ISSN (print) 2522-1906, ISSN (online) 2522-1914
PHYSICAL REHABILITATION AND RECREATIONAL HEALTH TECHNOLOGIES
Vol. 10 No. 6, 2025

Original Scientific Article DOI: 10.15391/prrht.2025-10(6).02

# Resistance Training Significantly Increases Brain-Derived Neurotrophic Factor Levels in Women with a Sedentary Lifestyle: A Randomized Controlled Trial

**Junian Cahyanto Wibawa[a], Novadri Ayubi[b], Vega Mareta Sceisarriya[a], Lilik Herawati[c], Mert Kurnaz[d]**

[a]Department of Physical Education Health and Recreation, STKIP PGRI Trenggalek, Indonesia
[b]Department of Physical Education Health and Recreation, Faculty of Sports and Health Sciences, Universitas Negeri Surabaya, Indonesia
[c]Department of Physiology, Faculty of Medicine, Universitas Airlangga, Indonesia
[d]Department of Physical Education and Sports Teaching, Faculty of Sport Sciences, Haliç University, Turkey

**Corresponding author:** Junian Cahyanto Wibawa
e-mail: juniancahyanto96@stkippgritrenggalek.ac.id

## Abstract

**Purpose.** Cognitive decline and dementia are increasing, driven by a lack of movement and physical exercise. Critical aspects of brain cognitive function are influenced by levels of brain-derived neurotrophic factor (BDNF). The development and proliferation of synapses, which support thinking skills such as memory and learning, which are vital for survival, are influenced by BDNF levels. One non-pharmacological treatment for dementia caused by a sedentary lifestyle is exercise. This study aimed to determine the effect of resistance training and aerobic exercise on BDNF levels in women with a sedentary lifestyle.

**Material & Methods.** Experimental and control groups before and after were used in this experimental study. People were selected through random sampling, and after they were selected, three groups were formed: the treatment group (RT) received a resistance exercise intervention, an aerobic exercise intervention was given to the treatment group (AT), while the control group (CO) did not do any activity, just sitting. This study involved thirty-nine healthy women with a sedentary lifestyle. Women aged 18 to 26 years participated as respondents in this study. Data collection took place over the course of two days, beginning with the collection of information regarding the characteristics of the subjects. Then, before the exercise, the subjects had their blood drawn as pre-test data. After then, the participants were told to warm up. Then, the subjects performed physical exercises according to their group. The exercises performed included resistance and aerobic exercises. After the exercise intervention, blood samples were taken as post-test data.

**Results.** BDNF levels in the resistance training group experienced a significant increase in women with a sedentary lifestyle $p<0.05$.

**Conclusions.** Therefore, these experimental test data provide information that acute resistance training can increase BDNF levels. Resistance training can be recommended as an alternative exercise for people with a sedentary lifestyle to improve cognitive function.

**Keywords:** Sedentary, Resistance Training, Physical Exercise, BDNF.



The online version available at https://doi.org/10.15391/prrht.2025-10(6).02

## Introduction

A sedentary lifestyle is increasingly recognized as a trigger for various diseases. Prolonged sitting is closely can trigger various diseases such as type 2 diabetes mellitus, heart disease, and cancer (Henschel et al., 2020). Alzheimer's disease (AD) may potentially be linked to increased sedentary time and cognitive impairment, according to recent studies (Yan et al., 2020). Cutting back on inactive time could be a promising way to stop neurodegeneration. We still don't fully understand the processes behind the negative impacts of sedentary behavior. According to the International Alzheimer's Disease Association's Annual Statistical Report (World Alzheimer Report 2011 et al., 2018), dementia presently affects over 36 million people globally, and the number of new cases is rising at a pace of one patient every seven seconds. By 2030, there will likely be 66 million people with dementia, and by 2050, there will be 115 million (World Alzheimer Report 2011 et al., 2018). Finding such risk factors is therefore essential. The progression of dementia is non-linear and irreversible, making it a complex neurological illness. In addition to having a wide range of intricate causes, dementia can result in a host of additional health issues (Yan et al., 2020). Long periods of inactivity are believed to be a contributing factor to systemic and cerebral vascular dysfunction (Daniele et al., 2022), increased inflammation (Bergens et al., 2021), and decreased synaptic plasticity (Chandrasekaran et al., 2021). Higher levels of oxidative stress indicators are found in sedentary lifestyles (Gungor-Orhan et al., 2025). As living standards have steadily improved, people's life expectancy has also increased. According to certain research, dementia prevalence also seems to be steadily rising (Deng et al., 2018).

BDNF plays a key role in memory formation, synaptic plasticity, neuronal survival, and cell shape determination (Bathina & Das, 2015). Reduced levels of BDNF in the blood closely related to cognitive decline in a number of illnesses, including Alzheimer's (Chen et al., 2016). Results from earlier research indicated that among those suffering from temporal lobe epilepsy, lower serum BDNF levels were substantially linked to lower verbal memory and design fluency scores (Chen et al., 2016), however, additional research has demonstrated that BDNF levels and cognitive function are positively correlated in individuals with epilepsy receiving valproate and phenytoin (Madi et al., 2023). In the central nervous system (CNS), BDNF plays a role in synaptogenesis, neuronal growth and differentiation, neurogenesis, and synaptic plasticity (Okezie et al., 2022). CNS regions like the thalamus, hippocampus, and limbic system are the main sites for BDNF synthesis (Azman & Zakaria, 2022). Furthermore, platelets, skeletal muscle, vascular endothelium, and immune cells all peripherally produce BDNF (Murawska-Ciałowicz et al., 2021). The blood-brain barrier, however, is inaccessible to peripheral BDNF (Diniz et al., 2020). The main locations of central BDNF expression are the midbrain, striatum, hippocampus, frontal cortex, and hypothalamus (Dou et al., 2022). BDNF which is secreted by neurons and glial cells, mainly supports synaptic plasticity, encourages neurogenesis, and aids in neuronal survival (Romero Garavito et al., 2024). BDNF is essential for several brain processes, including learning, memory, and emotional control. Additionally, in the context of neurodegenerative illnesses or following injury, BDNF has been connected to the neurological system's defense and recovery (Tsai, 2018).

One well-known lifestyle tactic for preserving brain health is regular exercise (Won et al., 2021). According to reports, physical activity improves older persons' brain structure, function, and cognition via increasing neurotrophic factors and synaptogenesis (Casaletto et al., 2022). Trials of physical exercise interventions have shown promise in lowering neurodegeneration, especially in those who are susceptible to AD (Yu et al., 2021). Exercise has garnered more attention as a non-pharmacological dementia treatment in recent years (Fleiner et al., 2017). In fact, a several investigations have demonstrated that dementia sufferers' mental and physical well-being can benefit from frequent exercise (Matura et al., 2016). Physical activity significantly improves muscle function and metabolism, and its impact on cognitive performance is also receiving increasing attention. It is crucial to remember that because of their potential benefits for a variety of ailments, such as psychiatric illnesses and neurodegenerative diseases, these effects necessitate further research. Exercise is now being considered as treatment method in both clinical and research settings as a result of these advantages (Feigin et al., 2019). To prevent various diseases and improve their pathophysiological characteristics, it is important to investigate the interaction between BDNF and physical exercise. Therefore, the aim of this study was to determine the effect of resistance training and aerobic exercise on BDNF levels in women with a sedentary lifestyle.

