

THE RELATIONSHIP BETWEEN EXERCISE AND COGNITIVE HEALTH

By

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A Thesis Submitted to The W.A. Franke Honors College

In Partial Fulfillment of the bachelor's degree

With Honors in

Physiology and Medical Sciences

THE UNIVERSITY OF ARIZONA

M A Y 2 0 2 5

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Abstract

Due to an aging population, it is expected for there to be a higher incidence of neurological diseases. It is thus important to understand how to maximize one's healthy years while minimizing one's years living with disease. Exercise is a key component in maintaining a healthy lifestyle. It is known that exercise has numerous benefits regarding physical health, but it is important to also understand its effects on cognitive health in the pursuit of longevity. This literature review examines the relationship between exercise and cognitive health. Exercise reduces the risk of cognitive decline and dementia, enhances physical and cognitive health, and has varying effects on physical and cognitive health depending on the type of exercise as well as intensity, duration, and frequency of exercise. While it may possibly improve cognitive health in cases of dementia, exercise seems to be better as a preventative measure as opposed to a treatment measure. Consistent physical activity seems to improve cognitive health and slow the aging process via stimulation of metabolic pathways that are typically associated with younger populations. Aerobic and resistance exercise should ideally be implemented together to improve cognitive health outcomes. It is important to find the proper balance to challenge without overworking oneself. Exercise improves cognitive health and is essential in sustaining positive health outcomes.

Introduction

Humans are living longer than ever before. With advancements in modern medicine and a more pervasive, deeper understanding and education of wellness on a societal level, it has become more essential than ever to maximize longevity. Most people can agree that the quality of one's life vastly outweighs the sheer quantity of years within one's life, a concept informally referred to as "healthspan." The goal should be not to only simply extend the number of years in which we are healthy but to minimize the years in which we are in poor health that will inevitably arrive at the end of our natural lives. But what even is health, and what is good health?

Health is not exclusively being free from injury or illness; it includes this component while simultaneously encompassing the condition of being physically, mentally, and socially well. Exercise, and the lack thereof, has a profound effect on the state of our health. While the World Health Organization defines exercise as "any bodily movement produced by skeletal muscles that requires energy expenditure" (World Health Organization, 2024),¹ exercise is so much more than a scientific term found in a dictionary. It is, rather, any activity requiring effort to sustain or improve health or wellbeing. Exercise tends to be normally associated within the physical sphere; anaerobic exercises like weightlifting will stimulate muscle growth and increased bone mineral density, and aerobic exercises like biking and walking will reduce cardiovascular disease in addition to promoting a wide variety of holistic effects. The equally important cognitive effects of exercise, however, are often overlooked. While humans are indeed living longer, this subsequently suggests that the rates of neurological disorders associated with aging, such as dementia and Alzheimer's disease, will also increase. Thus, the investigation into the effects of exercise on cognitive health is of the utmost importance.

Before exploring the effects of exercise on cognitive health, it is essential to define cognitive health. In general, cognitive processing involves “specific mental functions such as: memory (conceived in its different forms), attention (both general and selective), language, praxis functions (which is the capacity of making finalized movements to reach a result),... gnostic functions (namely being able to perceive and recognize), [and] ‘executive functions’: the ability to plan, control, and coordinate thoughts and actions” (Caponnetto et al., 2021).² In essence, cognitive health encapsulates our ability to perform a myriad of daily functions.

The concept of “good” cognitive health can be quite subjective, as human beings have various opinions of and measures for assessing what is good, particularly regarding health and well-being. “Good” cognitive health can generally be described as the ability to think, learn, and remember clearly, effectively, and efficiently. Researchers from England, however, implemented a method to quantitatively label good cognitive health, known as a Mini-Mental State Examination (MMSE). The MMSE includes 23 items with a maximum score of 30 and assesses individuals for orientation (knowing the date, time, location, and season), attention and concentration, memory, language, visual and spatial relationships, and following instructions. Scores of 26 or higher indicate good cognitive health, while scores of 25 or lower indicate fair or poor cognitive health. Furthermore, scores are also used to indicate impairment status for the purpose of assessing disability, with 0-17 representing severe impairment, 18-25 representing mild impairment, and 26-30 representing no impairment. The researchers “used a measure of disability based on basic activities of daily living (BADL) and instrumental activities of daily living (IADL). Participants were classified as having moderate-severe disability if they were unable to do at least one of five activities without human help: transfer to and from a chair..., put on shoes and socks, prepare a hot meal, get around outside, or have a bath or all-over wash.

Participants who were able to do all five activities without help from another person but who needed help with at least one of the two additional IADLs (shop, including carrying of heavy bags, and do heavy housework) were classified as having mild disability” (Jagger et al., 2016).³ While tools like the MMSE are valuable for measuring cognitive health, seeking to measure and prevent cognitive decline and disease is not the sole objective. As we age, we should be seeking to promote growth, learning, and maintenance of a high degree of cognitive function. The goal is to thrive, not just survive.

