The Effect of Functional Training on Brain-Derived Neurotropic Factor and Cognitive Flexibility in Obese Elderly Men

Abstract

Aims: Physical exercise is a useful stimulus in improving cognitive function in the elderly, which seems to be mediated by stimulating the secretion of neurotrophic growth factors, including brain-derived neurotrophic factor. Therefore, the aim of the present study was to investigate the effect of functional training on brain-derived neurotrophic factor and executive functions in obese elderly men.

Materials & Methods: The present study was a quasi-experimental study with a pre-test-post-test design. For this purpose, 30 elderly men living in a nursing home in Khorramabad, aged 60 to 75, were randomly assigned to two groups of 15: Training and control. In the pre-test phase, blood was drawn from the participants after a 12-hour fast, and then the participants performed the Stroop task test. Physical training was performed for eight weeks, 3 sessions per week, each session lasting 40 minutes. The post-test phase was conducted 48 hours after the last training session and was conducted like the pre-test. Data were analyzed using paired t-test and univariate analysis of covariance.

Findings: The results of the present study showed that functional training has a significant effect on increasing the level of brain-derived neurotrophic factor in obese elderly men ($p<0.05$). Functional training also has a significant effect on improving executive functions (number of correct responses, reaction time of correct responses) in obese elderly men ($p<0.05$).

Conclusion: According to the results of the present study, it is recommended that trainers and geriatric specialists pay attention to teaching functional exercises to improve executive functions.

Introduction

Aging is considered one of the major global challenges of today. According to credible reports, a significant proportion of the population over the age of 65 suffers from obesity. Due to sedentary lifestyles and reduced physical activity associated with modern, mechanized living, the prevalence of this condition is steadily increasing, bringing numerous complications for this segment of society [1]. Statistics indicate that the prevalence of overweight is higher among men than women [2].

There is growing evidence that obesity has detrimental effects on the brain and cognitive functioning. Among the many aging-related issues, cognitive decline—particularly in executive functions such as cognitive flexibility—holds special significance [3]. Cognitive flexibility, defined as the ability to shift attention between tasks, adapt to changes, and think beyond fixed patterns, is a key factor in maintaining independence and quality of life in older adults. Any impairment in this domain can lead to deficits in processes such as problem-solving, planning, and everyday decision-making [4].

Previous studies have also demonstrated a link between changes in body composition (e.g., obesity and overweight) and cognitive dysfunction in the elderly [3, 5]. Supporting this evidence, research findings have shown that executive functions (EFs) in these individuals are significantly impaired, with noticeable deficits in cognitive performance and working memory [6]. Thus, the evidence suggests a direct relationship between obesity and impairments in executive functions [7].

Immunometabolic alterations induced by obesity have been identified as one of the key mechanisms underlying cognitive dysfunction [8]. Supporting this notion, previous research has shown that both abnormal fat accumulation and cognitive impairments are associated with reduced concentrations of brain-derived neurotrophic factor (BDNF)—a critical protein linked to neuronal health and brain function [9, 10].

BDNF is the most abundant neurotrophic factor in the body, and its role in modulating neurodegenerative processes is well established. As a member of the neurotrophin family, BDNF contributes to neural plasticity, differentiation, and survival. Studies have demonstrated that BDNF levels significantly decline in conditions such as glucose dysregulation, type 2 diabetes,

hyperglycemia, obesity, and insulin resistance. Conversely, physical activity-induced increases in BDNF secretion are considered one of the mechanisms involved in enhancing neuroprotection and cognitive performance [9].

Given the link between obesity, cognitive impairment, and BDNF levels, developing effective weight-loss strategies to mitigate such disorders and improve executive functions is of great importance. In this context, exercise is recognized as a cost-effective and practical intervention [11]. Previous findings have clearly demonstrated the relationship between physical activity, improved fitness, and reductions in body mass index (BMI). Moreover, exercise has been identified as a key factor in enhancing cognitive and brain function. Both aerobic and resistance training have been extensively studied in this regard [12].