## Material and methods

### Study Design

After being chosen at random, thirty-nine female responders were split up into three groups. There were three groups: 13 for resistance training (RT), 13 for aerobic training (AT), and 13 for

ISSN (print) 2522-1906, ISSN (online) 2522-1914
PHYSICAL REHABILITATION AND RECREATIONAL HEALTH TECHNOLOGIES
Vol. 10 No. 6, 2025

control (CO). While the control group did nothing, the RT group followed a program that involved weight training, and the AT group followed a program that involved aerobic exercise on a treadmill. The training intervention that follows will go into additional detail about the training program.

**Subjects**

The Malang State Polytechnic of Health's ethical committee accepted in this experimental research, which is done in compliance with the Declaration of Helsinki. This study included thirty-nine healthy women (table 1 displays the characteristics of the subjects). The researchers created inclusion and exclusion criteria to assess if volunteers fulfilled the study requirements. Subjects had to be between the ages of 18 and 26, have a normal body mass index (BMI), lead a sedentary lifestyle, not smoke, have no history of cancer, cardiovascular disease, or musculoskeletal disorders, not use dietary or ergogenic supplements, and be willing to take part in the research. A short version of the International Physical Activity Questionnaire (IPAQ), a sedentary lifestyle is defined as a physical activity level of less than 600 MET minutes per week (Moghaddam et al., 2012). Additionally, respondents were not required to engage in regular exercise. Participants under the age of eighteen were not permitted to participate in this study. Our study additionally eliminated respondents with hypertension whose blood pressure was abnormally high (systolic ≥130 mmHg and/or diastolic ≥85 mmHg) before activity. Additionally, subjects were disqualified if they were abducted nonsteroidal anti-inflammatory medicines (NSAIDs).

Pregnancy, beginning a particular diet, using medication, and not wanting to continue the recommended exercise intervention (not attending all of the sessions) were all reasons for exclusion. A formal consent form was read and signed by each chosen participant. Three groups of 39 female volunteers participated in this study: 13 were assigned to the resistance training (RT) group, 13 to the aerobic training (AT) group, and 13 to the control (CO) group. The study was conducted at a Fitness Center in Tulungagung City, East Java Province. Additionally, all participants were guided by certified professional fitness trainers during the exercise intervention.

**Research Instruments**

The following instruments we used include measurements of weight, height, and blood pressure, data collection sheets, stationery, blood drawing equipment, treadmills, and gym equipment used for weight training.

**Procedure**

There were multiple steps in the data collection process for this study. Before the study started, the subjects went through a screening procedure. This method was based on specific criteria that allowed data to be included in or excluded from the study. Additionally, after being educated about the research protocols, individuals provided their informed consent in order to participate in the research. Out of the trial participants, three groups were chosen at random and split into treatment groups receiving resistance training and aerobic training interventions and a control group receiving no intervention.

Data collection was conducted over two days, beginning with information on the subjects' characteristics. Before the investigation, subjects were not allowed to eat anything. The day before the study, subjects were instructed to maintain a

**Table 1.** Characteristics of research subjects

| Data | Group | N | Mean ± SD | p-value |
|---|---|---|---|---|
| Age (y) | RT | 13 | 20.38±1.04 | 0.940 |
| | AT | 13 | 20.53±1.98 | |
| | CO | 13 | 20.61±1.89 | |
| Height (cm) | RT | 13 | 157.31±5.20 | 0.782 |
| | AT | 13 | 155.69±5.69 | |
| | CO | 13 | 156.77±6.84 | |
| Weight (kg) | RT | 13 | 55.15±7.64 | 0.433 |
| | AT | 13 | 54.00±7.84 | |
| | CO | 13 | 51.46±6.51 | |
| BMI (kg/m²) | RT | 13 | 22.26±2.72 | 0.441 |
| | AT | 13 | 22.24±2.77 | |
| | CO | 13 | 21.02±2.91 | |
| Systolic (mmHg) | RT | 13 | 116.15±15.13 | 0.568 |
| | AT | 13 | 114.15±9.26 | |
| | CO | 13 | 110.38±16.34 | |
| Diastolic (mmHg) | RT | 13 | 76.15±9.20 | 0.724 |
| | AT | 13 | 73.69±9.43 | |
| | CO | 13 | 73.61±8.73 | |

regular diet and rest patterns. They were then instructed to warm up before exercising. Afterward, they engaged in physical activity, consisting of resistance training and moderate-intensity aerobic exercise.

Before the exercise, 3cc of blood was taken as pretest data, and after the exercise, 3cc of blood was taken as posttest data. After that, the blood samples were centrifuged to separate the serum. After centrifugation was complete, the blood serum was taken for laboratory analysis to check BDNF levels. This analysis was conducted in the lab at the Physiology Science Laboratory Installation, Faculty of Medicine, University of Brawijaya, Malang. The method for examining BDNF expression used the ELISA (Enzyme-linked immunosorbent assay) method with Human BDNF reagents. After analyzing the data, the researchers finally created a written report outlining the findings as a measure of responsibility.

**Exercise Intervention**

Resistance Training (RT) consists of group training sessions where participants receive instruction on exercise techniques and have their performance evaluated by trained professional trainers. Each training session lasts 60 minutes and is administered as a single acute session Targeting both the upper and lower body, the 40-minute strength training session consists of three sets of ten exercises, such as the triceps pushdown, seated row, shoulder press, chest press, lateral pull-down, abdominal crunch, leg press, leg extension, and sitting bicep curl. Every resistance exercise is carried out in compliance with the National Strength and Conditioning Association's criteria, which have been applied in earlier research (Amanat et al., 2020). Each exercise involved 8–10 repetitions in 3 sets, with 5–10 minutes of recovery in between sets. The intensity of the exercise was 75–80% of 1RM. Participants were assessed using seated leg presses and upper and lower body bicep curls to determine their 1RM. Participants were placed with their knees bent at a 90-degree angle following their leg press warm-up. After applying a conservative load to the machine, participants were told to bend their knees completely and do so again until they became fatigued. The weight was raised for sitting bicep curl participants in a range of 100 degrees, from full extension to fatigue. Due to the participants' inexperience and potential for harm, 1RM was calculated for each participant using a formula rather than being measured directly Brzycki, 1993: 1RM = (Total weight lifted (kg)/(102.78 - (002.78 × number of repetitions)).

