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The effect of eight weeks of aerobic exercise and garlic supplementation on brain tissue inflammatory markers and sensorimotor function in rats with Parkinson's disease

Mohammad Reza Khosravi[1]
Department of exercise physiology, Bo.C., Islamic Azad University, Borujerd, Iran

Seyed Ali Hosseini[2]
Department of exercise physiology, Marv.C, Islamic Azad University, Marvdasht, Iran

Ghobad Hasanpoor[3]
Department of exercise physiology, Marv.C, Islamic Azad University, Marvdasht, Iran

Mehdi Roozbehani[4]
Department of exercise physiology, Bo.C., Islamic Azad University, Borujerd, Iran

ABSTRACT

Introduction: Inflammation of the nervous system and impaired sensory-motor function reduce the quality of life of patients with Parkinson's disease (PD). Although the role of exercise and medicinal plants in the treatment of neurological diseases has been demonstrated, the anti-inflammatory effects of aerobic exercise (AT) and garlic supplementation (G) on this pathway are not yet well understood. Therefore, the present study aimed to investigate the effect of eight weeks of AT and GS on inflammatory markers of brain tissue and sensory-motor function in rats with PD.

Material & Methods: In this experimental study, 32 parkinson rats were divided into groups (1) Res, (2) AT, (3) G, and (4) AT+G by injection of 2 mg/kg IP of reserpine. Also, to investigate the effects of PD induction on research variables, 8 healthy rats were placed in the healthy control (HC) group. AT was performed for eight weeks, five sessions per week, each session lasting 15-48 minutes and at a speed of 10-24 meters per minute. Also, 500 mg/kg/day of garlic aqueous extract was fed to rats daily. One-way ANOVA and Tukey post hoc test were used to analyze the data in SPSS 26 software.

Results: In the AT, G and AT+G groups, TLR and CRP values were significantly lower, and the slope of balance maintenance and the time of balance maintenance were significantly longer than in the Res group (P=0.001). Also, in the AT+G group, TLR values were significantly lower, the slope of balance maintenance and the time of balance maintenance were significantly longer than in the AT and G groups. The time of balance maintenance in the AT+G group was significantly longer than in the AT group ($P \leq 0.05$).

Conclusion: It seems that although AT and G alone have effects on reducing inflammation in brain tissue and improving sensory-motor function in conditions that induce PD, the combination of these two interventions appears to enhance each other's effects.

Keywords: Exercise, Garlic, Inflammation, Parkinson's Disease.

***Correspondence:** Alihoseini_57@iau.ir
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1. Introduction

Parkinson's disease (PD) is the second most common neurodegenerative disease, which continues to spread despite extensive research by health organizations to prevent and treat it. In other words, this disease has shown different prevalence depending on gender, race, geographical region, and age (1). It is believed that PD is caused by damage to the substantia nigra, increased oxidative stress, and increased alpha-synuclein, which predisposes to inflammation (1,2). Subsequently, increased oxidative stress activates granulocyte macrophage colony-activating factor (GM-CSF) and ultimately leads to the activation of the Toll-like receptor (TLR) on the surface of neurons (2). Activation of this DNA-binding protein triggers the expression of pro-inflammatory mediators such as TNF-α, IL-6, IL-1α, and pro-IL-1β, ultimately leading to an increase in the acute-phase inflammatory protein C-reactive protein (CRP) (2). Therefore, evidence indicates that dysfunction in the function of various parts of the nervous system is due to an increase in inflammatory factors, which gradually changes with the loss of sensory and motor neurons, motor balance, psychological disorders, and the quality of life of the affected person (3).

On the other hand, given the irreversible side effects of synthetic drugs and the lack of appropriate treatment solutions, researchers believe that the use of low-cost and effective treatment methods, such as exercise, can be effective in psychological illnesses. So that the data shows that sports activities can lead to improvement of physical-psychological disorders in neurodegenerative disorders by improving neurotransmitters (4), increasing antioxidants, reducing oxidative stress, improving cognitive function (5), and ultimately improving physical performance (6).More specifically, it can be stated that regular exercise activities can reduce the expression of inflammatory factors in brain tissue by regulating macrophage function, modulating nuclear factor kappa B (NF-κB) transcription, and increasing antioxidants (7). In this context, researchers showed that two models of aerobic and strength exercise can reduce the expression of NF-κB p65, TNF-α, IFN-γ, IL-1β, and TGF-β1 in an animal model of PD (7). In another study, researchers showed that 12 weeks of aerobic exercise led to an increase in the anti-inflammatory factor IL-10, nerve growth factor beta, TGF-β1, and brain-derived neurotrophic factor (BDNF) in elderly patients with PD (8). Also, in another study, the results indicated a favorable effect of four weeks of endurance training on positive and negative inclines on motor balance and pain in rats with Alzheimer's disease (9) and MS (10).