Historically, adult cognitive health was typically viewed as fixed or static, with a peak in early adulthood and an inevitable decline later in life that is of varying degrees and rates and is considered to be a normal component of aging. Today, cognitive health is seen as being more fluid and dynamic due to better understanding of plasticity, which is the capacity to adjust in response to one’s environment and the brain’s ability to change, learn, and adapt over time. A normal cognitive decline is usually expected with age but does not necessarily indicate a neurological disorder. As we age, our cognition and thought processes slow, and it can become more difficult to multitask, remember names, sustain attention, process information, and solve problems. Dementia and other neurological disorders, however, typically bear more striking changes that significantly interfere with daily living, including notable memory loss, personality changes, disorientation, and/or difficulties with language.

It is important to identify that this thesis will explore a correlational relationship between exercise and cognitive health rather than a causal relationship. There is no way to definitively conclude that exercise directly affects cognitive health, either positively or negatively, when there are a multitude of external variables of varying effects present throughout one’s life. Modifiable behavioral factors all contribute to one’s life outcomes and can potentially affect

cognitive health; these include nutrition, sleep, use of alcohol and substances, social relationships, stress, and smoking as well as uncontrollable factors such as genetics, environment, family dynamics, family history, race, and socioeconomic status. Even if it was concluded that exercise improves cognitive health in individuals, one must consider that perhaps individuals with good cognitive health are more likely to exercise more. Exercise cannot be designated as the sole determinant of cognitive health.

Preface

I desire to discuss this topic for a multitude of reasons. I am interested in the general topics of exercise and longevity, having participated in sports and physical activity for my entire life. As time has progressed, I have developed a deep interest in exercising not only for the present but also for the future. In the fall semester of his junior year of my undergraduate career, I enrolled in the course, “The Physiology of Aging,” instructed by Dr. Allyson Roof, who is also the advisor for this thesis. This course was one of my favorite courses in my collegiate career, as it exposed me to a variety of age-related diseases and preventative measures, many of which are actively being researched today. I am particularly interested in the aging brain and the associated neurological disorders. For two years, I actively participated in Elder Rehab, a program created and directed by Doctor of Psychology and former University of Arizona researcher, Dr. Sharon Arkin. The program, which was a significant inspiration for this thesis, matches students with seniors afflicted with Alzheimer's Disease and enables them to lead senior participants in various physical exercises such as stretching, weightlifting, treadmill walking, and memory recall as well as cognitive exercises such as story recall, naming terms within a category, and word association. Students worked with their partners for 20 sessions over the course of a semester and their efforts were synthesized into exercise and cognitive reports that mapped the progress of their partners. I,

who had the pleasure of working with three unique individuals over the course of two years, particularly enjoyed the authentic connections I made and the feeling of making a genuine impact on the lives of these seniors. From a familial perspective, my own maternal grandfather was diagnosed with dementia, so I have a personal stake in this subject. The passion I hold regarding aging and cognitive health has motivated me to conduct a thorough investigation into this subject.

Methods

This thesis takes the format of a literature review. Various research databases were scoured, such as Mendeley, PubMed, the University of Arizona Library, and a plethora of sources were collected regarding the potential relationship between exercise and cognitive health. Common search terms that were used included, “exercise,” “cognitive health,” “longevity,” “aging,” “aging brain,” and “cognition.” The main conclusions from these resources are stated and summarized within, highlighting common themes that concisely synthesize the findings. A common theme was constituted by the instance in which three or more individual sources reported the same or, at the very least, quite similar conclusion. The aim of this thesis is to neatly present the previous and ongoing research regarding this subject.

Results

It is important to note that most, if not all, studies pertaining to exercise and cognitive health exclusively feature older adults. While this fact should come as no surprise, as older adults are more prone to cognitive decline compared to younger adults, the following claims regarding exercise and cognitive health are primarily based on older adults and may not necessarily merit extrapolation to the greater population. Many studies even address this as a potential

shortcoming and acknowledge that future research needs to be done to include non-geriatric populations.

Various claims will be made in this section and will be individually expounded upon in greater detail in the following section. This section serves to concisely present these claims. The following list is representative of the main findings of this thesis:

- 1. Exercise reduces the risk of cognitive decline and dementia.** Consistent physical exercise is an essential modifiable risk factor in reducing dementia and age-related cognitive decline.
- 2. Exercise enhances physical and cognitive health.** Exercise improves mobility, balance, gait speed, bone health, and daily, functional status as well as potentially improving cognitive function.
- 3. Different types of exercise have varying effects on physical and cognitive health.** Aerobic, resistance, and multicomponent exercises have varying degrees of effect on physical and cognitive health. Aerobic exercise improves global cognition, memory, and brain health. Resistance training seems to be particularly effective for executive function in dementia patients.
- 4. Exercise intensity, duration, and frequency have varying effects.** Moderate to high-intensity exercise seems to be associated with cognitive benefits. Optimal effects derive from structured sessions and there is a non-linear dose-response relationship between exercise and cognition.