Aerobic exercise (AE) consists of brisk walking on a treadmill for 30 minutes at a pace of 5–6 km/h. The following formula is used to measure each participant's maximal heart rate (HRmax), which determines the exercise's intensity: HRmax is equal to 208 - (0.7 × age) (Tanaka et al., 2001). During a single training session, the exercise's intensity progressively increases from 65% of HRmax to 75% of HRmax.

The control group (CO) was asked to just sit and lie down at the designated research location. The only activities allowed were playing with cell phones, sitting, and walking to the bathroom in the designated area. Participants in this group were allowed to play with their cell phones and communicate with their groupmates to overcome boredom while waiting in line to have their blood drawn.

**Statistical analysis**

After data collection, statistical analysis was performed using SPSS software. The data were then analyzed descriptively to determine the mean and standard deviation. This study also

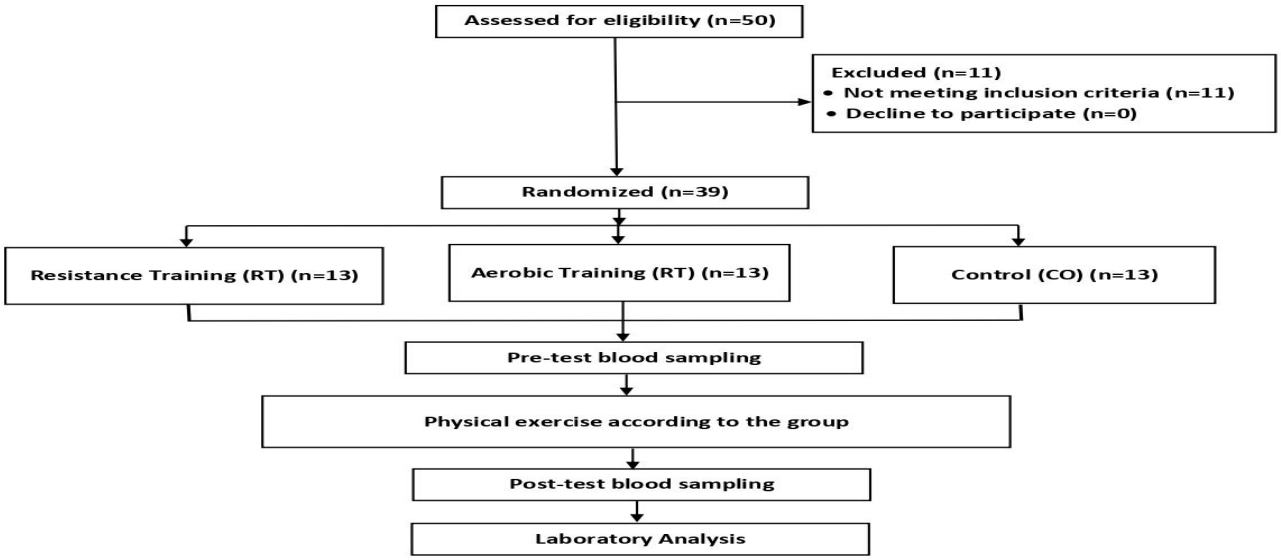


**Figure 1.** The CONSORT flowchart

ISSN (print) 2522-1906, ISSN (online) 2522-1914
PHYSICAL REHABILITATION AND RECREATIONAL HEALTH TECHNOLOGIES
Vol. 10 No. 6, 2025

used the Shapiro-Wilk test to test for normality. A paired t-test was used to determine whether the data were normally distributed. Data were examined using the Wilcoxon Signed Rank test if the results indicated otherwise.

### Ethics

With registration number DP.04.03/F.XXI.30/00841/2025, we received ethical approval from the Malang Health Polytechnic Ethics Committee prior to data collection.

## Results

Statistics and details regarding the general description of the participants in Table 1 are presented in this section. These statistics provide information about the characteristics of each group. Mean ± standard deviation is used to display the data. There were no significant differences between the resistance training, aerobic training, and control groups, based on the results of the t-test ($p>0.05$).

The BDNF data of all groups were normally distributed ($p>0.05$), based on the normality test in Table 2. Therefore, the paired sample t-test was the next test.

Figure 2 displays the findings of the BDNF analysis for each group between the pre-test and post-test.

Figure 2 shows that the RT group given resistance training intervention significantly increased BDNF levels in women with a sedentary lifestyle (*$p<0.05$).

The paired-samples t-test results are displayed in Table 3. The mean ± standard deviation is used to display the data.

Meanwhile, there was no significant difference

**Table 2.** Normality test results

| Data | Group | Shapiro-Wilk | |
|---|---|---|---|
| | | N | P-value |
| BDNF | RT (Pre-test) | 13 | 0.254 |
| | RT (Post-test) | | 0.307 |
| | AT (Pre-test) | 13 | 0.873 |
| | AT (Post-test) | | 0.716 |
| | CO (Pre-test) | 13 | 0.816 |
| | CO (Post-test) | | 0.443 |

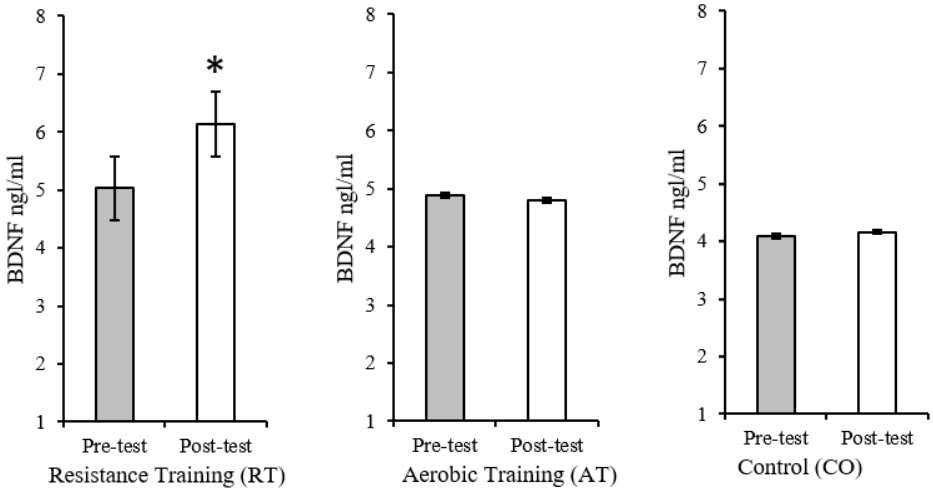


**Figure 2.** BDNF analysis results for each group between pre- and post-testing.

**Table 3.** Results of BDNF (ng/ml)

| Data | Group | Paired-Samples T Test | |
|---|---|---|---|
| | | Mean ± SD | P-value |
| BDNF | RT (Pre-test) | 5.03±1.01 | *0.000 |
| | RT (Post-test) | 6.14±1.32 | |
| | AT (Pre-test) | 4.89±0.81 | 0.484 |
| | AT (Post-test) | 4.80±0.96 | |
| | CO (Pre-test) | 4.09±0.95 | 0.581 |
| | CO (Post-test) | 4.16±1.03 | |

Information:
In the group (RT) with resistance training intervention, there was a significant difference between the pre-test and post-test (*$p<0.05$).

between the group (AT) with aerobic exercise intervention and the control group (CO) ($p>0.05$).