However, most existing research has focused on aerobic exercise [13], likely due to its historical emphasis in neurocognitive studies and early findings—particularly in animal models—suggesting that resistance training does not significantly elevate BDNF levels [14]. For instance, acute aerobic exercise has been shown to increase tissue metabolism, leading to physiological changes such as elevated cardiac output, vascular stress, energy demands, and biological responses to hypoxia. These physiological responses—especially hypoxia—and increased cerebral and peripheral blood flow contribute to elevated BDNF levels [13].

Notably, considerable variability has been observed in BDNF levels following different types of exercise interventions**,** which appears to be influenced by factors such as individual differences, exercise intensity, and duration [15]. Research on the effects of resistance training and BDNF suggests a strong association between variables such as dosage and prescription method of resistance exercise and changes in BDNF levels [16]. These changes may occur through multiple mechanisms, including cardiovascular adaptations, heightened sympathetic activity, and increased lactate production [17].

It is important to note that previous studies have reported inconsistent findings regarding the impact of resistance training on BDNF. While many have observed increases in BDNF, others have reported no significant changes [16]. These discrepancies are likely due to variations in how the exercise protocols were administered. Based on the above, it seems that combining aerobic and resistance training may produce a synergistic effect, leading to more pronounced increases in BDNF.

Although the beneficial effects of exercise have been well-documented in healthy individuals, there remain considerable uncertainties regarding its impact on obese older adults [18]. Some researchers argue that the evidence supporting executive function improvements from exercise is limited [18], while others maintain that the findings are consistent and positive [19]. For example, Walsh & Tschakovsky conducted a study on elderly men and women and found that eight weeks of resistance training significantly increased BDNF levels [20]. Similarly, Erickson *et al.* (2011) examined the effects of six months of aerobic exercise in healthy older adults and reported that the intervention not only significantly elevated serum BDNF levels but also increased hippocampal volume and improved spatial memory [21].

Moreover, previous studies have faced methodological and empirical limitations. For instance, the American College of Sports Medicine (ACSM) recommends that exercise prescriptions aimed at improving health and physical fitness should be based on the FITT principle—Frequency, Intensity, Time, and Type—with specific guidelines regarding how many days per week (frequency), how hard the exercise is (intensity), how long each session lasts (time), and what kind of exercise is performed (type) [19]. However, earlier research has provided relatively limited information on these exercise prescription variables.

As a result, a specific training approach known as functional training has recently gained attention among researchers. This method incorporates both endurance and resistance components and emphasizes functional, multi-joint movements through aerobic activity and muscle strengthening [22]. Functional exercises can be adapted to any fitness level and typically involve greater muscular engagement than repetitive aerobic routines, thereby improving cardiovascular endurance, strength, and flexibility [22, 23].

Functional training also includes full-body exercises that engage movement patterns across multiple planes, delivered in short, intense, and varied circuit-style sessions. These sessions apply stress to various physiological systems in a balanced and integrative manner [24]. Some previous studies have demonstrated the beneficial effects of this type of training on anthropometric and body composition variables in overweight women [25]. Furthermore, functional training has

emerged as one of the leading global fitness trends [26], utilizing complex movement patterns that appear to increase energy expenditure—making it particularly appealing to individuals with obesity [27]. Given the high prevalence of obesity and cognitive decline among elderly men, and the urgent need for effective interventions to address these challenges, the present study aims to investigate the effects of a functional training program on serum BDNF levels and cognitive flexibility in obese older men [28]. We hypothesize that this exercise regimen will not only help modulate obesity-related risk factors but also enhance brain plasticity and cognitive flexibility through increased BDNF levels. Therefore, the findings of this research may contribute to the development of targeted exercise programs and practical strategies for improving brain health and quality of life in obese elderly populations. The current study was conducted to examine the impact of functional training on BDNF and executive functions in obese older men. Accordingly, the study hypothesizes that functional training will positively influence BDNF levels and cognitive flexibility in this population.