It seems apparent that exercise is a key contributor to positive cognitive health and overall life outcomes. Generally, exercise can both extend one's lifespan and improve one's quality of life. Not all exercise is equally effective, however, since intensity, duration, and frequency of

exercise can have varying effects on health outcomes. Despite increases in both lifespan and “healthspan” being common after habitual exercise and often occurring in congruence with one another, an increase in the length of one’s life does not always equate to improved quality of life in every circumstance or for every individual. While exercise does seem to have the potential to improve life circumstances in the case of dementia patients, it seems much more effective in preventing dementia and other neurological disorders; exercise is more effective as a preventative method rather than as a treatment, even though it still has the capacity to lessen cognitive ailments. It is important to clarify that simply partaking in exercise is not the sole determinant of inducing positive changes to cognitive health. The consistency of exercise is also essential, and individuals are more likely to continue exercising throughout life if they opt for physical activities that interest them. Exercise seems to have numerous benefits for cognitive health in most individuals.

Discussion

The claims made in the previous section are individually dissected in this section.

1. Exercise reduces the risk of cognitive decline and dementia.

As mentioned previously, cognitive decline is typically expected with age. Exercise is a key intervention for reducing dementia risk and age-related cognitive decline, with physical inactivity being a modifiable risk factor that neurologists can address in prevention strategies.⁴ Low levels of physical activity are a risk factor associated with Alzheimer's disease. Older adults who exercise are more likely to maintain cognition. Exercise modulates turnover of amyloid β (the protein that is believed to lead to Alzheimer’s disease when accumulated), inflammation, synthesis and release of neurotrophins, and cerebral blood flow.⁷ A randomized trial found that 6-month aerobic cycling and stretching interventions slowed cognitive decline compared to

natural progression in Alzheimer's patients, suggesting exercise may help attenuate dementia-related cognitive deterioration.²¹ Exercise training, particularly aerobic exercise, improves cerebrovascular function, cognition, and brain health in adults over 50, potentially reducing dementia risk.²² Consistent physical exercise increases blood flow to the brain, enabling the creation of new brain cells while strengthening the brain's ability to counteract disease. While it may be possible to improve cognitive health in cases of dementia, exercise seems to be a better preventative measure as opposed to a treatment measure in this instance.

2. Exercise enhances physical and cognitive health.

The familiar concept of “use it or lose it” is often demonstrated in human physiology. Muscles will begin to eventually atrophy when they are not stimulated, and the brain can begin to deteriorate when it is not cognitively challenged. Some of the key hallmarks of aging include hormonal imbalances, increased inflammation, and increased production of reactive oxygen species (ROS), which are unstable, highly reactive molecules containing oxygen that can be damaging to cellular components such as DNA, proteins, and lipids. ROS are a natural byproduct of cellular metabolism and are neutralized through antioxidants but can lead to cell dysfunction and death in excess. Through youth and middle age, the enzyme known as endothelial nitric oxide synthase (eNOS) produces nitric oxide (NO) in blood vessels which ultimately regulates cardiovascular function via improving blood pressure, vessel tone, and the prevention of blood clots. With age, eNOS becomes disconnected, decreasing NO production which initiates a cascade of events that can lead to cognitive impairment and dementia (Figure 1).