## Discussion

This study aimed to determine the effect of acute physical activity, both resistance training and aerobic exercise, on BDNF levels in sedentary women. The results showed that resistance training significantly increased BDNF levels in sedentary women ($p<0.05$). The findings of this study are corroborated by earlier research showing that respondents who received a resistance training intervention had significantly higher BDNF levels (de Souza et al., 2025). Pre-test and post-test scores within the aerobic exercise group did not differ significantly. This suggests that the type of exercise plays a decisive role in influencing the increase in BDNF levels. Exercise has a beneficial effect on increasing BDNF levels, based on previous meta-analyses and comprehensive reviews (Andreu-Caravaca et al., 2025). Resistance training encompasses five distinct forms of exercise reverse arm curl, deadlift, seated leg flexion, barbell back squat, and flat bench press has been shown in previous research to significantly increase BDNF levels in individuals (Zuo et al., 2025). Accordingly, resistance training is beneficial to health; however, the intensity of the exercises should be supervised or regulated by a qualified professional trainer. These findings, which are supported by several studies in senior citizens between the ages of 66 and 70, show that a 16-week resistance and cognitive training program significantly increased BDNF levels in older adults (Castaño et al., 2022). Resistance exercise is therefore strongly advised for seniors, especially older persons, in order to preserve physical health, especially with relation to cognitive function. For seniors, resistance exercise has a big impact on staying fit and healthy.

The benefits of resistance exercise for preserving human health are enormous. BDNF levels were significantly raised in older people who underwent resistance training that included ten repetitions of leg presses, lat pulldowns, knee flexions, bench presses, calf raises, and arm curls at 65-70% of their 1RM (Arazi et al., 2021). Church et al., 2016 examined the variations in how the BDNF reacts to exercise between high-volume and high-intensity resistance training. Twenty guys who have been strength training for at least two years participated in a nine-week program. The pre-study phase lasted two weeks, and the training phase lasted seven weeks. Each group consisted of ten males and may be classified as either high-volume or high-intensity. The four weekly training sessions for both groups focus on multi-joint exercises with free weights, including triceps extensions, leg presses, chin-ups, shoulder presses, bench presses, deadlifts, and squats. Strength tests: 1RM barbell bench press and barbell squat and anthropometric evaluations (height, weight, and body composition) were also conducted. Additionally, blood samples were taken four times, and dietary habits and nutrient intake were examined. The findings demonstrated that both the high-intensity and high-volume groups exhibited considerably higher BDNF concentrations. After seven weeks of the training regimen, the data indicated that circulating BDNF concentrations had increased, while resting concentrations had remained same.

Additional studies demonstrate that a mix of strength training focusing on hypertrophy and endurance physical training, such as the leg press, leg extension, exercises that raise BDNF levels include the dumbbell arm curl, seated row, bench press, military press, and latissimus dorsi pull-down (lat pull-down) (Marston et al., 2017). BDNF levels were significantly raised in older adults who got a 12-week interventions for resistance exercises that support leg extensions, leg presses, and sitting rows three times a week, according to other research findings (Forti et al., 2015). Additional research found that among the instrument exercises that significantly raised BDNF levels in older adults who received resistance training interventions three times a week for six months were bilateral chest press, squat, unilateral row, unilateral knee extension, unilateral shoulder press, hip thrust, unilateral knee flexions, biceps curl, unilateral hip adduction, unilateral elbow extension, unilateral hip abduction, and seated calf raises (Deus et al., 2021). The effect of 12 weeks of exercise on BDNF levels in Parkinson's disease patients was investigated in a prior study. The findings demonstrated that following the exercise intervention, BDNF levels considerably rose (Davoudi-Kiakalayeh et al., 2017). Exercise has a beneficial impact on raising BDNF levels, according to other study findings (Ghanizadeh et al., 2021). This reinforces our findings, indicating that increasing BDNF levels is a meaningful and tangible benefit of acute resistance exercise.

*Molecular Mechanisms of Resistance Training Increase BDNF Levels*

Resistance training can include a range of muscle activities, such as dynamic (a mix of eccentric and concentric actions), isokinetic (constant movement velocity), and isometric (no net change in muscle length). The most popular type of resistance training is dynamic (Wang et al., 2025). It is commonly acknowledged that the best way to reverse age-related decreases in muscle mass, strength, and physical function is through resistance training (RT) (Bårdstu et al., 2020).

Progressive RT, in particular, has been demonstrated to be a secure and successful method in order to avoid and even reverse sarcopenia (Fragala et al., 2019). Seniors who receive RT benefit from increased muscle strength, improved respiratory muscle function, thicker diaphragms, and lower liver fat levels (Akkuş Uçar et al., 2025). Functional advantages include improved balance, a lower chance of falling, and heightened neuromuscular activity have also been extensively studied (Akkuş Uçar et al., 2025).

A number of proteins, including many myokines that activate muscles, are expressed while you exercise. Immediately following exercise, irisin, a muscle-derived substance, is released into the bloodstream (Panati et al., 2016). When the extracellular region of the transmembrane glycoprotein fibronectin type III domain containing 5 (FNDC5) is cleaved by proteases, irisin is released (Panati et al., 2016). One theory that has been put forth is that exercise increases FNDC5 expression, which raises the expression of BDNF (Wrann et al., 2013), a myokine that needs the peroxisome proliferator-activated receptor gamma coactivator 1-alpha (PGC-1α). According to this theory, the FNDC5 protein cleaves into irisin, a tiny circulating protein that has been connected to fat browning (Wu et al., 2012). These factors influence how the brain and tissues interact to modulate the positive health effects of exercise. Tropomyosin receptor kinase B (TrkB) signaling responds to increased BDNF protein levels by blocking the synthesis of FNDC5 through a negative feedback loop. Prolonged exercise has been shown to decrease FNDC5 expression levels, which is consistent with elevated hippocampal BDNF protein levels (Wrann et al., 2013). Among other neurological and metabolic functions, BDNF controls the oxidation of fat in skeletal muscles and maintains homeostasis throughout the body (Apan et al., 2020).

