Physiological responses of resistance training in increasing brain-derived neurotrophic factor levels: a systematic review

Respuestas fisiológicas del entrenamiento de resistencia para aumentar los niveles de factor neurotrófico derivado del cerebro: una revisión sistemática

Authors

Dany Pramuno Putra[1]
Devi Arianti[1]
Melya Rossa[1]
Dimas Aji Prayitno[1]
Fransiskalina Erfarenata[1]
Junian Cahyanto Wibawa[2]
[1] Universitas Airlangga (Indonesia)
[2] STKIP PGRI Trenggalek (Indonesia)

Corresponding author:
Dany Pramuno Putra
dany.pramuno@vokasi.unair.ac.id

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Abstract

Background: Cognitive function decline is a hallmark of dementia, a progressive neurological disease. One neurotrophin that is crucial to neuroplasticity, cognition, and mental health is brain-derived neurotrophic factor (BDNF). Exercise has currently been shown to be an effective non-pharmacological treatment for enhancing overall health. It is still unknown whether weight exercise raises BDNF levels.
Objective: The purpose of this research was to ascertain whether resistance training raised human BDNF levels. Materials and methods: We looked through a number of literature databases, including Scopus, Pubmed, Web of Science, and Science Direct, for our systematic review study. A search was conducted for articles published between 2015 and 2025 that discussed resistance training and BDNF. The databases Scopus, Web of Science, Pubmed, and Science Direct were used to locate 707 published publications in total. For this systematic review, ten papers that satisfied the inclusion criteria were chosen and examined. This study evaluated the standard operating procedures using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).
Results: It has been shown that resistance training can increase BDNF levels in humans.
Conclusions: Physical exercise has been shown to significantly increase BDNF levels in humans. Resistance training has the potential to be a preventive and therapeutic approach to dementia through increasing BDNF levels, but more standardized clinical trials are needed to prove this.

Keywords

BDNF; resistance training; dementia; physical exercise.

Resumen

Antecedentes: El deterioro de la función cognitiva es un sello distintivo de la demencia, una enfermedad neurológica progresiva. Una neurotrofina crucial para la neuroplasticidad, la cognición y la salud mental es el factor neurotrófico derivado del cerebro (BDNF). Actualmente, se ha demostrado que el ejercicio es un tratamiento no farmacológico eficaz para mejorar la salud general. Aún se desconoce si el ejercicio con pesas aumenta los niveles de BDNF.
Objetivo: El propósito de esta investigación fue determinar si el entrenamiento de resistencia aumentaba los niveles de BDNF en humanos.
Materiales y métodos: Para nuestra revisión sistemática, revisamos diversas bases de datos bibliográficas, como Scopus, Pubmed, Web of Science y Science Direct. Se realizó una búsqueda de artículos publicados entre 2015 y 2025 que abordaran el entrenamiento de resistencia y el BDNF. Se utilizaron las bases de datos Scopus, Web of Science, Pubmed y Science Direct para localizar un total de 707 publicaciones. Para esta revisión sistemática, se seleccionaron y examinaron diez artículos que cumplían los criterios de inclusión. Este estudio evaluó los procedimientos operativos estándar (PRISMA) utilizando los Elementos de Informe Preferidos para Revisiones Sistemáticas y Metaanálisis.
Results: Se ha demostrado que el entrenamiento de resistencia puede aumentar los niveles de BDNF en humanos.
Conclusiones: Se ha demostrado que el ejercicio físico aumenta significativamente los niveles de BDNF en humanos. El entrenamiento de resistencia tiene el potencial de ser un enfoque preventivo y terapéutico para la demencia al aumentar los niveles de BDNF, pero se necesitan más ensayos clínicos estandarizados para demostrarlo.

Palabras clave

BDNF; Entrenamiento de resistencia; Demencia; Ejercicio físico.