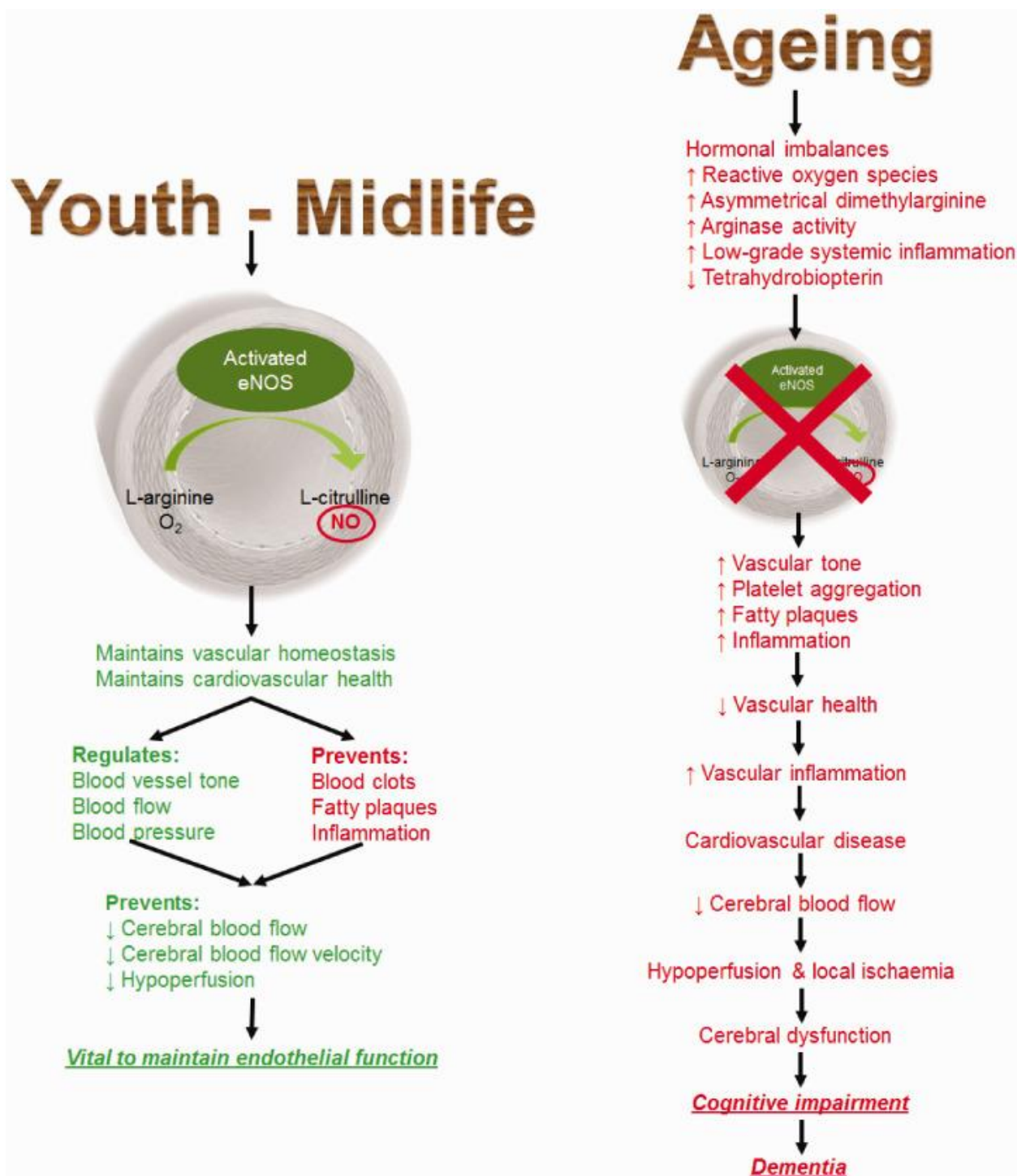


Figure 1. Mechanisms of how aging can lead to the development of dementia. This figure was used with permission from (Bliss et al., 2021).²²

Exercise is shown to improve cerebrovascular function and cognition through a variety of mechanisms (Figure 2). It initiates pathways that mimic the metabolic behavior of cells found in young to middle-aged individuals. Exercise seemingly slows the aging process.

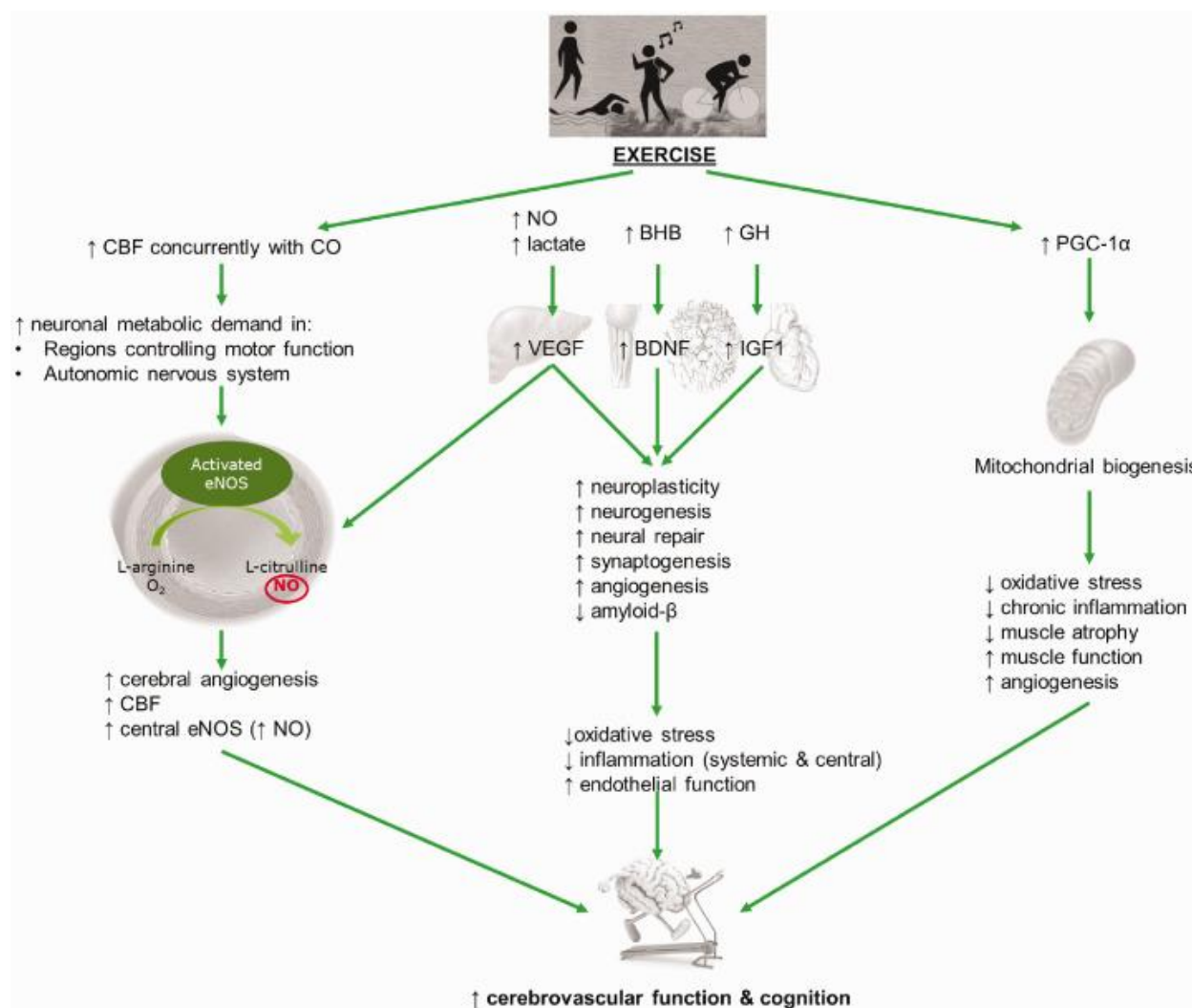


Figure 2. Mechanisms of how exercise can improve cerebrovascular function and cognition.