Through myogenic hormones including irisin, insulin-like growth factor-1 (IGF-1), and BDNF, endurance training also affects brain plasticity (Ben-zeev & Hoffman, 2022). Since its initial discovery as a protein encoded downstream of the transcriptional co-activator-1 α (PGC1-α) of the peroxisome proliferator-activated receptor gamma (PPAR-γ), irisin has gained widespread recognition in the fields of neurodegenerative diseases, obesity, metabolic syndrome, diabetes, and muscle physiology. This protein was initially identified as a byproduct of muscular contraction and exercise (Wu et al., 2012). In C2C12 myoblast cells, irisin has been demonstrated to enhance mitochondrial respiration, oxidative phosphorylation, and glucose absorption through the p38-mitogen-activated protein kinase (MAPK)-PGC-1α pathway (Ye et al., 2019). Insulin resistance, metabolism, and energy expenditure are all impacted by irisin. Apart from its function in metabolism, FNDC5/irisin is also expressed in the cortex and hippocampal regions (Lourenco et al., 2019). Since FNDC5 significantly decreased the neuronal differentiation of mouse embryonic stem cells, irisin has an impact on neuronal development (Hashemi et al., 2013).

Overexpression of FNDC5 restores memory and synaptic plasticity in a mouse model of AD (Lourenco et al., 2019). Next, in an AD mouse model, exercise stopped the reduction in FNDC5/irisin, BDNF, and memory function. Increased BDNF expression mediated irisin's neuroprotective impact. Exercise promoted FNDC5 expression in the hippocampus, but not in areas of the brain where FNDC5 is not expressed, increasing BDNF expression in the brain (Wrann et al., 2013). In primary cortical neurons, FNDC5 expression raises the expression of BDNF and BDNF mediators that are important for hippocampus function, including as Npas4, c-Fos, and Arc (Wrann et al., 2013). The cAMP/PKA/CREB pathway is stimulated when recombinant irisin is applied to human cortical slices and rat hippocampus slices (Lourenco et al., 2019), which is known to increase BDNF mRNA and protein levels (Fahnestock, 2011). Increased BDNF mRNA levels and brain cell proliferation were linked to elevated levels of the proteins PGC1α and FNDC5 in the hippocampus as well as plasma irisin in treadmill-running animals. An irisin-neutralizing antibody administered peripherally to mice prevented these increases (Park et al., 2022). Lastly, peripheral FNDC5 expression in the liver by an adenovirus vector raised BDNF expression in the brain, suggests that peripheral irisin or its metabolites can penetrate the blood-brain barrier and cause BDNF expression (Wrann et al., 2013). It's uncertain if irisin is produced by exercise primarily affects cognition through peripheral or central irisin. Neither the transporter nor the mechanism are known. However, exercise-induced irisin plays a critical function in memory and spatial learning and has a direct impact on hippocampal BDNF expression levels.

With important neurotrophic and neuromodulatory signaling functions, BDNF is thought to be the most prevalent neurotrophic factor in the adult brain (Bazzari & Bazzari, 2022). BDNF, a member of the related nerve growth factor family, is expressed by both the central and peripheral neural systems (Mazur-Bialy, 2021). It has been demonstrated that adipose tissue stores fat and functions as an active endocrine organ (Prickett et al., 2014). Resistance training increases BDNF levels in a number of ways. Resistance exercise, for example, has been demonstrated to increase

muscle mass and strength, which in turn can increase the production of myokines like IL-15 and interleukin-6 (IL-6), which in turn can increase the expression of BDNF (Kandola et al., 2016). Additionally, resistance exercise increases blood and oxygen flow to the brain, which can increase the production and release of BDNF (Gomez-Pinilla & Hillman, 2013). Additionally, it has been suggested that resistance exercise's antidepressant benefits could raise BDNF levels (Babyak et al., 2000). The discovery that resistance training raised total BDNF levels is in line with earlier studies that demonstrated the beneficial effects of exercise on BDNF levels (Eidukaitė et al., 2023).

*Strength and Limitations*

This study's strength is that it was a randomized controlled experiment, the most reliable scientific method, which eliminates the possibility of ambiguous cause-and-effect relationships. Furthermore, we discuss our study's shortcomings, such as its limited sample size. We acknowledge that a larger sample size would provide a better understanding of the results. This is indeed a limitation of our study. Furthermore, our intervention focused only on resistance training and aerobic exercise. Perhaps in the future, we could examine how raising BDNF levels is affected when aerobic exercise and various forms of strength training are combined. This is important to determine which type of exercise is effective in increasing BDNF levels. Furthermore, our age justification focused only on those aged 18 to 26. Future research might examine the rise in BDNF levels following exercise in those aged 30 and older, or those approaching old age. Furthermore, it is also important to look into how exercise affects people who are experiencing cognitive loss. This would enable a more tangible understanding of how exercise affects these patients' cognitive deterioration.

## Conclusion

Resistance training has been shown to significantly increase BDNF levels in inactive women. For inactive women, resistance training can be an alternative exercise to improve cognitive performance.

### Author's contribution

**Junian Cahyanto Wibawa:** Conceptualization, Methodology, Resources, Writing – Review and Editing; **Novadri Ayubi:** Formal Analysis, Data Curation; **Vega Mareta Sceisarriya:** Software, Project Administration; **Lilik Herawati:** Writing – Rough Preparation, Supervision; **Mert Kurnaz:** Visualization. All authors have read and agreed with the published version of the manuscript.

### Acknowledgements

The successful completion of this research would not have been possible without the support and contributions of many individuals and institutions. First and foremost, I would like to express my sincere gratitude to Dr. Lilik Herawati, dr., M.Kes., for her guidance, expertise in medical physiology, particularly exercise physiology, and for her invaluable support throughout the course of this research. Her insightful feedback and commitment to academic excellence have been instrumental in shaping this research. I am especially grateful to my colleague, Dr. Novadri Ayubi, M.Kes., my friend, for her constant input, support, and guidance, for her expertise in physiological mechanisms and research methodology, and for her constructive feedback throughout this project. Special thanks to Vega Mareta Sceisarriya, M.Pd., for her assistance in statistical analysis and technical assistance with the research activities and planning for the initial respondent screening. Also, my friend in Turkey, Mert Kurnaz, Ph.D., contributed with input on the types of resistance and aerobic exercises that were useful in conducting this research.

### Conflict of Interest Statement

Authors state no conflict of interest.

### Ethical approval and consent to participate

Participants signed written informed consent before participating. Participants signed written informed consent before the intervention. This study has been approved by the Research Ethics Committee of the Health Polytechnic of the Ministry of Health of Malang with reference number DP.04.03/F.XXI.30/00841/2025.

### Funding Statement

This research received financial support from the Ministry of Higher Education, Science and Technology of the Republic of Indonesia with contract number 128/C3/DT.05.00/PL/2025.