Introduction

Geriatric syndromes and chronic disorders may arise as a result of the aging process, which is marked by a substantial decline in physiological function and gradual biological deterioration (Cruz-Jentoft et al., 2019). The World Health Organization states that attention should be paid to age-related declines in functions such as neuromuscular performance and cognitive function (Pruchno and Carr, 2017). Aging has detrimental effects on neuromuscular processes including changes in several processes such as reduced muscle mass, strength, power, and mobility (Cruz-Jentoft et al., 2019). Reduced physical performance and muscle atrophy are indicators of sarcopenia, frailty, and risk factors for unfavorable health outcomes, such as falls (Castaño et al., 2022). In addition, aging caused by age factors also triggers an increase in Alzheimer's disease.

The most prevalent age-related dementia, Alzheimer's disease was initially identified in 1907 by neuropathologist Gaetano Perusini and neurologist Alois Alzheimer. It is typified by a gradual deterioration in cognitive function and memory loss (De Ninno et al., 2024). According to estimates, the prevalence of Alzheimer's disease in people over 65 is between 10 and 30 percent, and in women, it is between 1 and 3 percent more common due to aging-related variables (Dev et al., 2021). The most prevalent type of dementia is Alzheimer's disease, a complicated degenerative condition of the central nervous system. Amyloid-beta (Aβ) buildup, neurofibrillary tangles, and permanent neuronal death in the frontal, temporal, parietal, hippocampus, and basal forebrain are the primary pathogenic characteristics of Alzheimer's disease (Kent et al., 2020). Severe clinical dementia may arise from these pathological alterations, which can also include synapse loss, poor immunological response, neurovascular dysfunction, inflammatory response, and brain atrophy (Colonna and Holtzmann, 2017).

Brain-derived neurotrophic factor (BDNF), a member of the neurotrophin family, is crucial for promoting the growth, differentiation, and survival of neurons. Both neuroplasticity and cognitive function depend on BDNF (Ventriglia et al., 2013). The polypeptides that make up neurotrophins are mostly found in the neurological system. Brain nerve cell survival, differentiation, and activation are all influenced by neurotrophins (Wang et al., 2012). Neurotrophic factor generated from the brain one important component of the central nervous system (CNS) that has a positive correlation with cognitive function is BDNF. By controlling the BDNF/TrkB/PI3K/Akt signaling cascade, it governs synaptic function and neuronal longevity (Jiang et al., 2023). Furthermore, it has been demonstrated that BDNF improves cognitive function by restoring mitochondrial function in neurons during physical exercise, which facilitates neurotransmitter production (Jiménez-Maldonado et al., 2025).

A well-liked training method with numerous health advantages is resistance training (Barakat et al., 2020). Prior studies have demonstrated that various skeletal muscle adaptations can be produced by resistance training prescription parameters like volume and intensity (Bagheri et al., 2019). Resistance training is a type of exercise that promotes muscle growth and strength by using either one's own body weight or external weights. It works well for enhancing general metabolic health, body composition, and physical fitness (Westcott, 2012). Because it improves bone density, functional strength, and quality of life, this exercise is advised for everyone, even the elderly, not just athletes (Phillips and Winett, 2010). According to findings from earlier studies, aerobic exercise can raise BDNF levels in people (Muñoz Ospina and Cadavid-Ruiz, 2024). However, there are not many studies that discuss the type of resistance training. In addition, the physiological mechanisms underlying resistance training on increasing BDNF levels have not provided conclusive evidence or have not been found in depth and there are still limitations in the study, so this indicates that there is an opportunity for further research. Therefore, this systematic review will try to discuss and examine in depth the stages and how resistance training affects increasing BDNF levels in humans.

Materials and method

Study Design

Researchers conducted thorough searches in journal databases such as Pubmed, Science Direct, Web of Science, and Scopus for systematic review studies. These databases are considered the best in the world for collecting papers with strong scientific basis and significant influence. Duplicate items were eliminated using this initial search strategy. The search results were further filtered using preset inclusion and exclusion criteria.