CBF: cerebral blood flow; BHB: beta-hydroxybutyrate; GH: growth hormone; VEGF: vascular endothelial growth factor; BDNF: brain-derived neurotrophic factor; IGF-1: insulin-like growth factor-1; PGC-1 α : peroxisome proliferator-activated receptor gamma coactivator 1-alpha. This figure was used with permission from (Bliss et al., 2021).²²

Exercise benefits cognitive function preventively and therapeutically.² It improves physical fitness and may enhance functional reserve, mobility, gait speed, bone health, and cognitive capacity while also supporting autonomy and quality of life in older adults.^{5, 10, 11, 13} Both aerobic and resistance exercise enhance spatial learning and memory through multiple neuroplasticity mechanisms, including BDNF/IGF-1 signaling, hippocampal neurogenesis, synaptic plasticity, and angiogenesis (the creation of new blood vessels).²⁰ Most physical exercises even benefit motor symptoms and quality of life for individuals with Parkinson's, emphasizing the potential benefits of exercise across a variety of neurodegenerative diseases.¹⁶ Between 1991 and 2011 in England, life expectancy at age 65 increased with significant gains in cognitive health and self-perceived good health.³ Over a period of 23 years in the Netherlands, life expectancy at age 65 increased alongside gains in cognitively healthy years, while combined poor physical and cognitive health remained stable.⁶ A meta-analysis of 20 randomized controlled trials (RCTs) found that physical activity significantly improves cognition in Alzheimer's patients (Figures 3 and 4).¹⁵ The overall values shown at the bottom of Figures 3 and 4 demonstrate a positive correlation between physical activity and improved cognition in individuals with Alzheimer's.