**Received: September 18, 2025; Accepted: November 30, 2025**
**Published: December 30, 2025**

## References

Akkuş Uçar, M., Yılmaz, C., Soylu, H. H., Sarıakçalı, B., Budak, C., Kavuran, K., Durmuşoğlu, M. V., & Ceylan, L. (2025). Short-term resistance training enhances functional and physiological markers in older women: implications for biomechanical and health interventions in aging. *Frontiers in Public Health*, *13*(July), 1–10. https://doi.org/10.3389/fpubh.2025.1630525

Amanat, S., Sinaei, E., Panji, M., MohammadporHodki, R., Bagheri-Hosseinabadi, Z., Asadimehr, H., Fararouei, M., & Dianatinasab, A. (2020). A Randomized Controlled Trial on the Effects of 12 Weeks of Aerobic, Resistance, and Combined Exercises Training on the Serum Levels of Nesfatin-1, Irisin-1 and HOMA-IR. *Frontiers in Physiology*, *11*(October), 1–14. https://doi.org/10.3389/fphys.2020.562895

Andreu-Caravaca, L., Ramos-Campo, D. J., Moncada-Jiménez, J., Abellán-Aynés, O., & Rubio-Arias, J. (2025). Immediate and short-term effect of physical exercise on BDNF in multiple sclerosis patients: a systematic review and meta-analysis. *Scientific Reports*, *15*(1), 1–12. https://doi.org/10.1038/s41598-025-04675-0

Apan, B., Bala, C., Cristina, A., & Buzoianu, A. D. (2020). The Effects of Exenatide on Serum CRP Levels in Patients with Type 2 Diabetes : A Systematic Review of Randomized Controlled Trials. *Romanian Journal of Diabetes Nutrition and Metabolic Diseases, 27*(1), 66–72. https://bit.ly/3YbFJLp

Arazi, H., Babaei, P., Moghimi, M., & Asadi, A. (2021). Acute effects of strength and endurance exercise on serum BDNF and IGF-1 levels in older men. *BMC Geriatrics*, *21*(1), 1–8. https://doi.org/10.1186/s12877-020-01937-6

Azman, K. F., & Zakaria, R. (2022). Recent Advances on the Role of Brain-Derived Neurotrophic Factor (BDNF) in Neurodegenerative Diseases. *International Journal of Molecular Sciences*, *23*(12). https://doi.org/10.3390/ijms23126827

Babyak, M., Blumenthal, J. A., Herman, S., Khatri, P., Doraiswamy, M., Moore, K., Edward Craighead, W., Baldewicz, T. T., & Ranga Krishnan, K. (2000). Exercise treatment for major depression: Maintenance of therapeutic benefit at 10 months. *Psychosomatic Medicine*, *62*(5), 633–638. https://doi.org/10.1097/00006842-200009000-00006

Bårdstu, H. B., Andersen, V., Fimland, M. S., Aasdahl, L., Raastad, T., Cumming, K. T., & Sæterbakken, A. H. (2020). Erratum: Effectiveness of a resistance training program on physical function, muscle strength, and body composition in community-dwelling older adults receiving home care: A cluster-randomized controlled trial (European Review of Aging and Physical Activi. *European Review of Aging and Physical Activity*, *17*(1), 1–11. https://doi.org/10.1186/s11556-020-00245-7

Bathina, S., & Das, U. N. (2015). Brain-derived neurotrophic factor and its clinical Implications. *Archives of Medical Science*, *11*(6), 1164–1178. https://doi.org/10.5114/aoms.2015.56342

Bazzari, A. H., & Bazzari, F. H. (2022). BDNF Therapeutic Mechanisms in Neuropsychiatric Disorders. *International Journal of Molecular Sciences*, *23*(15). https://doi.org/10.3390/ijms23158417

Ben-zeev, T., & Hoffman, J. R. (2022). *The Effect of Exercise on Neurogenesis in the Brain*.

Bergens, O., Nilsson, A., Papaioannou, K. G., & Kadi, F. (2021). Sedentary Patterns and Systemic Inflammation: Sex-Specific Links in Older Adults. *Frontiers in Physiology*, *12*(February), 1–8. https://doi.org/10.3389/fphys.2021.625950

Brzycki, M. (1993). Strength Testing—Predicting a One-Rep Max from Reps-to-Fatigue. *Journal of Physical Education, Recreation & Dance*, *64*(1), 88–90. https://doi.org/10.1080/07303084.1993.10606684

Casaletto, K., Ramos-Miguel, A., VandeBunte, A., Memel, M., Buchman, A., Bennett, D., & Honer, W. (2022). Late-life physical activity relates to brain tissue synaptic integrity markers in older adults. *Alzheimer's and Dementia*, *18*(11), 2023–2035. https://doi.org/10.1002/alz.12530

Castaño, L. A. A., Castillo de Lima, V., Barbieri, J. F., Lucena, E. G. P. de, Gáspari, A. F., Arai, H., Teixeira, C. V. L., Coelho-Júnior, H. J., & Uchida, M. C. (2022). Resistance Training Combined With Cognitive Training Increases Brain Derived Neurotrophic Factor and Improves Cognitive Function in Healthy Older Adults. *Frontiers in Psychology*, *13*(October). https://doi.org/10.3389/fpsyg.2022.870561

Chandrasekaran, B., Pesola, A.J., Rao, C.R. et al. (2021). Does breaking up prolonged sitting improve cognitive functions in sedentary adults? A mapping review and hypothesis formulation on the potential physiological mechanisms. *BMC Musculoskelet Disord,* 22, 274. https://doi.org/10.1186/s12891-021-04136-5

Chen, N. C., Chuang, Y. C., Huang, C. W., Lui, C. C., Lee, C. C., Hsu, S. W., Lin, P. H., Lu, Y. T., Chang, Y. T., Hsu, C. W., & Chang, C. C. (2016). Interictal serum brain-derived neurotrophic factor level reflects white matter integrity, epilepsy severity, and cognitive dysfunction in chronic temporal lobe epilepsy. *Epilepsy and Behavior*, *59*, 147–154. https://doi.org/10.1016/j.yebeh.2016.02.029

Church, D. D., Hoffman, J. R., Mangine, G. T., Jajtner, A. R., Townsend, J. R., Beyer, K. S., Wang, R., La Monica, M. B., Fukuda, D. H., & Stout, J. R. (2016). Comparison of high-intensity vs. high-volume resistance training on the BDNF response to exercise. *Journal of Applied Physiology*, *121*(1), 123–128. https://doi.org/10.1152/japplphysiol.00233.2016

Daniele, A., Lucas, S. J. E., & Rendeiro, C. (2022). Detrimental effects of physical inactivity on peripheral and brain vasculature in humans: Insights into mechanisms, long-term health consequences and protective strategies. *Frontiers in Physiology*, *13*(September), 1–34. https://doi.org/10.3389/fphys.2022.998380

Davoudi-Kiakalayeh, A., Mohammadi, R., Pourfathollah, A. A., Siery, Z., & Davoudi-Kiakalayeh, S. (2017). Alloimmunization in thalassemia patients: New insight for healthcare. *International Journal of Preventive Medicine*, *8*, 1–6. https://doi.org/10.4103/ijpvm.IJPVM

de Souza, D. C., Marchini, K. B., Nunhes, P. M., Domingues, W. J. R., Bertolini, D. A., Oliveira, V., Mazzardo, O., & Avelar, A. (2025). Resistance Training Improves Cognitive Function and Depression Without Changing BDNF Levels in People Living with HIV: a Randomized Controlled Clinical Trial. *AIDS and Behavior*. https://doi.org/10.1007/s10461-025-04824-6