In addition to the role of exercise, proper diet also seems to be of great importance in the treatment and prevention of diseases. In other words, using medicinal plants in the diet can have beneficial effects on the treatment of diseases. One of these medicinal plants that has long been used as a therapeutic herb is garlic (G) (11). Data show that G, due to its content of substances such as allicin, S-allyl cysteine, diallyl sulfide, diallyl disulfide, and diallyl trisulfide, can have antioxidant, anti-inflammatory, and anti-apoptotic properties and can have favorable effects on the nervous system and improve neuronal function (12). In this context, researchers have stated that G can inhibit the NF-κB signaling pathway by modulating natural killer cells, lymphocytes, monocytes, and macrophages, and this ultimately leads to a decrease in TNF-α, IFN-γ, IL-1β, and TGF-β1 (13). A study also showed that G consumption led to an increase in antioxidants and a decrease in inflammatory factors in the brain tissue of rats with stroke (14).

Despite the studies, various studies have examined the effects of exercise and garlic supplementation on some diseases. However, their simultaneous effect on inflammatory markers and motor function in neurodegenerative disorders is not yet well understood. In addition, the progressive nature of PD and the limited treatment window are likely the main reasons why researchers are combining therapeutic approaches to identify the most effective method. Therefore, a fundamental study is warranted to examine the simultaneous effect of exercise and G on these markers. The present study aimed to investigate the effect of eight weeks of AT and garlic supplementation (G) on inflammatory markers of brain tissue and sensorimotor function in rats with PD.

2. Methodology

2.1. Materials and methods

In this experimental study with a post-test design with a control group.

2.2. Participants

In this experimental study with a post-test design with a control group, 40 male Sprague-Dawley rats, aged 18-20 months and weighing approximately 250-270 grams, were initially obtained from the Laboratory Animal Breeding and Reproduction Center of Islamic Azad University, Marvdasht Branch. After being transferred to the Animal Exercise Physiology Laboratory of this university, they were kept in the laboratory environment for a week to familiarize themselves with the environment. Throughout the entire research period, the samples were kept under standard conditions, including a 12-hour light cycle, a temperature of 22°C to 24°C, and a relative humidity of 55 to 60 percent, and in washable polycarbonate cages. During the research period, animals had ad libitum access to either water and food. All ethical principles of working with laboratory animals were carried out in accordance with the Helsinki Guidelines and under the supervision of the Ethics Committee for Biomedical Research of Islamic Azad University, Marvdasht Branch, with the approval code IR.IAU.M.REC.1402.013.

2.3. Measurements

On the eighth day, 32 out of 40 rats were given an intraperitoneal injection of 2 mg/kg of reserpine (Sigma-Aldrich, USA) after 12 hours of fasting and anesthesia with ketamine and xylazine. The rats were then monitored for 14 days following reserpine neurotoxin injection, during which clinical signs of the disease were observed. It is worth noting that during this period, behaviors such as aggression, tail twitching, tail tremor, and gait imbalance were evaluated in the rats (18). After ensuring disease induction, PD rats were divided into groups based on motor power and balance test (to homogenize groups) into (1) reserpine control (Res), (2) aerobic exercise (AT), (3) garlic supplement (G), and (4) aerobic exercise + garlic supplement (AT+G). Also, to investigate the effects of Parkinson's disease induction on research variables, 8 healthy rats were placed in the healthy control (HC) group.