Materials and Methods

Research design and participants

This study employed a quasi-experimental design with a pre-test-post-test structure and a control group. The statistical population consisted of healthy men aged 60 to 75 years residing in elderly care centers in Khorramabad. According to data obtained from the Khorramabad Elderly Center, the total population was 412 individuals. The minimum sample size was determined to be 26 obese elderly men (13 per group), calculated using G*Power software version 3.1.9.2 with an alpha level of 5%, beta of 80%, and an effect size of 0.3, based on previous studies. To account for potential dropout, a total of 30 obese elderly men were selected [29]. Sampling was conducted using a convenience sampling method, and participants were randomly assigned to either the functional training group or the control group.

Inclusion Criteria: Participants were eligible if they met the following criteria:

1. Body mass index (BMI) greater than 30 kg/m^2
2. Ability to walk 10 meters independently
3. Ability to stand independently for at least 10 seconds
4. Normal vision
5. Ability to follow simple instructions

To ensure safety and capability, all participants were asked to perform these movements one week prior to the start of the study.

Exclusion Criteria: Participants were excluded if they had any of the following conditions:

1. Limiting musculoskeletal disorders
2. Neurological disorders (e.g., stroke, Parkinson's disease, paralysis)
3. Cardiovascular diseases
4. Uncontrolled high blood pressure
5. Memory-related dementia (defined as scoring below 22 out of 30 on the Mini-Mental State Examination)
6. Any illness or medication affecting balance and movement

If any of these conditions were observed, the participant was immediately withdrawn from the study protocol.

Instruments

Mini-Mental State Examination (MMSE): This test was developed by Marshal Folstein in 1975 to screen for cognitive decline in older adults. The MMSE consists of 20 items, yielding a total score of 30. According to standard references, a score below 22 indicates a probable cognitive impairment. The questionnaire includes five subscales: 1) orientation, 2) registration, 3) attention and calculation, 4) recent memory, and 5) various language functions. Folstein *et al.* (1975) reported a reliability coefficient of 0.87 using Cronbach's alpha and confirmed its validity through discriminant analysis between dementia and healthy groups. In Iran, the psychometric properties of this questionnaire were evaluated by Saeidian *et al.* (2018), who reported a reliability of 0.81 using Cronbach's alpha and confirmed its validity through discriminant validity [42]. In the present study, the reliability of the questionnaire was calculated to be 0.72.

Stroop Test: Originally developed by Stroop in 1935, this test is designed to assess selective attention and cognitive flexibility, and is widely used in cognitive evaluations [28]. The version used

in this study was a computerized adaptation based on standard Stroop test variables. The test consists of three stages:

- Stage 1: Color Naming Participants are asked to identify colored circles (red, blue, yellow, green) displayed randomly on a computer monitor by pressing the corresponding color-labeled keys on the keyboard. This stage serves as a training phase and does not influence the final results.
- Stage 2: Congruent and Incongruent Word Recognition A total of 96 color words—48 congruent and 48 incongruent—are randomly and sequentially displayed on the monitor. Participants must respond based solely on the color of the word, ignoring its semantic meaning, by pressing the appropriate labeled key. Each stimulus is presented for 2 seconds, with an inter-stimulus interval of 800 milliseconds.
- Stage 3: Rapid Color Identification Colored circles (red, yellow, green, blue) are shown in succession, and participants must quickly press the corresponding labeled keys. They are instructed that the visual color may differ from the word's meaning, and emphasis is placed on identifying the color itself.

The key performance indicators measured in this test were:

- Accuracy: Number of correct responses
- Speed: Mean reaction time for correct responses, measured in milliseconds [49].

