%20share,2050%20to%20reach%20426%20million.

2. Dementia, World Health Organization, 2023, https://www.who.int/news-room/fact-sheets/detail/dementia

3. Pauwels L, Chalavi S, Swinnen S. Aging and brain plasticity. Aging (Albany NY)., 10: 1789-1790, 2018, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6128435/

4. McGill University. New insight into aging: Plasticity is enhanced but dysregulated in the aging brain. Science Daily, 2018, www.sciencedaily.com/releases/2018/09/180919115827.htm

5. What Is Cognitive Training?. BrainWare, https://mybrainware.com/what-is-cognitive-training/

6. Cognitive Training. direct. https://directindia.org/therapies/cognitive-training/#:~:text=Cognitive%20Training%20(CT)%20works%20on,the%20brain's%20core%20cognitive%20skills.

7. Johnson J. 22 brain exercises to improve memory, cognition, and creativity. MedicalNewsToday, https://www.medicalnewstoday.com/articles/brain-exercises

8. Commisso M. What Is Cognitive Training and Why Is It So Important to Invest in?. CoreSenses. https://www.coresenses.org.au/post/what-is-cognitive-training-and-why-is-it-so-important-to-invest-in#:~:text=Benefits%20of%20Cognitive%20Training,for%20reasoning%20and%20problem%2Dsolving

9. Li T, Yao Y, Cheng Y, Xu B, Cao X, Waxman D, et al. Cognitive training can reduce the rate of cognitive aging: a neuroimaging cohort study. BMC Geriatr., 16: 12, 2016, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4712458/

10. Fissler P, Küster O, Loy L, Laptinskaya D, Rosenfelder M, Arnim C, et al. Jigsaw Puzzles As Cognitive Enrichment (PACE) - the effect of solving jigsaw puzzles on global visuospatial cognition in adults 50 years of age and older: study protocol for a randomized controlled trial.

Trials, 18: 415. 2017, https://trialsjournal.biomedcentral.com/articles/10.1186/s13063-017-2151-9#Sec19

11. Fissler P, Küster O, Laptinskaya D, Loy L, Arnim C, Kolassa I. Jigsaw Puzzling Taps Multiple Cognitive Abilities and Is a Potential Protective Factor for Cognitive Aging. Front Aging Neurosci, 10: 299, 2018, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6174231/

12. Smith G, Housen P, Yaffe K, Ruff R, Kennison R, Mahncke H, et al. A Cognitive Training Program Based on Principles of Brain Plasticity: Results from the Improvement in Memory with Plasticity-based Adaptive Cognitive Training (IMPACT) Study. AGS, 57: 594-603, 2009, https://agsjournals.onlinelibrary.wiley.com/doi/10.1111/j.1532-5415.2008.02167.x

13. Simon S, Tusch E, Feng N, Håkansson K, Mohammed A, Daffner K. Is Computerized Working Memory Training Effective in Healthy Older Adults? Evidence from a Multi-Site, Randomized Controlled Trial. J Alzheimers Dis, 65: 931-949, 2018, https://pubmed.ncbi.nlm.nih.gov/30103334/

14. Pereira-Morales A, Cruz-Salinas A, Aponte J, Pereira-Manrique F. Efficacy of a computer-based cognitive training program in older people with subjective memory complaints: a randomized study. Int J Neurosci, 128: 1-9, 2018, https://www.tandfonline.com/doi/abs/10.1080/00207454.2017.1308930

15. Kuider A, Parisi J, Gross A, Rebok G. Computerized Cognitive Training with Older Adults: A Systematic Review. PLoS One. 7: 7, 2012, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3394709/

16. Brinke L, Davis J, Barha C, Liu-Ambrose T. Effects of computerized cognitive training on neuroimaging outcomes in older adults: a systematic review. BMC Geriatr. 17: 139, 2017, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3394709/