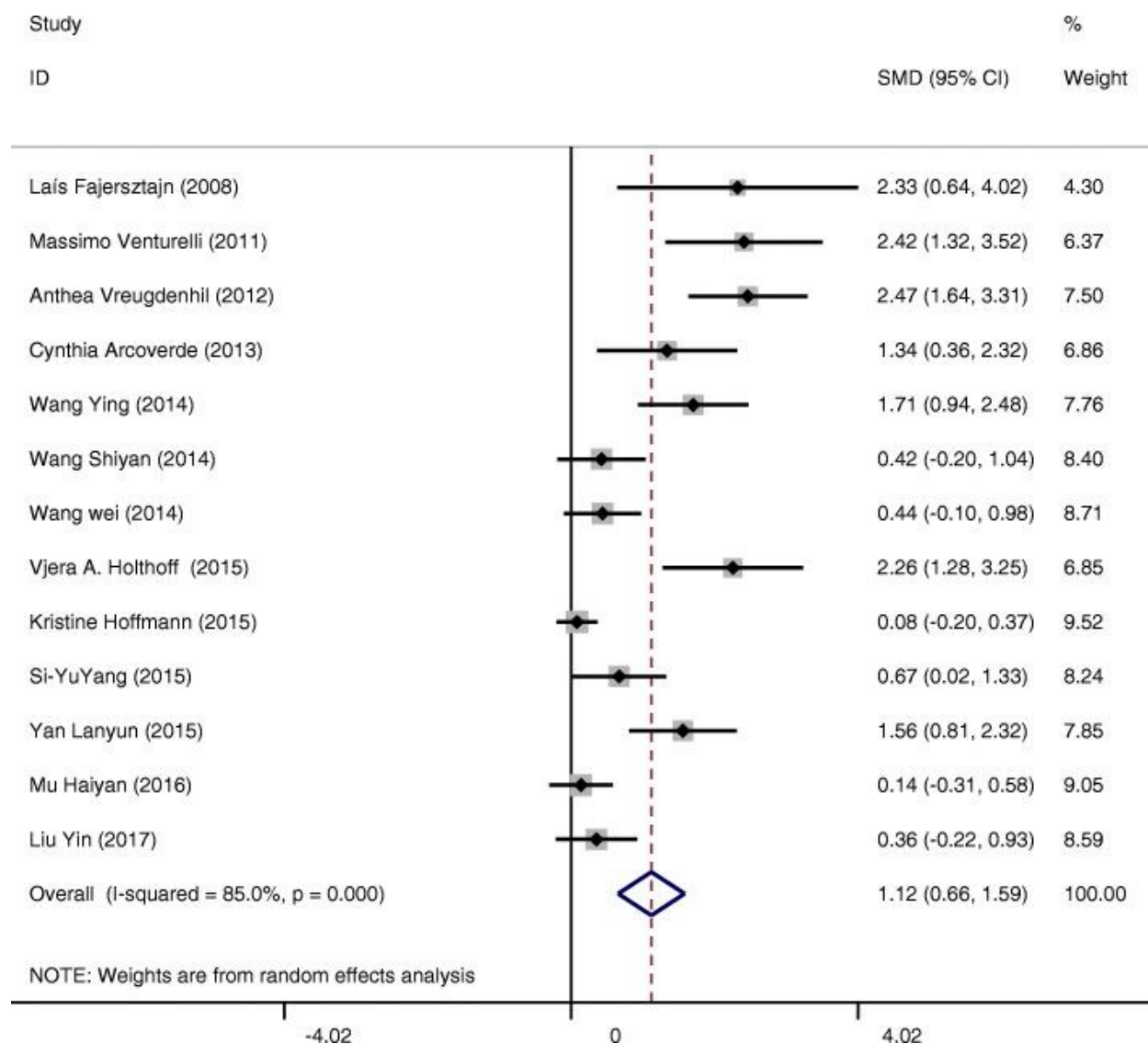


Figure 3. A total of 13 studies researching the effects of exercise on cognitive function in Alzheimer's patients. This figure was used with permission from (Jia et al., 2019).¹⁵

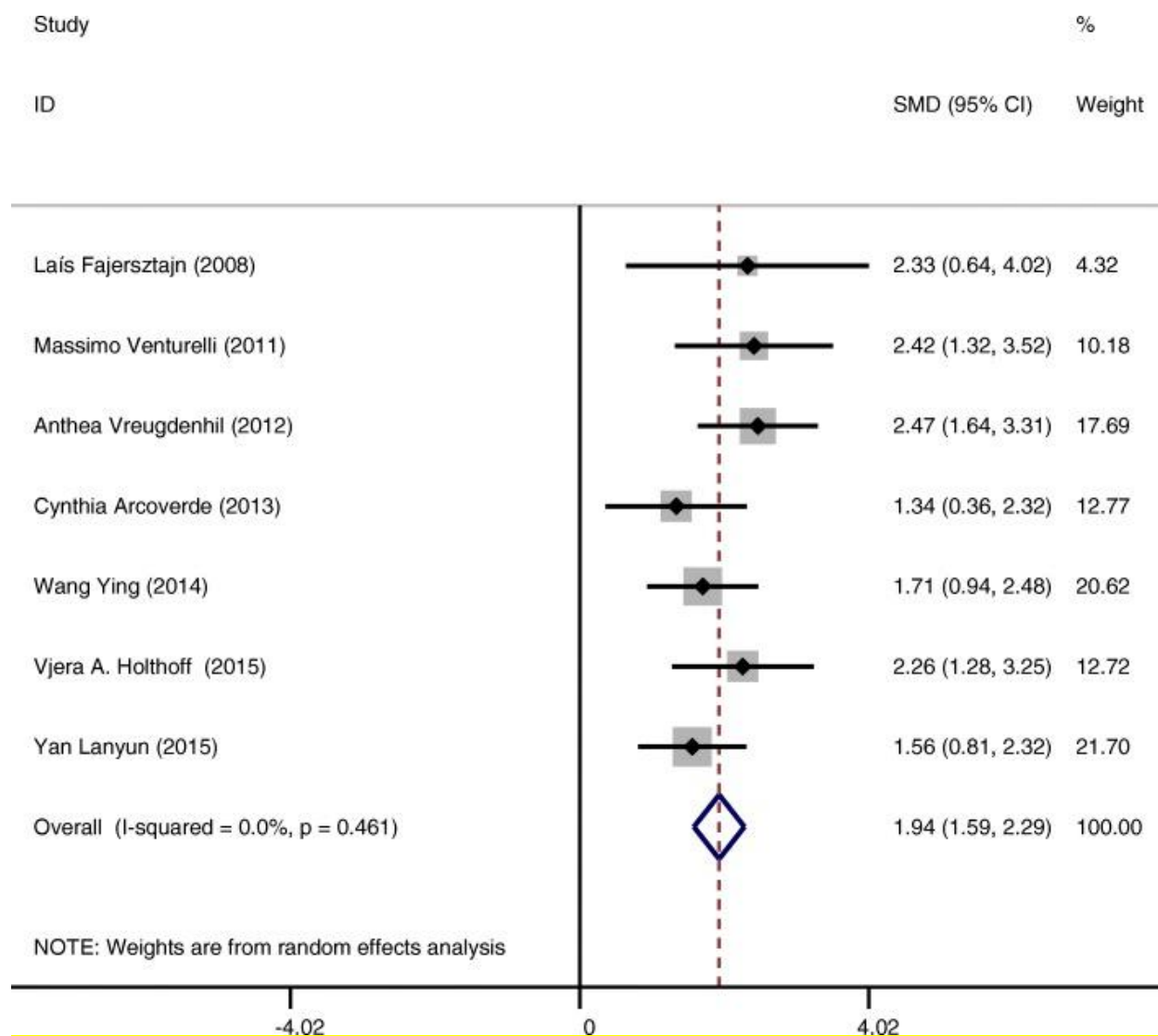


Figure 4. A total of 7 studies researching the effects of exercise on cognitive function in Alzheimer’s patients. This figure was used with permission from (Jia et al., 2019).¹⁵

Exercise has known benefits on physical health, but consistent physical activity seems to improve cognitive health and slow the aging process via the stimulation of metabolic pathways that typically show higher activation in younger populations.