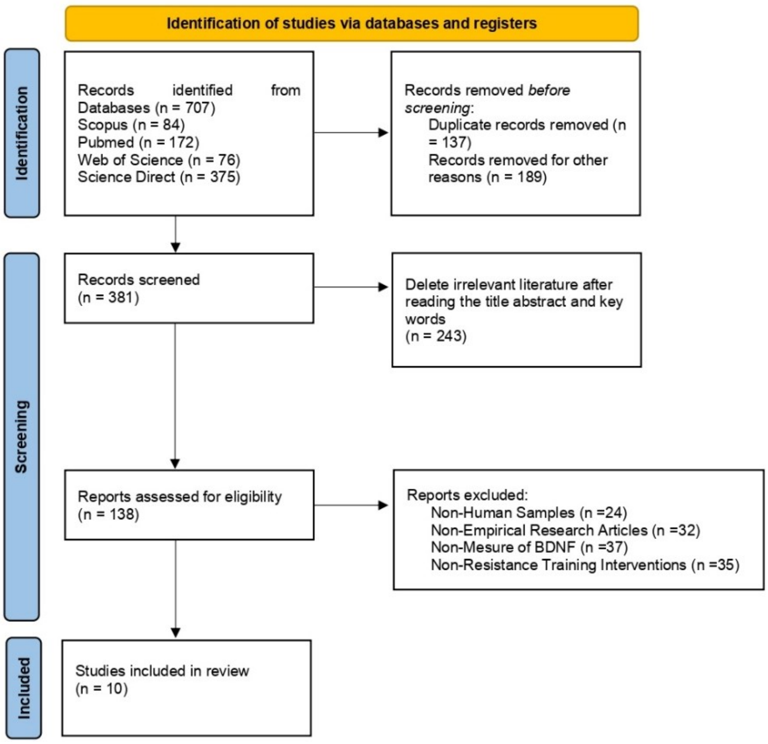
Eligibility Criteria

By looking through publications from a predefined database published within the last ten years, the inclusion criteria for this study were established. Additionally, the pieces covered experimental research on how exercise raises BDNF levels. BDNF levels and resistance training were among the search terms utilized. Furthermore, our analysis excluded publications that were not included in trustworthy search indexes like Scopus, Web of Science, Pubmed, or Science Direct, or that did not adhere to scientific validity requirements. Therefore, we actually used the inclusion criteria that we established to filter the chosen articles.

Procedure

Following evaluation and verification, the publications' titles, abstracts, and full texts were added to the Mendeley database. Using the databases Scopus, Science Direct, Pubmed, and Web of Science, 707 publications were discovered during the initial screening phase. 381 eligible papers were chosen for the second screening step after duplicate articles and reasons for title inconsistencies were identified. 138 papers were chosen in the third round after the title, abstract, and keywords were reviewed. We studied every article in this last step and decided that, depending on their suitability, the study had to be original, the parameter had to be a BDNF biomarker, the intervention had to be resistance training of some kind, and the sample had to be human. We now arranged the materials according to their general appropriateness. Following a rigorous review and observation process, ten papers that satisfied the inclusion criteria were chosen for analysis. Meeting the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) was the operational condition for this study.