17. Bonnechere B, Langley C, Sahakian B. The use of commercial computerised cognitive games in older adults: a meta-analysis. Sci Rep. 10(1): 15276, 2020, https://pubmed.ncbi.nlm.nih.gov/32943742/

18. Randolph C, Tierney M, Mohr E, Chase T. The Repeatable Battery for the Assessment of Neuropsychological Status (RBANS): preliminary clinical validity. J Clin Exp Neuropsychol. 20(3):310-319, 1998, https://pubmed.ncbi.nlm.nih.gov/9845158/

19. Ball K, Berch D, Helmers K, Jobe J, Leveck M, Marsiske M, et al. Effects of cognitive training interventions with older adults: a randomized controlled trial. JAMA, 288: 2271-2281, 2002, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2916176/

20. Willis S, Tennstedt S, Marsiske M, Ball K, Elias J, Koepke K, et al. Long-term effects of cognitive training on everyday functional outcomes in older adults. JAMA. 296(23): 2805-2814, 2006, https://pubmed.ncbi.nlm.nih.gov/17179457/

21. Rebok G, Ball K, Guey L, Jones R, Kim H, King J, et al. Ten-year effects of the advanced cognitive training for independent and vital elderly cognitive training trial on cognition and everyday functioning in older adults. J Am Geriatr Soc. 62: 16-24, 2014, https://pubmed.ncbi.nlm.nih.gov/24417410/

22. Cassilhas RC, Sergio T, Tulio de Mello M. Physical exercise, neuroplasticity, spatial learning and memory. Cell Mol Life Sci. 73(5): 975-983, 2016, https://pubmed.ncbi.nlm.nih.gov/26646070/

23. Physical Activity Boosts Brain Health. Centers for Disease Control and Prevention. 2023, https://www.cdc.gov/nccdphp/dnpao/features/physical-activity-brain-health/index.html#:~:text=It%20can%20improve%20memory%20and,to%20those%20who%20are%20active.

24. Di Liegro C, Schiera G, Proia P, Di Liegro I. Physical Activity and Brain Health. Genes (Basel). 10(9): 720, 2019, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6770965/

25. Godman H. Regular exercise changes the brain to improve memory, thinking skills. Harvard Health Publishing. 2014, https://www.health.harvard.edu/blog/regular-exercise-changes-brain-improve-memory-thinking-skills-201404097110

26. Exercise and the Brain: The Neuroscience of Fitness Explored. Neuroscience News. 2023, https://neurosciencenews.com/fitness-neuroscience-23228/

27. How Exercise Protects Your Brain's Health. Cleveland Clinics. 2022, https://health.clevelandclinic.org/exercise-and-brain-health/

28. Vecchio L, Meng Y, Xhima K, Lipsman N, Hamani C, Aubert I. The Neuroprotective Effects of Exercise: Maintaining a Healthy Brain Throughout Aging. Brain Plast. 4(1):17-52, 2018, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6296262/

29. Goh J, Park D. Neuroplasticity and cognitive aging: The scaffolding theory of aging and cognition. Restor Neurol Neurosci. 27(5): 391-403, 2009, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3355626/

30. Hotting K, Roder B. Beneficial effects of physical exercise on neuroplasticity and cognition. NeuroSci Biobehav Rev. 37(9 Pt B): 2243-2257, 2013, https://pubmed.ncbi.nlm.nih.gov/23623982/

31. Get Active!. Centers for Disease Control and Prevention. 2022, https://www.cdc.gov/diabetes/managing/active.html#:~:text=If%20you%20have%20diabetes%2C%20being,heart%20disease%20and%20nerve%20damage.