Measurement of serum BDNF levels

Serum levels of brain-derived neurotrophic factor (BDNF) were measured using an enzyme-linked immunosorbent assay (ELISA) kit. Specifically, the Promega BDNF Emax ImmunoAssay System (Catalog No. G7611), manufactured in the United States, was employed according to the manufacturer's standard protocol. The kit features a sensitivity of 15.6 picograms per milliliter and a detection range of 0.325 to 20 nanograms per milliliter.

Research procedure

At the outset of this study, necessary coordination was established with the elderly care center in Khorramabad, and ethical approval was obtained under the code IR.IAU.B.REC.1403.045. After explaining the objectives and significance of the research, official permissions for implementation were secured. The study was conducted from September to November 2023. Following approval, participants underwent pre-test assessments. After a 12-hour overnight fast, blood samples were collected from participants between 8:00 and 9:00 AM at Noor Laboratory in Khorramabad by a qualified specialist. To prevent post-sampling hypotension, each participant was provided with a small cake and a glass of milk (approximately 300 calories). Subsequently, participants completed the computerized Stroop test to assess their executive functions. Based on their pre-test scores for executive function and serum BDNF levels, participants were randomly assigned into two homogeneous groups: Functional training and control. The intervention phase then commenced, consisting of eight weeks of training, with three sessions per week, each lasting 40 minutes. Participants in the functional training group engaged in the prescribed exercise regimen, while the control group continued their usual daily activities. Post-test assessments were conducted 48 hours after the final training session. As in the pre-test phase, blood samples were collected after a 12-hour fast between 8:00 and 9:00 AM at Noor Laboratory. Participants then completed the Stroop test again to reassess their executive functions.

Descriptive statistics were used to organize and summarize the data, including measures of central tendency (mean), dispersion (standard deviation), and graphical representation. The Shapiro-Wilk test was employed to assess the normality of data distribution. To test the research hypotheses, analysis of covariance (ANCOVA) was conducted. Data analysis was performed using SPSS software version 22, with a significance level set at $p>0.05$.

Training protocol

As recommended by La Scala Teixeira *et al.* [26], participants in the functional training group followed a supervised, in-person exercise protocol designed to enhance various physical capacities through an integrated, synergistic, and balanced approach. All training sessions were conducted in a controlled environment equipped with ergometers and meters (treadmills and stationary bicycles), as well as resistance training accessories and equipment.

Participants engaged in functional training three times per week, which included both aerobic and resistance-based functional exercises. Each session lasted 45 minutes and was structured as follows: 5 minutes of warm-up, followed by 15 minutes of aerobic exercise and 15 minutes of functional resistance training, ending with a 5-minute cool-down.

Aerobic exercises were performed on treadmills or bicycles at a moderate intensity level, corresponding to a rating of perceived exertion (RPE) of 4-6 on the Borg scale. Resistance training was organized in a circuit format, consisting of three rounds across eight stations. Each round involved 40 seconds of activity followed by 20 seconds of passive rest.
Table 1 illustrates intensity control using the 10-point RPE scale. In total, four distinct circuits were designed and rotated monthly, as suggested by La Scala Teixeira *et al.* [26]. To ensure progressive overload, exercises incorporated free weights (barbells, plates, dumbbells), elastic bands, and bodyweight movements—except for the fourth circuit, which was based on manual resistance exercises.

Table 1. Characteristics of functional training components; Adapted from La Scala Teixeira *et al.* [26]

Variable	Description
Activities performed	Integrated resistance exercises, including simultaneous upper and lower limb movements, multi-planar motions, core stability drills, motor coordination, and balance training
Intensity	Weeks 1-8; Rating of Perceived Exertion (RPE) 4-6 on a 0-10 scale
Volume/format/method	Circuit training with 8 stations; 40 seconds of exercise, 20 seconds of rest, 3 rounds; Total duration: 25 minutes

Statistical analysis
To verify the homogeneity of normal distribution, the Shapiro-Wilk test was employed, and the results confirmed the assumption of normality. For statistical analysis of the data, paired t-tests and analysis of covariance (ANCOVA) were used.