Figure 1. PRISMA flowchart of the article selection process



Results

Table 1. Summary of the design and intervention of the studies

Author	Design	Participants	Participants Age	Intervention	Outcome
(Zuo et al., 2025)	Randomized controlled trials	Twelve young male adults	18-30 years	Exercise Program 1. Study participants completed 2 exercise protocols including high intensity resistance training and low intensity resistance training. 2. Five exercises (flat bench press, barbell back squat, deadlift, seated leg flexion, and reverse arm curl) at 80% of 1RM were part of the high-intensity resistance training regimen. The workouts lasted roughly 60 minutes and consisted of four to five sets of 12 repetitions with 2-minute breaks.. 3. The exercises used in the HIRT program were also used in the low intensity resistance training protocol. With a 2-minute gap between each session, the LIRT protocol's repetitions were assessed using the formula: (80% of 1RM load (kg) × repetitions (HIRT))/40% 1RM to volitional fatigue. 4. As a result, the LIRT regimen was carried out for roughly 60 minutes, with 40% 1RM and 4–5 sets of 24 repetitions.	1. Training with high intensity resistance training is proven to significantly increase BDNF levels.
(Eidukaitė et al., 2023)	Randomized controlled trials	12 adults	60 years	Exercise Program 1. For 12 weeks, resistance training was done twice a week. 2. Leg extension, leg curl, leg press, and calf raises were the four lower limb exercises that were part of the training regimen. 3. Participants completed three working sets and a warm-up set prior to the working set for each of the four activities. 4. There was a 2-minute rest period in between sets and a 3-minute break period in between workouts. For every working set, the exercise intensity was kept between 70% and 85% of the participant's 1-RM. The exercises have a repetition range of 6–10 repetitions.	1. There was a significant increase in BDNF levels after resistance training intervention.
(Castaño et al., 2022)	Randomized controlled trials	Thirty community-dwelling older adults	66-70 years	Exercise Program 1. For 16 weeks, twice-weekly resistance training and resistance training plus cognitive training interventions were carried out. 2. A 2-week introductory period and a 14-week physical training term comprised the two stages of the training. 3. Training sessions lasted roughly 60 minutes in both periods, which included a 5-minute warm-up, a 50-minute workout, and a 5-minute cool-down. 4. All sessions were led by two seasoned personal trainers and took place in groups of four	1. There was a significant increase in both groups, but the highest increase in BDNF levels occurred in the group with a combination of resistance training + cognitive training.

				individuals. Based on the evaluation of perceived effort (RPE), full range of motion exercises were carried out at a moderate level of intensity.	
(Arazi et al., 2021)	Randomized controlled trials	Thirty older men	60 years	Exercise Program 1. The duration of each exercise intervention was 45 minutes, which included a typical warm-up of 10 minutes, a primary exercise of 30 minutes, and a cool-down of 5 minutes. 2. Resistance training: Participants in the strength group had two circuits of resistance training to complete the following exercises for ten repetitions at 65–70% of 1RM: leg press, lat pulldown, knee flexion, bench press, calf raise, and arm curl. 3. There were 60 and 120 seconds of rest in between stations and circuits, respectively. 4. Endurance training: Running at 65–70% for 30 minutes (3 × 10 minutes with 120-second intervals) was the endurance group's primary workout.	1. Both resistance training and endurance training significantly increased BDNF levels.
(Jiménez-Maldonado et al., 2025)	Randomized controlled trials	Fifteen college students	21-24 years	Exercise Program 1. Jumping jacks, wall sits, push-ups, abdominal crunches, step-ups to a chair, squats, triceps dips on a chair, planks, high knees/running in place, lunges, push-ups and rotations, and side planks were all part of the high-intensity circuit training program. 2. The protocol did not contain an introductory session because the participants reported having adequate motor abilities and technique knowledge for the activities. 3. The training session lasted 24 minutes, with each exercise lasting 30 seconds, the maximum number of repetitions allowed, and a passive recovery period of 30 seconds (1:1 ratio). The circuit was completed twice. 4. For eight weeks, the high-intensity circuit exercise was done three times a week on Mondays, Wednesdays, and Fridays.	1. There was a significant increase in BDNF levels in both intervention and control groups.
(Banitalebi et al., 2020)	Randomized controlled trials	Ninety four women	18-50 years	Exercise Program 1. To put it briefly, the exercise regimen included three sessions a week for 12 weeks of supervised compound exercise, with each session lasting roughly 100 minutes. 2. Pilates, stretching, balancing, resistance, and endurance training were all part of the fitness regimen. 3. Biceps curls, triceps extensions, bench presses, seated rows, heel raises, leg extensions, and squats were all part of the resistance training regimen. 4. Three sets of twelve repetitions at 40–70% 1RM were done three times a week.	1. There was a significant increase in BDNF levels in the group with physical exercise intervention.
(Ozkul et al., 2018)	Randomized controlled trials	36 participants	18-60 years	Exercise Program 1. Incorporate weight exercise, such Pilates, with aerobic training. 2. For eight weeks, exercise	1. There was a significant increase in BDNF levels in the physical exercise intervention group.