32. Physical Activity and Cancer. National Cancer Institute. 2020, https://www.cancer.gov/about-cancer/causes-prevention/risk/obesity/physical-activity-fact-sheet

33. Booth F, Gordon S, Carlson C, Hamilton M. Waging war on modern chronic diseases: primary prevention through exercise biology. Journal of Applied Physiology. 88(2): 774-787, 2000, https://journals.physiology.org/doi/full/10.1152/jappl.2000.88.2.774?rfr_dat=cr_pub++0pubmed&url_ver=Z39.88-2003&rfr_id=ori%3Arid%3Acrossref.org

34. Wayne P, Walsh J, Taylor-Pilae R, Wells R, Papp K, Donovan N, et al. Effect of tai chi on cognitive performance in older adults: systematic review and meta-analysis. J Am Geriatr Soc, 62: 25-39, 2014, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4055508/

35. Liu F, Chen X, Nie P, Lin S, Guo J, Chen J, et al. Can Tai Chi Improve Cognitive Function? A Systematic Review and Meta-Analysis of Randomized Controlled Trials. The Journal of Alternative and Complementary Medicine. 27(12), 2021, https://www.liebertpub.com/doi/abs/10.1089/acm.2021.0084

36. Yoga. Wikipedia. 2023, https://en.wikipedia.org/wiki/Yoga

37. Yoga for better mental health. Harvard Health Publishing. 2021, https://www.health.harvard.edu/staying-healthy/yoga-for-better-mental-health#:~:text=When%20you%20do%20yoga%2C%20your,awareness%2C%20thought%2C%20and%20language.

38. Hishkawa N, Yakahashi Y, Fukui Y, Tokuchi R, Furusawa J, Takemoto M, et al. Yoga-plus exercise mix promotes cognitive, affective, and physical functions in elderly people. Neurol Res, 41: 1001-1007, 2019, https://www.tandfonline.com/doi/abs/10.1080/01616412.2019.1672380?journalCode=yner20

39. Gothe N, Khan I, Hayes J, Erlenbach E, Damoiseaux J. Yoga Effects on Brain Health: A Systematic Review of the Current Literature. Brain Plasticity. 5(1): 105-122, 2019, https://content.iospress.com/articles/brain-plasticity/bpl190084

40. Exercise and the Brain: The Neuroscience of Fitness Explored. Neuroscience News. 2023, https://neurosciencenews.com/fitness-neuroscience-23228/

41. Ferrer-Uris B, Ramos M, Busquets A, Angulo-Barroso R. Can exercise shape your brain? A review of aerobic exercise effects on cognitive function and neuro-physiological underpinning mechanisms. AIMS Neurosci. 9(2): 150-174, 2022, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9256523/

42. Chertoff J. 10 Aerobic Exercise Examples: How to, Benefits, and More. healthline. 2022, https://www.healthline.com/health/fitness-exercise/aerobic-exercise-examples#:~:text=Aerobic%20exercise%20is%20any%20type,will%20increase%20during%20aerobic%20activities.

43. How much physical activity do older adults need?. Centers for Disease Control and Prevention. 2023, https://www.cdc.gov/physicalactivity/basics/older_adults/index.htm#:~:text=Adults%20aged%2065%20and%20older,hiking%2C%20jogging%2C%20or%20running.

44. Dustman R, Ruhling R, Russel E, Shearer D, Bonekat H, Shigeoka J, et al.. Aerobic exercise training and improved neuropsychological function of older individuals. Neurobiol Aging, 5: 35-42, 1984, https://www.sciencedirect.com/science/article/abs/pii/0197458084900836

45. Miyazaki A, Okuyama T, Mori H, Sato K, Kumamoto K, Hiyama A. Effects of Two Short-Term Aerobic Exercises on Cognitive Function in Healthy Older Adults during COVID-19 Confinement in Japan: A Pilot Randomized Controlled Trial. Int J Environ Res Public Health, 19: 6202, 2022, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9140575/

46. Colmenares A, Voss M, Fanning J, Salerno E, Gothe N, Thomas M, et al. White matter plasticity in healthy older adults: The effects of aerobic exercise. Neuroimage. 239: 118305, 2021, https://pubmed.ncbi.nlm.nih.gov/34174392/

47. Sarnat HB, Flores-Sarnat L. Nervous System, Neuroembryology of. ScienceDirect. 2016, https://www.sciencedirect.com/topics/psychology/myelination#:~:text=Myelination%20is%20formation%20of%20the,to%20allow%20for%20improved%20conduction.