Findings
Table 1 presents the physical characteristics of the subjects. Table 2 also presents the mean and standard deviation of the research variables in the research groups during different measurement times.

Table 1. Physical characteristics of study participants

Group	N	Age (years)	Height (cm)	Weight (kg)	Body Mass Index (BMI)
Control	15	67.50±26.52	164.40±13.30	84.50±30.54	31.60±2.50
Experimental	15	68.30±23.29	165.60±86.94	84.70±53.33	31.60±2.50

Table 2. Descriptive Statistics for BDNF, accuracy, and reaction time in pre-test and post-test phases

Variable group	BDNF (ng/mL)		Accuracy (correct responses)		Reaction time (ms)	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Functional training	939/13 (83/83)	934/80 (68/77)	32/33 (89/4)	27/93 (39/6)	55/13 (47/7)	49/80 (28/7)
Control	944/00 (87/60)	871/53 (28/97)	27/46 (36/6)	28/33 (80/4)	49/26 (67/7)	06/49 (28/9)

In general, the results of Table 2 showed that there was a change in the BDNF variables and executive functions (accuracy (number of correct answers) and speed (reaction time)) in the intervention groups compared to the control group in the post-test phase, compared to the pre-test phase.
To assess the homogeneity of variances between the experimental and control groups in the post-test phase, Levene's test was conducted. The results confirmed homogeneity of variances for BDNF ($F(1,28)=0.54$, $p<0.05$), accuracy ($F(1,28)=0.81$, $p<0.05$), and reaction time ($F(1,28)=1.77$, $p<0.05$).
The Shapiro-Wilk test confirmed normal distribution of scores for BDNF ($Z=0.952$, $df=30$, $p<0.05$), accuracy ($Z=0.938$, $df=30$, $p<0.05$), and reaction time ($Z=0.946$, $df=12$, $p<0.05$).
A prerequisite for conducting ANCOVA is the presence of a significant correlation between pre-test and post-test scores. Correlation analysis revealed significant relationships between pre- and post-test scores for BDNF ($r=0.622$, $p<0.01$), accuracy ($r=0.413$, $p<0.01$), and reaction time ($r=0.589$, $p<0.01$).
The assumption of homogeneity of regression slopes was also examined. The regression slopes for BDNF ($F=1.09$, $df=27$, $p<0.05$), accuracy ($F=3.30$, $df=27$, $p<0.05$), and reaction time ($F=2.72$, $df=27$, $p<0.05$) were found to be similar across groups, indicating a linear relationship between the dependent variables and their predictors.
To test the study hypotheses, both univariate ANCOVA and paired t-tests were applied, with results presented in Tables 3 and 4.

Table 3. ANCOVA results for comparing BDNF and executive functions between research groups

Variable	Source	Sum of squares	df	Mean square	F Value	p-Value	Effect size (η^2)
BDNF	Pre-test	4.03	1	4.03	0.05	0.81	0.002
	Between groups	220.88	1	220.88	6.45	0.017	0.193
	Error	225.81	27	8.36	-	-	-
Accuracy (correct responses)	Pre-test	20.94	1	20.94	0.64	0.43	0.023
	Between groups	172.96	1	172.96	5.29	0.029	0.164
	Error	882.12	27	32.67	-	-	-
Reaction time	Pre-test	1265.81	1	1265.81	0.18	0.669	0.007
	Between groups	38964.71	1	38964.71	5.74	0.024	0.175
	Error	183111.92	27	6781.92	-	-	-

As shown in Table 3, there was a statistically significant difference between the groups in serum BDNF levels among elderly men, with an effect size of 0.19 (F=6.45, p=0.017). Additional results indicated a significant difference in accuracy (number of correct responses) between the groups, with an effect size of 0.16 (F=5.29, p=0.029). Furthermore, reaction time (response speed) also showed a significant difference between the groups, with an effect size of 0.17 (F=5.74, p=0.024).
To compare the groups pairwise, an independent t-test was conducted, and the results are presented in Table 4.