				is done. 3. Walking on a treadmill is the method used for aerobic exercise. 4. Segmental extremity movements, single-leg and double-leg stretches, one-leg circles, shoulder bridges, the hundreds, chest lifts, oblique chest lifts, toes apart, heels together, side bands, clams, arm openings, cobras, breast strokes, swimming, four-point kneeling, single- and double-leg stretches, camel and cat stretches, lying trunk rotation, and relaxation exercises are all part of Pilates.	
(Marston et al., 2017)	Randomized controlled trials	Sixteen individuals	23-25 years	Exercise Program 1. Participants received verbal and visual guidance on correct lifting technique for seven resistance exercises during the first session: dumbbell arm curl, seated row, leg press, leg extension, latissimus dorsi pull-down [lat pull-down], bench press, and military press. 2. Participants underwent either a strength-based or a hypertrophy-based resistance training regimen during the next two lab sessions.	1. There was a significant increase in BDNF levels in the physical exercise intervention group.
(Forti et al., 2015)	Randomized controlled trials	Fifty-six apparently healthy elderly	67-69 years	Exercise Program 1. Resistance training is performed three times every two weeks till the age of twelve. 2. Exercise consists of seated rows, leg extensions, and leg presses. 3. Exercise begins with a more thorough examination using a treadmill or statistical device. 4. Based on the ACSM protocol for resistance training, the High protocol consists of two sets that are performed at intervals of one minute, with 10 to 15 repetitions at 80% of 1RM. 5. In the Low resistance test, participants are instructed to complete one set with 80–100 repetitions at 20% of 1RM. 6. Participants in the Low+ group are instructed to perform 60 repetitions, starting at 20% of 1RM and ending quickly (without injury), with external resistance increased to 40% of 1RM and participants instructed to perform 10–20 repetitions as well.	1. There was a significant increase in BDNF levels in the Low + resistance training intervention group.
(Deus et al., 2021)	Randomized controlled trials	157 participants	66-67 years	Exercise Program 1. Resistance training was performed three times every six weeks. 2. Participants performed twelve exercises for each session lasting approximately sixty minutes. 3. They performed three sets of eight to twelve repetitions with a two-minute rest between each set and exercise. To produce concentric and eccentric muscle, the repetitions were characterized by two different rhythms. 4. Resistance training consisted of the following exercises: unilateral chest press, squat,	1. There was a significant increase in BDNF levels in the resistance training group.

		unilateral row, bilateral knee extension, unilateral shoulder press, hip thrust, unilateral knee flexion, biceps curl, unilateral hip adduction, unilateral elbow extension, unilateral hip abduction, and seated calf raise.

Discussion

Determining the impact of resistance training on raising BDNF levels in humans was the aim of this investigation. Previous research has demonstrated that resistance training, which includes five different workout types the flat bench press, barbell back squat, deadlift, seated leg flexion, and reverse arm curl significantly raises BDNF levels in people (Zuo et al., 2025). Other research data involving 60-year-olds proved that resistance training consisting of calf lifts, leg extensions, leg curls, and leg presses performed twice a week for 12 weeks was shown to have a significant impact on increasing BDNF levels (Eidukaitė et al., 2023). So resistance training does have a good impact on the elderly. Strengthening the data based on other research data on elderly people with a sample of 66-70 years old proves that the combination of resistance training and cognitive training carried out for 16 weeks has been proven to have a significant impact on increasing BDNF levels in humans (Castaño et al., 2022). So, it is highly recommended for elderly people to do resistance training to keep the body healthy, especially in relation to cognitive function.

Resistance training in elderly people has a very good impact in keeping the body healthy and fit. Resistance training has extraordinary benefits in maintaining the human body. The results of research that were also conducted on the elderly who had done resistance training consisting of ten reps of the leg press, lat pulldown, knee flexion, bench press, calf raise, and arm curl at 65-70% of 1RM were proven to have a significant impact on increasing BDNF levels (Arazi et al., 2021). Other data also proves the same thing that resistance training has a significant impact on increasing BDNF levels (Banitalebi et al., 2020). In addition to just doing resistance training, combination training is also important in improving the health of the body. As previously conducted research data proves that the combination of aerobic training and resistance training carried out for 8 weeks consisting of walking on a treadmill and pilates exercises has been proven to be significant in increasing BDNF levels in humans (Ozkul et al., 2018). So this can be an alternative combination of exercises that is useful in improving cognitive function in humans.