48. Hazeghazam S. Aerobic vs. Resistance Exercise. Sutter Health. https://www.sutterhealth.org/ask-an-expert/answers/aerobic-vs-resistance-exercise#:~:text=Aerobic%20exercise%20is%20helpful%20to,hopefully%20build%2Fmaintain%20muscle%20mass.

49. Liu-Ambrose T, Nagamatsu L, Graf P, Beattie B, Ashe M, Handy T. Resistance training and executive functions: a 12-month randomized controlled trial. Arch Intern Med, 170: 170-178, 2010, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3448565/

50. Coelho-Júnior H, Goncalves I, Sampaio R, Sampaio P, Cadore E, Calvani R, et al. Effects of Combined Resistance and Power Training on Cognitive Function in Older Women: A Randomized Controlled Trial. Int J Environ Res Public Health, 17: 3435, 2020, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7277751/

51. Cheng A, Zhao Z, Liu H, Yang J, Jiong Luo. The physiological mechanism and effect of resistance exercise on cognitive function in the elderly people. Front Public Health, 10: 1013734, 2022, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9723356/

52. Herold F, Torpel A, Shega L, Muller N. Functional and/or structural brain changes in response to resistance exercises and resistance training lead to cognitive improvements - a systematic review. Eur Rev Aging Phys Act, 16: 10, 2019, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6617693/

53. Li Z, Peng X, Xiang W, Han J, Li K. The effect of resistance training on cognitive function in older adults: a systematic review of randomized clinical trials. Aging Coin Exp Res, 30: 1259-1273, 2018, https://pubmed.ncbi.nlm.nih.gov/30006762/

54. Falck R, Davis J, Best J, Crockett R, Liu-Ambrose T. Impact of exercise training on physical and cognitive function among older adults: a systematic review and meta-analysis. Neurobiol Aging, 79: 119-130, 2019, https://www.sciencedirect.com/science/article/abs/pii/S0197458019300855?via%3Dihub

55. Gallardo-Gomez D, Pozo-Crus J, Noetel M, Alvarez-Barbosa F, Alfonso-Rosa R, Cruz B. Optimal dose and type of exercise to improve cognitive function in older adults: A systematic review and bayesian model-based network meta-analysis of RCTs. Ageing Res Rev. 76: 101591, 2022, https://pubmed.ncbi.nlm.nih.gov/35182742/

56. Joubert C, Chainay H. Aging brain: the effect of combined cognitive and physical training on cognition as compared to cognitive and physical training alone - a systematic review. Clin Interv

Aging. 13: 1267-1301, 2018, https://pubmed.ncbi.nlm.nih.gov/30057444/

57. Lauenroth A, Loannidis A, Teichmann B. Influence of combined physical and cognitive training on cognition: a systematic review. BMC Geriatr. 16: 141, 2016, https://pubmed.ncbi.nlm.nih.gov/27431673/

58. Brinke L, Best J, Chan J, Chag C, Erickson K, Handy T, et al. The Effects of Computerized Cognitive Training With and Without Physical Exercise on Cognitive Function in Older Adults: An 8-Week Randomized Controlled Trial. J Gerontol A Biol Sci Med Sci, 75: 755-763, 2020, https://academic.oup.com/biomedgerontology/article/75/4/755/5485711

59. Castaño L, Lima V, Castillo de Barbieri J, Peixoto de Lucena E, Caspari A, Arai H, et al. Resistance Training Combined With Cognitive Training Increases Brain Derived Neurotrophic Factor and Improves Cognitive Function in Healthy Older Adults. Front Psychol, 13: 870561, 2022, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC9613948/

60. Centers for Disease Control and Prevention. How much physical activity do children need?. CDC, 2022, https://www.cdc.gov/physicalactivity/basics/children/index.htm

61. Centers for Disease Control and Prevention. How much physical activity do adults need?. CDC, 2022, https://www.cdc.gov/physicalactivity/basics/adults/index.htm#:~:text=Each%20week%20adults%20need%20150,Physical%20Activity%20Guidelines%20for%20Americans.&text=We%20know%20150%20minutes%20of,do%20it%20all%20at%20once.