Table 4. Independent t-Test results comparing the effectiveness of functional training vs. control on BDNF and executive functions

Variable	t	p-Value
BDNF	5.43	0.017
Accuracy (correct responses)	4.80	0.029
Reaction time (ms)	-72.10	0.024

As shown in Table 4, the results indicate a statistically significant difference in BDNF levels between the functional training and control groups (p=0.017). Similarly, the accuracy of responses differed significantly between the two groups (p=0.029). Likewise, the reaction time in the functional training group was significantly different from that of the control group (p=0.024).
The present study aimed to investigate the effects of functional training on brain-derived neurotrophic factor (BDNF) and executive functions in obese elderly men. The key findings revealed that functional training significantly increased BDNF levels in this population. Moreover, the training program led to notable improvements in executive functions, including the number of correct responses and reaction time.
Consistent with these results, Ben-Zeev *et al.* [46] reported that a three-month high-intensity functional training program improved spatial learning, visual pattern discrimination, and attention span in adolescents. Their findings showed significant differences in attention-related tasks between the training and control groups [30].
Previous research has demonstrated that BDNF plays a critical role in neurodegenerative disease mechanisms, including neuronal survival, growth, differentiation, and plasticity. This protein is essential for learning, memory, and other cognitive functions. Low levels of BDNF have been associated with neuropsychiatric and degenerative disorders such as Alzheimer's disease and depression [14].
BDNF is also considered a key biological mediator of the effects of physical and cognitive training. Its levels in the human body are influenced by various factors, including gender, body weight, nutrition, and age. It is well established that BDNF concentration declines with aging, contributing to neural deterioration in older adults. Additionally, the number of BDNF-specific receptors is reduced in both healthy and Alzheimer's-affected elderly individuals, limiting their ability to benefit from this neurotrophic factor [13].
Studies have shown that reduced BDNF levels and receptor availability negatively impact hippocampal synaptic plasticity and neurogenesis—two processes crucial for memory and learning. Therefore, physical activity may help counteract age-related cognitive decline by enhancing BDNF levels and supporting hippocampal function [14].
Currie *et al.* investigated the relationship between serum BDNF levels and cardiorespiratory fitness, reporting an inverse correlation between the two variables. Specifically, individuals with higher cardiorespiratory fitness exhibited significantly lower BDNF levels. Although the precise mechanisms by which physical exercise affects the nervous system remain unclear, previous research suggests that reductions in oxidative stress and inflammation, increased angiogenesis,

secretion of neurotrophins and catecholamines, and enhanced neurogenesis—particularly in the hippocampus—may play a role [31].

Given BDNF's critical role in neuronal excitability and synaptic function, it is likely that BDNF is one of the key mediators through which physical activity induces structural and functional changes in the brain. Moreover, skeletal muscle, as the largest organ in the body, contributes significantly to neurogenesis, neuronal survival, and plasticity through the release of myokines such as BDNF, thereby supporting cognitive performance [32].

Evidence suggests that resistance training may be more effective than aerobic training in elevating BDNF levels. High-intensity resistance and interval training have also been shown to be particularly beneficial for cognitive enhancement. Notably, functional training—which typically involves multi-joint movement patterns, balance challenges, and coordination tasks—may be especially effective in stimulating BDNF secretion. Compared to single-mode exercises, functional training demands greater cognitive engagement and activates broader brain regions involved in motor planning and sensorimotor processing, potentially enhancing BDNF signaling [9, 34].