Other research data also proves that resistance training physical exercises including bench press, military press, dumbbell arm curl, seated row, leg press, leg extension, and latissimus dorsi pull-down (lat pull-down) and a combination of hypertrophy-based strength training have been shown to have a significant impact on increasing BDNF levels (Marston et al., 2017). Other research data conducted on elderly people who received a 12-week, three-time-weekly resistance training intervention consisting of leg press, leg extension and seated row exercises had a significant impact on increasing BDNF levels in elderly people (Forti et al., 2015). Other data that was also conducted on elderly people who had been given resistance training interventions carried out 3x a week for 6 months consisting of unilateral chest press instrument exercises, squats, unilateral rows, bilateral knee extensions, unilateral shoulder presses, hip thrusts, unilateral knee flexions, biceps curls, unilateral hip adduction, unilateral elbow extension, unilateral hip abduction, seated calf raises were significantly proven to increase BDNF levels (Deus et al., 2021). So resistance training is effective as a non-pharmacological therapy in improving cognitive function through increasing BDNF levels. Especially for the elderly, resistance training can be an alternative type of physical exercise that must be done routinely to improve cognitive function that occurs due to age-related decline.

Physiological Mechanisms of Resistance Training in Increasing BDNF Levels in Humans

Physical exercise is the best non-pharmacological therapy because of its many health benefits and its ability to protect nerve cells and other organs without the use of drugs (Wibawa et al., 2024). Exercise causes mechanical and physiological changes in human muscles that allow them to adapt to stress. The human body physiologically increases more free radicals when doing physical exercise as a form of exercise adaptation response (Ayubi et al., 2024). Oxidative stress results from ROS production exceeding the body's antioxidant defense systems, which damages cells (Wibawa et al., 2025). The effects of exercise-induced cell damage cause the body's antioxidant levels to rise in an attempt to combat free radicals (Wibawa et al., 2024). It is a physiological response triggered by exercise. It is important for us to understand the cellular mechanisms of the stages that occur when the human body performs physical exercise.

In those with chronic illnesses, the improvement of quality of life is significantly influenced by physical activity and lowering morbidity and mortality. It has been demonstrated that physical activity is beneficial in both managing and preventing these conditions. However, the majority of individuals do not exercise enough, and there are few supervised programs available in global health care systems, which restricts the adoption of long-term measures to encourage active lives (Pollán et al., 2020). According to the American College of Sports Medicine (ACSM), physical activity has a major positive impact on the brain and nervous system, which helps prevent and treat disease (Garavito et al., 2024). Activities like jogging on a moderately intense treadmill three times a week have been demonstrated to strengthen brain networks, enhance spatial memory, and increase hippocampus capacity by 2% in older adults (55–80 years old) (Erickson et al., 2011). Additionally, this kind of exercise enhances brain memory and neural network connectivity (Vivar et al., 2016). Furthermore, the cerebral cortex and hippocampus have been shown to exhibit angiogenesis and endothelial cell growth (Van Der Borght et al., 2009).

Exercise has been shown to increase FNDC5 expression in the hippocampus, which in turn increases BDNF expression (Wrann et al., 2013), ERRα-dependent myokine and PGC-1α. TrkB signaling uses a negative feedback loop to suppress FNDC5 production when BDNF protein level rises. Long-term exercise has been shown to reduce FNDC5 expression levels, which is in line with higher hippocampal BDNF protein levels (Wrann et al., 2013). BDNF regulates skeletal muscle fat oxidation and homeostasis throughout the body, among other neurological and metabolic processes (Apan et al., 2020). The central and peripheral nervous systems both express BDNF, which is a member of the family of related nerve growth factors (Mazur-Bialy, 2021). Adipose tissue has been shown to be an active endocrine organ and a location for fat reserves to be stored (Prickett et al., 2015). Research conducted by Karczewska-Kupczewska et al., 2012 revealed that BDNF disrupts the energy metabolism of peripheral organs and takes part in central metabolism as well. Numerous investigations have demonstrated that BDNF affects key pathways related to energy expenditure in a certain way. BDNF can also influence glucose metabolism. Body mass index, total cholesterol, and triglycerides are metabolic syndrome risk variables that are directly connected with serum BDNF. Additionally, there is an inverse relationship between plasma BDNF and the risk of insulin resistance (Karczewska-Kupczewska et al., 2012).