3. Different types of exercise have varying effects on physical and cognitive health.

While engaging in exercise is critical for maintaining a healthy lifestyle, the type of exercise is equally important. Physical exercise, especially aerobic exercise, combined with cognitive therapies, improves physical and cognitive functions in older adults with dementia.⁸ Aerobic exercise improves cognition, independent functioning, and psychological health in older adults with mild cognitive impairment or dementia, offering potential for prevention and intervention.¹² Furthermore, aerobic exercise significantly improves cognitive function in Alzheimer's patients (MMSE score increase: WMD=1.50, p=0.002).¹⁹ Resistance exercise is the most effective for slowing cognitive decline in dementia patients, while multicomponent exercise (exercise that combines multiple forms of exercise such as aerobics and resistance) is optimal for protecting cognition in patients with mild cognitive impairment.⁹ Multicomponent exercise, however, improves global cognition in older adults with mild cognitive impairment or dementia only when it includes aerobic training, supporting the integration of structured aerobic-inclusive programs in cognitive care.²⁵ Resistance training providing superior cognitive results was supported by a network meta-analysis of 44 RCTs that included 4,793 participants.¹⁸ This meta-analysis found that high-speed resistance training in particular significantly improves cognitive function (processing speed, executive function) and physical performance (mobility, strength) in older adults with cognitive frailty.²³ Another meta-analysis of 54 RCTs found that exercise improves cognition across all age groups, with aerobic training best for global cognition, resistance best training for executive function, and mind-body exercise best for memory. Older adults showed the greatest cognitive benefits among all age groups.¹⁷ Although the exact mechanisms for how different types of exercise correlate with various outcomes are a subject of future research, aerobic and resistance training both initiate the pathways described previously that result in decreased inflammation, improved blood flow, and generation of new neural pathways. Aerobic

and resistance exercise should ideally be implemented together to improve cognitive health outcomes.

4. Exercise intensity, duration, and frequency have varying effects.

The degree to which how intense, how long, and how often one exercises can influence the benefits one might receive from exercise. A moderate-to-high-intensity exercise program improves physical fitness and is recommended to produce physical benefits.¹⁴ Too intense exercise and/or exercise that does not encourage adequate rest or sleep can be detrimental to one's health. Metabolic Equivalent of Task (MET) is an energy expenditure measurement during physical exercise. More intense exercises, such as running, have higher MET values than rest or lower intensity exercises, such as walking. There are clinically meaningful improvements achievable at 724 METs-min/week -- below WHO guidelines -- demonstrating a non-linear dose-response relationship across exercise modalities.¹⁸ A non-linear dose-response relationship suggests that the effect of one variable does not increase proportionally with the subsequent response. In other words, doubling the amount of exercise does not necessarily double the benefits on cognitive health. Optimal benefits are achieved through 30-minute exercise sessions no more than 150 min/week or $\leq 3x/week$, and greater improvements are seen in patients with a worse baseline cognition.¹⁹ As cognitive decline and dementia pose growing challenges for aging populations, evidence suggests that structured, higher-intensity exercise programs may help preserve brain function by enhancing neuroprotective mechanisms.²⁴ To maximize cognitive benefits, exercise should be at least of moderate-intensity without exceeding high-intensity, should be approximately 30 minutes each session, and should not surpass 150 minutes per week or 3 sessions per week. It is important to find the proper balance to challenge without overworking oneself.

As mentioned previously in the “Introduction,” I was a proud participant of Elder Rehab for four semesters, and my findings were synthesized into an exercise report and a cognitive report at the end of each semester. Over the course of my Elder Rehab tenure, I wrote four unique exercise reports and four unique cognitive reports for three distinct individuals. I had the privilege of working with the same individual for my third and fourth semesters in the program, so I had the opportunity to note the progress of my partner over the course of an entire school year as opposed to a single semester. My partner during this time was a white, 81-year-old male with Alzheimer’s. At the beginning and the end of each semester, a partner performs baseline tests that can be used to assess their progress. These tests include measuring the total distance covered during a 6-minute walk, measuring the total number of repetitions of 7-lb bicep curls in 30 seconds, and measuring the total number of repetitions of standing from a seated position without the use of hands in 30 seconds. My partner had massive increases after the first semester, and his starting measurements for the second semester were even higher than his ending measurements for the first semester. My partner was also much stronger than I had anticipated, as he was able to lift a considerable amount of weight in several exercises such as chest press, leg press, and seated row, which was especially surprising considering his age.

During each Elder Rehab session (of which there are 20 per semester), the same cognitive exercises are implemented. One of the first activities performed each session was asking my partner to name as many terms as possible within a specific category in 60 seconds. For example, I would ask my partner to name as many animals, colors, or countries as possible in 60 seconds. I noticed that by the end of the second semester, my partner was able to name significantly more terms compared to the beginning of the first semester. Similar observations were observed in a story recall activity in which I would read a story with specific details then ask my partner to

retell the story and answer questions regarding the story. Each story had about six questions associated with it. Toward the beginning, my partner had difficulty with retelling the story and could answer about one or two questions correctly. By the end of our time together, my partner could not only retell the story with several details but could consistently answer four, five, or even all six questions correctly.