To measure TLR in brain tissue was first homogenized in phosphate buffer saline, then 50 mg of tissue was isolated from the artery. In the first step, RNA extraction was performed according to the manufacturer's protocol (Kia gene, Germany). It is worth noting that to ensure the quality of RNA, agarose gel electrophoresis was used using optical absorption at a wavelength of 260 nm with a Sigma PicoDrop device (made in the USA) and the formula (C (μg/μl) = A260×ε×d/1000). After confirming the desired concentration, the samples were stored for subsequent procedures. Next, cDNA synthesis was performed using the manufacturer's protocol provided with the Fermentase kit (K1621). The reverse transcription reaction was carried out using the primers designed based on the TLR-4 gene guide available on the PUBMED site (Table 1). To determine the efficiency and specificity of the primers, the pre-primers were evaluated using software available on the NCBI website. After ensuring that the qReal Time PCR device was complete and the samples reached the expression threshold (Cycle Threshold), the $2^{-\Delta\Delta CT}$ formula was used to quantify the ratio of the target gene to the reference gene.

Table 1. *Primer sequences utilized in the study*

Genes	Primer Sequences	Sizes(bp)
TBP	Forward: 5'- GCGGGGTCATGAAATCCAGT-3' Reverse: 5'- AGTGATGTGGGGACAAAACGA -3'	147
TLR-4	Forward: 5'- CCTTTCCTGCCTGAGACCAG -3' *Reverse: 5'- CAATTGTCTCAATTTCACACCTGGA -3'*	230

The levels of CRP in brain tissue were measured using a specific ELISA kit manufactured by MYBIOSOURCE (China), catalog number MBS2508830, with results expressed in pg/mL.

2.4. Intervention

Aerobic training protocol: In this study, aerobic exercise was performed for eight weeks, five sessions per week. For this purpose, in the first week, the rats trained for 15 minutes at a speed of 10 meters per minute on a treadmill specially designed for rats, manufactured by Danesh Salar Iranian Company. Subsequently, each week, 2 meters per minute were added to the treadmill speed and 4.8 minutes to the training time, until in the eighth week the speed reached 24 meters per minute and the training time reached 48 minutes. It is worth noting that at the beginning and end of aerobic exercise, a 5-minute warm-up and cool-down period at a speed of 8 m/min was considered for the animals (15).

Preparation and administration of garlic acid: To prepare the aqueous garlic extract, first, native garlic was purchased from reputable stores. Then, after washing and removing the skin, the garlic was carefully cut into small pieces with a scalpel. Finally, 100 grams of garlic was mixed with 200 ml of distilled water and placed in a blender for 15 minutes to obtain a homogeneous, milky solution. Then, this mixture was kept in the laboratory for 48 hours and then passed through a filter cloth. The filtered solution was transferred to a clean laboratory container and kept in an incubator at 38°C for 2 hours until the water evaporated and a white liquid remained in the container. Then, to consume garlic extract, 500 mg of this white substance per kilogram of the rats' body weight was dissolved in distilled water and fed to the rats individually in 1-ml bottles (16).

Sensorimotor Function Assessment: To evaluate motor performance, the inclined plane test was employed. This apparatus could be adjusted from 0 to 90 degrees. In this test, each animal was placed on the inclined surface, which was gradually elevated in 5-degree increments. The maximum angle at which the animal was able to maintain its position for at least 5 seconds was recorded as its score (17) (Khodaee, 2013).

Tissue collection: 48 hours after the last training session and in a 12-hour fast, rats were first anesthetized using ketamine (50 mg/kg) and xylazine (20 mg/kg) prepared from Alphasan, Netherlands. To ensure anesthesia, rats were tested by pain sensation and foot squeeze tests. After ensuring complete anesthesia, the cranial cavity of the rats was first opened using a cutter and then the brain tissue of the rats was carefully separated; immediately after extraction, the brain tissue was placed in special tissue preservation cryotubes and then transferred to a temperature of -70°C.

2.5. Statistical Methods

The normal distribution of data was assessed using the Shapiro-Wilk test. To analyze the data, one-way analysis of variance (ANOVA) test with Tukey post hoc tests was employed. The statistical analysis was conducted using SPSS 26.0 software (SPSS Statistics/IBM Corp, Chicago, IL, USA). A significance level of p< 0.05 was considered for all statistical analyses, indicating the threshold for determining statistically significant results.

3. Results

The results of one-way analysis of variance showed that there was a significant difference in the values of TLR-4 (P=0.001 and F=61.35), CRP (P=0.001 and F=37.12) and balance slope (P=0.001 and F=102.88) in the research groups. Tukey's post hoc test results showed that TLR in the Res group was significantly higher than the HC group (P=0.001); but in the G (P=0.001), AT (P=0.002) and AT+G (P=0.001) groups it was significantly lower than the Res group. There was no significant difference between the AT and G groups (P=0.99); but in the AT+G group it was significantly lower than the AT (P=0.001) and G (P=0.001) groups (Figure 1).