The beneficial benefits of resistance exercise on BDNF levels could be explained by a variety of mechanisms. For instance, it has been demonstrated that resistance training increases muscle mass and strength, which can raise the synthesis of myokines such IL-15 and interleukin-6 (IL-6), which can raise the expression of BDNF (Kandola et al., 2016). Resistance training can also increase blood flow and oxygen delivery to the brain, which can increase the synthesis and release of BDNF (Gomez-Pinilla and Hillman, 2013). Furthermore, it has been proposed that resistance training's antidepressant effects could raise BDNF levels (Babyak et al., 2000). From a different angle, chronic oxidative stress raises vulnerability to depressive symptoms and causes low BDNF levels, which can be addressed by strengthening antioxidant defenses (Setayesh and Mohammad Rahimi, 2023).

The discovery that resistance training raised overall BDNF levels is in line with earlier research that demonstrated the beneficial impact of exercise on BDNF levels (Eidukaitė et al., 2023). This rise in BDNF encourages the growth of new neurons, enhances memory and learning, and delays cognitive aging (Garavito et al., 2024). Acute increases in BDNF following a single resistance training session have been documented in multiple investigations (Rasmussen et al., 2009). Furthermore, research on animals has demonstrated that resistance training increases BDNF expression (Gómez-Pinilla et al., 2002). Our findings provide more credence to the notion that resistance exercise can increase human BDNF production. In the case of BDNF and irisin, lower levels of both molecular biomarkers were substantially linked to older people' worse cognitive function, especially in learning and memory (Tsai et al., 2021). BDNF levels and gene expression have been shown to decrease with age (Peng et al, 2005). Meanwhile, doing resistance training has been proven to increase BDNF levels as a prevention of cognitive decline in humans, so it has been recommended that elderly people do resistance training (Deus et al., 2021).

Strenght and Limitations

This systematic review's advantage is that it just examines randomized controlled trials, which eliminates the chance of unclear causal linkages and are the most trustworthy kind of scientific data. Furthermore, the samples collected are human-focused, exhibit consistent data, and aren't combined with samples from other categories, like animal samples.

The limitation that we found was the lack of discussion and discussion related to how physical exercise, especially resistance training, can increase BDNF. Therefore, this study is considered important to be conducted in order to increase insight and knowledge related to how the influence of physical exercise with the type of resistance training can increase BDNF levels, thereby increasing cognitive function. Physical exercise with the type of resistance training can be one of the recommendations for people especially with the elderly to reduce the decline in work and function of the cognitive system. However, it may be related to the effective duration and intensity that is not yet known for sure, therefore further experimental research is needed to determine what duration and intensity are more effective in increasing BDNF levels in humans.

Conclusions

Based on the related articles we found, it can be said that regular physical exercise with resistance training has been proven to significantly increase BDNF levels as a biomarker and indicator of cognitive function performance. Therefore, physical exercise with resistance training can be recommended especially for the elderly as the best non-pharmacological therapy in reducing age-related cognitive decline. In addition, as a therapeutic effort to reduce other adverse effects caused by age.

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Authors' and translators' details:

Dany Pramuno Putra	dany.pramuno@vokasi.unair.ac.id	Author
Devi Arianti	deviarianti@vokasi.unair.ac.id	Author
Melya Rossa	melya.rossa@vokasi.unair.ac.id	Author
Dimas Aji Prayitno	dimas.aji@vokasi.unair.ac.id	Author
Fransiskalina Erfarenata	f.erfarenata@staf.unair.ac.id	Translator
Junian Cahyanto Wibawa	juniancahyanto96@stkippgritrenggalek.ac.id	Author