Furthermore, my partner seemed to be in better spirits as time progressed. Initially, he had debilitating back pain, often requiring the use of a cane for walking. At the end of the school year, he barely (if at all) used the cane and rarely complained about his back. I was told by his wife prior to the start of the program that he held some reservations regarding the program, but, by the end, he seemed quite excited for each session and grew to enjoy the exercises and our time together.

While my retelling of my relationship with this individual is anecdotal and lacks empirical evidence and thus may not necessarily be applied to other individuals with neurological disorders, it is interesting to note that exercise seemed to improve my partner's cognitive performance and emotional state. This improvement was noted in addition to the physical improvements that are typically expected from exercise. Despite my partner having a diagnosis of Alzheimer's, he was still able to experience the plethora of benefits that exercise can provide. The key was consistency; it took an entire semester to see benefits and an additional semester to see further benefits. From elite athletes to average individuals, anyone who has naturally made any physical progress beyond the initial, beginner gain period can testify to the concept that steadfast dedication is necessary to achieve results. This can also be applied to other domains of life. Consistency is required in many avenues beyond simply physical performance.

Conclusion and Future Directions

Exercise is essential for sustaining a healthy lifestyle both physically and cognitively. Although physical activity shows promise in improving cognitive health or slowing cognitive impairment in cases of neurological diseases, exercise is most effective as a preventative measure, especially prior to the onset of dementia. Both aerobic and resistance exercise should be implemented to maximize results with multicomponent exercise being a useful method of engaging with both types of exercise. Aerobic exercise, however, is beyond critical for cognitive health. It is essential to participate in physical activity that is challenging without being too extreme. Therefore, individuals should prioritize exercise they find appealing. The continuity theory of aging contends that, as they age, individuals are more likely to maintain habits or continue to take part in activities that they enjoy. It is often said that the best form of cardiovascular exercise is the one you most enjoy. For example, I despise running on a treadmill, but I engage in cardiovascular exercise through playing basketball. It is important to develop these healthy habits as soon as possible to both slow the aging process and establish healthy behaviors that your future self can continue to enjoy.

Exercise alone may not be sufficient for optimal results, and further research is needed. While it offers both cognitive and functional benefits, exercise may need to be combined with other interventions such as cognitive therapies or psychological assessments for optimal results. Health is also holistic. Exercise has a massive influence on health outcomes, but modifiable behaviors alongside non-modifiable traits also have an influence on health outcomes. This thesis primarily examined cognitive health in terms of aging and in older populations. Future research could entail investigating how exercise affects cognitive health throughout life from early development to adulthood. The specific mechanisms behind the effects of aerobic and resistance exercise are also a subject of future research.

The population is aging. Decades ago, society could be imagined as a pyramid with there being substantially more younger people than older people. Now, and in the coming future, society can be imagined as a column due to greater numbers of older people and fewer younger people resulting from advancements in medicine and technology and declining birth rates. Thus, there will likely be a higher prevalence of neurodegenerative diseases, as these diseases primarily affect older populations. Cognitive decline tends to be exponential as opposed to linear. There is usually a steep drop in health and wellbeing in the later years of one's life. Although the impact medicine and technology have made on our society is undeniable, these advancements have ultimately prolonged the inevitability of death. It is of the utmost importance to increase "healthspan" rather than lifespan; extending one's healthy years and/or minimizing one's years of being in poor health is better than simply living longer. The goal should be to thrive, not just survive. Exercise is necessary in the pursuit of maximizing longevity and can enrich the human experience.

Acknowledgements

I would like to express deep appreciation and gratitude to several people and institutions who helped with this thesis in various ways. I would first like to thank the University of Arizona and the W.A. Franke Honors College for giving me the opportunity to complete this thesis and enrich my educational experience. Next, I want to extend my gratitude to the Physiology Department at the University of Arizona for their continual support during my undergraduate career. The content I have been exposed to via several courses in this department, particularly the course titled "The Physiology of Aging," has engaged me and refined my interests. I would like to thank Dr. Sharon Arkin for recruiting me for Elder Rehab, a program that is truly near and dear to me. The program and its surrounding research served as an avenue for me to get involved in my

community while simultaneously learning about cognitive health and spreading awareness about Alzheimer's. I found my time in the program to be deeply impactful and therapeutic. Last, but certainly not least, I would like to extend my deepest thanks to Dr. Allyson Roof of the Physiology Department. Dr. Roof was my professor for "The Physiology of Aging," which was one of my favorite courses that I have ever taken. I had the privilege of having Dr. Roof as my honors thesis mentor over the course of the entire 2024-2025 academic year, and she was even working with me starting from the end of the 2023-2024 academic year. She has provided me with numerous resources and overwhelmingly positive support and guidance. Her consistent feedback was monumental toward the development of this thesis, and I am beyond grateful.

Thank you to everyone who took the time to read this thesis and to everyone who provided support!

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