Deng, J., Cao, C., Jiang, Y., Peng, B., Wang, T., Yan, K., Lian, J., & Wang, Z. (2018). Prevalence and effect factors of dementia among the community elderly in Chongqing, China. *Psychogeriatrics*, *18*(5), 412–420. https://doi.org/10.1111/psyg.12343

Deus, L. A., Corrêa, H. de L., Neves, R. V. P., Reis, A. L., Honorato, F. S., Silva, V. L., Souza, M. K., de Araújo, T. B., de Gusmão Alves, L. S., Sousa, C. V., Reis, T. L., de Aguiar, L. S., Simões, H. G., Prestes, J., Melo, G. F., & Rosa, T. S. (2021). Are resistance training-induced BDNF in hemodialysis patients associated with depressive symptoms, quality of life, antioxidant capacity, and muscle strength? An insight for the muscle–brain–renal axis. *International Journal of Environmental Research and Public Health*, *18*(21), 1–13. https://doi.org/10.3390/ijerph182111299

Diniz, D. M., Franze, S., & Homberg, J. R. (2020). Crossing the Blood-Brain-Barrier: A bifunctional liposome for BDNF gene delivery – A Pilot Study. *BioRxiv*, https://doi.org/10.1101/2020.06.25.171264

Dou, S. H., Cui, Y., Huang, S. M., & Zhang, B. (2022). The Role of Brain-Derived Neurotrophic Factor Signaling in Central Nervous System Disease Pathogenesis. *Frontiers in Human Neuroscience*, *16*(June), 1–8. https://doi.org/10.3389/fnhum.2022.924155

Eidukaitė, S., Masiulis, N., & Kvedaras, M. (2023). Exploring the Preliminary Effects of Resistance Training on Total Brain-Derived Neurotrophic Factor (BDNF) Levels in Elderly Individuals: A Pilot Study. *Baltic Journal of Sport and Health Sciences*, *2*(129), 4–10. https://doi.org/10.33607/bjshs.v2i129.1377

Fahnestock, M. (2011). Brain-derived neurotrophic factor: The link between amyloid-β and memory loss. *Future Neurology*, *6*(5), 627–639. https://doi.org/10.2217/fnl.11.44

Feigin, V. L., Nichols, E., Alam, T., Bannick, M. S., Beghi, E., Blake, N., Culpepper, W. J., Dorsey, E. R., Elbaz, A., Ellenbogen, R. G., Fisher, J. L., Fitzmaurice, C., Giussani, G., Glennie, L., James, S. L., Johnson, C. O., Kassebaum, N. J., Logroscino, G., Marin, B., … Vos, T. (2019). Global, regional, and national burden of neurological disorders, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *The Lancet Neurology*, *18*(5), 459–480. https://doi.org/10.1016/S1474-4422(18)30499-X

Fleiner, T., Dauth, H., Gersie, M., Zijlstra, W., & Haussermann, P. (2017). Structured physical exercise improves neuropsychiatric symptoms in acute dementia care: A hospital-based RCT. *Alzheimer's Research and Therapy*, *9*(1), 1–9. https://doi.org/10.1186/s13195-017-0289-z

Forti, L. N., Van Roie, E., Njemini, R., Coudyzer, W., Beyer, I., Delecluse, C., & Bautmans, I. (2015). Dose-and gender-specific effects of resistance training on circulating levels of brain derived neurotrophic factor (BDNF) in community-dwelling older adults. *Experimental Gerontology*, *70*, 144–149. https://doi.org/10.1016/j.exger.2015.08.004

Fragala, M. S., Cadore, E. L., Dorgo, S., Izquierdo, M., Kraemer, W. J., Peterson, M. D., & Ryan, E. D. (2019). Resistance training for older adults: Position statement from the national strength and conditioning association. *Journal of Strength and Conditioning Research*, *33*(8), 2019–2052. https://doi.org/10.1519/jsc.0000000000003230

Ghanizadeh, M., Azarbayjani, M. A., Peeri, M., & Homaei, H. M. (2021). Effects of a Single Session of Eccentric or Concentric Resistance Exercise on Relative Expression of BDNF, PAX7 and IGF-1 in Young Men. *Nutrition & Food Sciences Research*, *8*(1), 11–19. http://nfsr.sbmu.ac.ir/article-1-439-en.html

Gomez-Pinilla, F., & Hillman, C. (2013). The influence of exercise on cognitive abilities. *Comprehensive Physiology*, *3*(1), 403–428. https://doi.org/10.1002/cphy.c110063

Gungor-Orhan, I., Akin, S., Powers, S. K., Olgaz-Bingol, S., & Demirel, H. A. (2025). Sedentary lifestyle induces oxidative stress and atrophy in rat skeletal muscle. *Experimental Physiology*, *110*(6), 857–865. https://doi.org/10.1113/EP092331

Hashemi, M. S., Ghaedi, K., Salamian, A., Karbalaie, K., Emadi-Baygi, M., Tanhaei, S., Nasr-Esfahani, M. H., & Baharvand, H. (2013). Fndc5 knockdown significantly decreased neural differentiation rate of mouse embryonic stem cells. *Neuroscience*, *231*, 296–304. https://doi.org/10.1016/j.neuroscience.2012.11.041

Henschel, B., Gorczyca, A. M., & Chomistek, A. K. (2020). Time Spent Sitting as an Independent Risk Factor for Cardiovascular Disease. *American Journal of Lifestyle Medicine*, *14*(2), 204–215. https://doi.org/10.1177/1559827617728482

Kandola, A., Hendrikse, J., Lucassen, P. J., & Yücel, M. (2016). Aerobic Exercise as a Tool to Improve Hippocampal Plasticity and Function in Humans: Practical Implications for Mental Health Treatment. *Frontiers in Human Neuroscience*, *10*(July), 1–25. https://doi.org/10.3389/fnhum.2016.00373

Lourenco, M.V., Frozza, R.L., de Freitas, G.B. et al. (2019). Exercise-linked FNDC5/irisin rescues synaptic plasticity and memory defects in Alzheimer's models. *Nat Med*, *25*(1), 165–175. https://doi.org/10.1038/s41591-018-0275-4

Madi, K., Bintoro, A. C., Samekto, M. I. W., Kustiowati, E., Muhartomo, H., & Diah, E. (2023). Correlation of Brain-Derived Neurotrophin Factor Levels in Epilepsy Patients Treated with Valproic Acid and Phenytoin with Cognitive Function. *Open Access Macedonian Journal of Medical Sciences*, *11*(B), 246–251. https://doi.org/10.3889/oamjms.2023.10844

Marston, K. J., Newton, M. J., Brown, B. M., Rainey-Smith, S. R., Bird, S., Martins, R. N., & Peiffer, J. J. (2017). Intense resistance exercise increases peripheral brain-derived neurotrophic factor. *Journal of Science and Medicine in Sport*, *20*(10), 899–903. https://doi.org/10.1016/j.jsams.2017.03.015