Therefore, functional training, by combining the benefits of both aerobic and resistance modalities, may contribute to increased BDNF levels—a hypothesis supported by the findings of this study. Following a period of functional training, a significant increase in BDNF was observed among obese elderly men, aligning with much of the existing literature. Numerous studies have demonstrated that exercise interventions—particularly those incorporating both aerobic and resistance components—can elevate BDNF levels [36, 37].

For example, Alizadeh & Dehghanizadeh [30] found that a functional training program significantly increased BDNF levels in overweight middle-aged women. However, contradictory findings also exist. Ruiz *et al.*, in an 8-week resistance training study on adults, reported no significant changes in serum BDNF levels post-intervention. These discrepancies may be attributed to differences in training type, participant age, and BMI, as the subjects in Ruiz's study were young and had normal body mass indices [38].

In contrast, Nascimento *et al.* [39] reported a significant increase in peripheral BDNF levels following a 16-week multimodal training program in elderly individuals with MCL disease. It is worth noting that the average age of participants in Nascimento *et al.*'s study (66 years) was similar to that of the present study, whereas participants in Ruiz *et al.*'s [38] study were considerably older (92 years) [40].

Discussion

It appears that age may serve as a moderating variable in the regulatory response of BDNF to exercise interventions. In line with this, other researchers agree that aging is a biological regulator of peripheral BDNF concentration in humans. Several molecular mechanisms may explain the impact of functional exercise on serum BDNF levels [41].

First, the present study included moderate-intensity aerobic training. It has been suggested that aerobic exercise increases intracellular calcium, which enhances neuronal activity and subsequently stimulates the synthesis and release of BDNF. Additionally, resistance training promotes the synthesis of insulin-like growth factor 1 (IGF-1) in skeletal muscles of older men and women. This anabolic molecule ultimately induces BDNF production in the brain [42].

Moreover, lactate produced during exercise has been shown to enhance BDNF synthesis in the brain. Other mechanisms, such as increased cerebral blood flow, modulation of inflammatory and oxidative responses, and regulation of neurotransmitter systems, also contribute to elevated peripheral BDNF levels. Notably, serum BDNF is released during platelet activation, as platelets are the primary reservoir of circulating neurotrophins [44].

The findings of this study also indicate that functional training significantly improves cognitive flexibility in obese elderly men. Supporting this, Pantoja-Cardoso *et al.* [45] reported that functional training improved executive functions in older women. Among younger participants, Ben-Zeev *et al.* found that high-intensity functional training enhanced spatial learning, visual pattern discrimination, and attention span in adolescents. Three months post-intervention, the training group outperformed the control group in all cognitive tasks, suggesting that such training may positively influence academic performance [46].

These observations may be attributed to increased BDNF expression following functional exercise, involving enhanced cellular processing in the brain (synthesis, secretion, uptake, and degradation). Given BDNF's role in memory, learning, synaptic plasticity, maturation of immature neurons, and

longevity of mature neurons, the observed improvements in executive functions among elderly participants may reflect adaptive neurobiological changes [47].

Supporting this, Fernández *et al.* (2017) demonstrated that functional training increases BDNF expression in the brain—particularly in the hippocampus—via activation of the TrkB receptor. Aerobic exercise has also been shown to stimulate BDNF synthesis and release in brain regions rich in TrkB receptors, promoting synaptic plasticity and memory enhancement, which in turn improves cognitive flexibility [47].

Overall, the findings of the present study suggest that a period of functional training significantly elevates serum BDNF levels and enhances cognitive flexibility in obese elderly men. Based on these results, occupational therapists and professionals working with older adults are encouraged to incorporate functional training to promote cognitive flexibility, synaptic connectivity, and BDNF regulation.

However, this study has certain limitations, including a small sample size and limited generalizability. Additionally, due to the cross-sectional design, causal inferences cannot be made. A longitudinal prospective study would better clarify the effects of functional training on BDNF and cognitive flexibility in obese elderly men. Finally, since the study was conducted exclusively among elderly men in Khorramabad, caution is advised when interpreting and generalizing the findings.