62. Centers for Disease Control and Prevention. How much physical activity do older adults need?. CDC, 2023, https://www.cdc.gov/physicalactivity/basics/older_adults/index.htm#:~:text=Adults%20aged%2065%20and%20older,hiking%2C%20jogging%2C%20or%20running.

63. Foods linked to better brainpower. Harvard Health Publishing. 2021, https://www.health.harvard.edu/healthbeat/foods-linked-to-better-brainpower

64. 15 "Brain Foods" That May Help Preserve Your Memory. UnityPoint Health. https://www.unitypoint.org/news-and-articles/15-brain-foods-that-may-help-preserve-your-memory

65. Jennings KA. 11 Best Foods to Boost Your Brain and Memory. healthline. 2023, https://www.healthline.com/nutrition/11-brain-foods

66. Burgess L. 12 foods to boost brain function. MedicalNewsToday. 2023, https://www.medicalnewstoday.com/articles/324044

67. Dye L, Boyle N, Champ C, Lawton C. The relationship between obesity and cognitive health and decline. Proceedings of the Nutrition Society. 76(4): 443-454, 2017, https://eprints.whiterose.ac.uk/121287/

68. Grosso G, Marventano S, Yang J, Micek A, Pajak A, Scalfi L, et al. A comprehensive meta-analysis on evidence of Mediterranean diet and cardiovascular disease: Are individual components equal?. Crit Rev Food Sci Nutr. 57(15): 3218-3232, 2017, https://pubmed.ncbi.nlm.nih.gov/26528631/

69. Tektonidis T, Akesson A, Gigante B, Wolk A, Larsson S. A Mediterranean diet and risk of myocardial infarction, heart failure and stroke: A population-based cohort study. Atherosclerosis. 243(1): 93-98, 2015, https://pubmed.ncbi.nlm.nih.gov/26363438/

70. Sofi F, Cesari F, Abbate R, Gensini G, Casini A. Adherence to Mediterranean diet and health status: meta-analysis. BMJ. 11: 337, 2008, https://pubmed.ncbi.nlm.nih.gov/18786971/

71. Aridi Y, Walker J, Wright O. The Association between the Mediterranean Dietary Pattern and Cognitive Health: A Systematic Review. Nutrients. 9(7): 674, 2017, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5537789/#B26-nutrients-09-00674

72. Mediterranean Diet. Cleveland Clinic. 2022, https://my.clevelandclinic.org/health/articles/16037-mediterranean-diet

73. Loughrey DG, Lavecchia S, Brennan S, Lawlor B, Kelly M. The Impact of the Mediterranean Diet on the Cognitive Functioning of Healthy Older Adults: A Systematic Review and Meta-Analysis. Adv Nutr, 8: 571-586, 2017, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5502874/

74. Coelho-Júnior H, Trichopoulou A, Panza F. Cross-sectional and longitudinal associations between adherence to Mediterranean diet with physical performance and cognitive function in older adults: A systematic review and meta-analysis. Ageing Res Rev, 70: 101395, 2021, https://pubmed.ncbi.nlm.nih.gov/34153553/

75. Titova O, Ax E, Brooks S, Sjogren P, Cederholm T, Kilander L, et al. Mediterranean diet habits in older individuals: associations with cognitive functioning and brain volumes. Exp

Gerontol, 48: 1443-1448, 2013, https://www.sciencedirect.com/science/article/pii/S0531556513003033?via%3Dihub