Matura, S., F. Carvalho, A., S. Alves, G., & Pantel, J. (2016). Physical Exercise for the Treatment of Neuropsychiatric Disturbances in Alzheimer's Dementia: Possible Mechanisms, Current Evidence and Future Directions. *Current Alzheimer Research*, *13*(10), 1112–1123. https://doi.org/10.2174/1567205013666160502123428

Mazur-Bialy, A. I. (2021). Asprosin—a fasting-induced, glucogenic, and orexigenic adipokine as a new promising player. Will it be a new factor in the treatment of obesity, diabetes, or infertility? a review of the literature. *Nutrients*, *13*(2), 1–10. https://doi.org/10.3390/nu13020620

Moghaddam, M. H. B., Aghdam, F. B., Jafarabadi, M. A., Allahverdipour, H., Nikookheslat, S. D., & Safarpour, S. (2012). The Iranian version of International Physical Activity Questionnaire (IPAQ) in Iran: Content and construct validity, factor structure, internal consistency and stability. *World Applied Sciences Journal*, *18*(8), 1073–1080. https://doi.org/10.5829/idosi.wasj.2012.18.08.754

Murawska-Ciałowicz, E., Wiatr, M., Ciałowicz, M., de Assis, G. G., Borowicz, W., Rocha-Rodrigues, S., Paprocka-Borowicz, M., & Marques, A. (2021). Bdnf impact on biological markers of depression—role of physical exercise and training. *International Journal of Environmental Research and Public Health*, *18*(14), 1–21. https://doi.org/10.3390/ijerph18147553

Okezie, U. M., Eze, P. M., Okoye, F. B. C., & Esimone, C. O. (2022). Orthosporin, a major component of the fermentation product of Lasiodiplodia theobromae ~ an endophytic fungus of Musa paradisiaca as a potential antimicrobial agent. *Notulae Scientia Biologicae*, *14*(2). https://doi.org/10.55779/nsb14211084

Panati, K., Suneetha, Y., & Narala, V. R. (2016). Irisin/FNDC5 - An updated review. *European Review for Medical and Pharmacological Sciences*, *20*(4), 689–697.

Park, J., Kim, J., & Mikami, T. (2022). Exercise hormone irisin prevents physical inactivity-induced cognitive decline in mice. *Behavioural Brain Research*, *433*(June), 114008. https://doi.org/10.1016/j.bbr.2022.114008

Prickett, C., Brennan, L., & Stolwyk, R. (2014). Examining the relationship between obesity and cognitive function : A systematic literature review. *Obesity Research & Clinical Practice*. https://doi.org/10.1016/j.orcp.2014.05.001

Romero Garavito, A., Díaz Martínez, V., Juárez Cortés, E., Negrete Díaz, J. V., & Montilla Rodríguez, L. M. (2024). Impact of physical exercise on the regulation of brain-derived neurotrophic factor in people with neurodegenerative diseases. *Frontiers in Neurology*, *15*(January), 1–16. https://doi.org/10.3389/fneur.2024.1505879

Tanaka, H., Monahan, K. D., & Seals, D. R. (2001). Age-predicted maximal heart rate revisited. *Journal of the American College of Cardiology*, *37*(1), 153–156. https://doi.org/10.1016/S0735-1097(00)01054-8

Tsai, S. J. (2018). Critical issues in BDNF Val66met genetic

studies of neuropsychiatric disorders. *Frontiers in Molecular Neuroscience*, *11*(May), 1–15. https://doi.org/10.3389/fnmol.2018.00156

Wang, T., Guan, N. Y., Amri, S., Kamalden, T. F., & Gao, Z. (2025). Effects of resistance training on performance in competitive badminton players : a systematic review. *Frontiers in Physiology*, *June*, 1–14. https://doi.org/10.3389/fphys.2025.1548869

Won, J., Callow, D. D., Pena, G. S., Gogniat, M. A., Kommula, Y., Arnold-Nedimala, N. A., Jordan, L. S., & Smith, J. C. (2021). Evidence for exercise-related plasticity in functional and structural neural network connectivity. *Neuroscience and Biobehavioral Reviews*, *131*(301), 923–940. https://doi.org/10.1016/j.neubiorev.2021.10.013

World Alzheimer Report 2011., Prince, Martin, Bryce, Renata, Ferri, & Cleusa. (2018). Alzheimer Report 2011 The benefits of early diagnosis and intervention. *World Alzheimer Report 2011*, 1–68. https://www.alzint.org/u/WorldAlzheimerReport2011.pdf

Wrann, C. D., White, J. P., Salogiannnis, J., Laznik-Bogoslavski, D., Wu, J., Ma, D., Lin, J. D., Greenberg, M. E., & Spiegelman, B. M. (2013). Exercise induces hippocampal BDNF through a PGC-1α/FNDC5 pathway. *Cell Metabolism*, *18*(5), 649–659. https://doi.org/10.1016/j.cmet.2013.09.008

Wu, J., Jedrychowski, M. P., Korde, A., Ye, L., Lo, J. C., Rasbach, K. A., Choi, J. H., Long, J. Z., Kajimura, S., Zingaretti, M. C., Vind, B. F., Bat, W., & Bat, M.-. (2012). *A PGC1- a -dependent myokine that drives brown-fat-like development of white fat and thermogenesis*. https://doi.org/10.1038/nature10777

Yan, S., Fu, W., Wang, C., Mao, J., Liu, B., Zou, L., & Lv, C. (2020). Association between sedentary behavior and the risk of dementia: a systematic review and meta-analysis. *Translational Psychiatry*, *10*(1). https://doi.org/10.1038/s41398-020-0799-5

Ye, X., Shen, Y. M., Ni, C., Ye, J., Xin, Y., Zhang, W., & Ren, Y. Z. (2019). Irisin reverses insulin resistance in C2C12 cells via the p38-MAPK-PGC-1α pathway. *Peptides*, *119*(July), 170120. https://doi.org/10.1016/j.peptides.2019.170120

Yu, F., Vock, D. M., Zhang, L., Salisbury, D., Nelson, N. W., Chow, L. S., Smith, G., Barclay, T. R., Dysken, M., & Wyman, J. F. (2021). Cognitive Effects of Aerobic Exercise in Alzheimer's Disease: A Pilot Randomized Controlled Trial. *Journal of Alzheimer's Disease*, *80*(1), 233–244. https://doi.org/10.3233/JAD-201100

Zuo, C., Yin, Y., Zheng, Z., Mu, R., Liang, Y., Wang, S., & Ye, C. (2025). Unlocking the full potential of resistance training: a comparative analysis of low- and high-intensity effects on neurotrophic growth factors and homocysteine. *Discover Applied Sciences*, *7*(2). https://doi.org/10.1007/s42452-025-06521-4