76. Heerema E. The 7MS Dementia Test: Purpose, Accuracy. verwellhealth. 2023, https://www.verywellhealth.com/what-is-the-7-minute-screen-98636

77. Qin B, Adair L, Plassman B, Batis C, Edwards L, Popkin B, et al. Dietary Patterns and Cognitive Decline Among Chinese Older Adults. Epidemiology, 26:758-768, 2015, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5928777/

78. Cherbuin N, Anstey K. The Mediterranean diet is not related to cognitive change in a large prospective investigation: the PATH Through Life study. Am J Geriatr Psychiatry. 20(7): 635-739, 2012, https://pubmed.ncbi.nlm.nih.gov/21937919/

79. Rajaram S, Jones J, Lee G. Plant-Based Dietary Patterns, Plant Foods, and Age-Related Cognitive Decline. Adv Nutr, 10: S422-S436, 2019, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6855948/

80. Nock E. What are Polyphenols? Another Great Reason to Eat Fruits and Veggies. Colorado State University. 2021, https://www.chhs.colostate.edu/krnc/monthly-blog/what-are-polyphenols-another-great-reason-to-eat-fruits-and-veggies/

81. World Health Organization. Healthy Diet. WHO, https://www.who.int/initiatives/behealthy/healthy-diet#:~:text=A%20healthy%20diet%20is%20essential,are%20essential%20for%20healthy%20diet.

82. Centers for Disease Control and Prevention. Healthy Eating for a Healthy Weight. CDC, 2023, https://www.cdc.gov/healthyweight/healthy_eating/index.html#:~:text=Emphasizes%20fruits%2C%20vegetables%2C%20whole%20grains,%2C%20trans%20fats%2C%20and%20cholesterol.

83. Imaoka M, Nakao H, Nakamura M. Tazaki F, Maebuchi M, Ibuki M, et al. Effect of Multicomponent Exercise and Nutrition Support on the Cognitive Function of Older Adults: A Randomized Controlled Trial. Clin Interv Aging. 14:2145-2153, 2019, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6912002/

84. Kachouri H, Fay S, Angel L, Isingrini M. Acta Psychologica., 227(1): 103609, 2022, http://dx.doi.org/10.1016/j.actpsy.2022.103609

85. Peters R. Ageing and the brain. Postgrad Med J., 82(964):84-88, 2006, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2596698/#:~:text=It%20has%20been%20widely%20found,age%20particularly%20over%20age%2070.&text=The%20manner%20in%20which%20this%20occurs%20is%20less%20clear.

86. Fujita S, Mori S, Onda K, Hanaoka S, Nomura Y, Nakao T, et al. Characterization of Brain Volume Changes in Aging Individuals With Normal Cognition Using Serial Magnetic Resonance Imaging .JAMA Netw Open, 6:6, 2023, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10308250/

87. Changes That Occur to the Aging Brain: What Happens When We Get Older. Columbia Mailman School of Public Health, 2021, https://www.publichealth.columbia.edu/news/changes-occur-aging-brain-what-happens-when-we-get-older

88. Van der Elst W, Boxtel M, Breukelen G, Jolles J. The Stroop Color-Word Test: Influence of Age, Sex, and Education; and Normative Data for a Large Sample Across the Adult Age Range. Assessment, 13(1):62-79, 2006, https://doi.org/10.1177/1073191105283427

89. Moreira H, Costa A, Machado A, Castro S, Lima C, Vicente S. Distinguishing mild cognitive impairment from healthy aging and Alzheimer's Disease: The contribution of the INECO Frontal Screening (IFS). PLoS ONe, 14:9, 2019, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6736301/

90. Rao M. Afshin A, Singh G, Mozaffarian D. Do healthier foods and diet patterns cost more than less healthy options? A systematic review and meta-analysis. BMJ Open, 2013, https://bmjopen.bmj.com/content/3/12/e004277