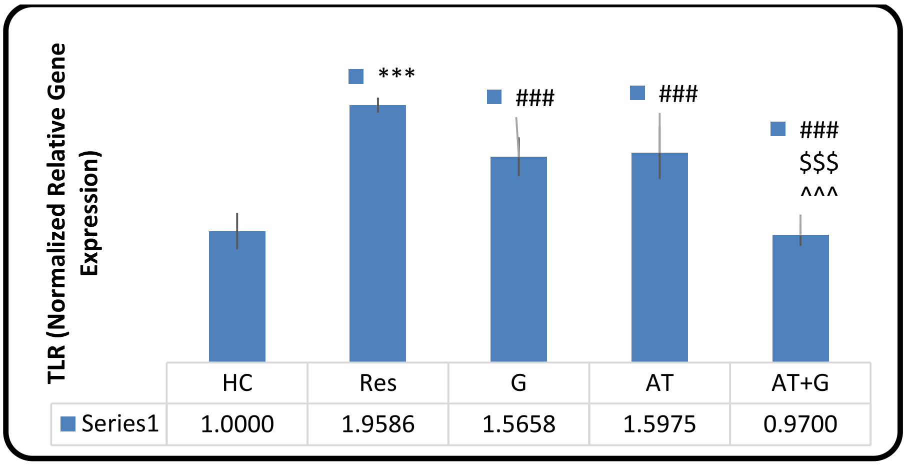

Figure 1. TLR gene expression levels in rat brain tissue in the research groups
*** (P=0.001) Significant increase compared to HC group, ### (P=0.001) Significant decrease compared to Res group, $$$ (P=0.001) Significant decrease compared to G group, ^^^ (P=0.001) Significant decrease compared to AT group

CRP values in the Res group were significantly higher than those in the HC group (P=0.001); but in the G (P=0.001), AT (P=0.002) and AT+G (P=0.001) groups, they were significantly lower than those in the Res group. There was no significant difference between the AT and G groups (P=0.99); there was also no significant difference in the AT+G group compared to the AT (P=0.23) and G (P=0.22) groups (Figure 2).

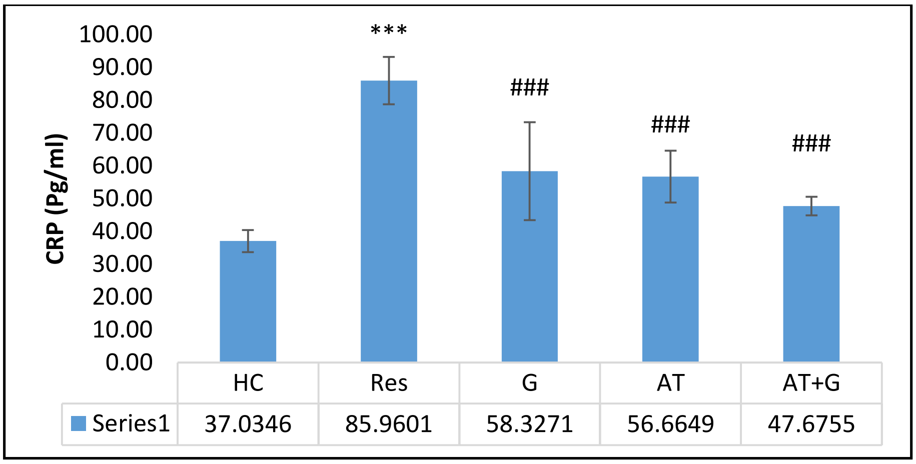

Figure 2. CRP levels in the brain tissue of rats in the research groups
*** (P=0.001) Significant increase compared to HC group, ### (P=0.001) Significant decrease compared to Res group

The slope of balance maintenance in the Res group was significantly lower than in the HC group (P=0.001); but in the G (P=0.001), AT (P=0.002) and AT+G (P=0.001) groups it was significantly higher than in the Res group. There was no significant difference between the AT and G groups (P=0.57); but in the AT+G group it was significantly higher than in the AT (P=0.001) and G (P=0.001) groups (Figure 3).

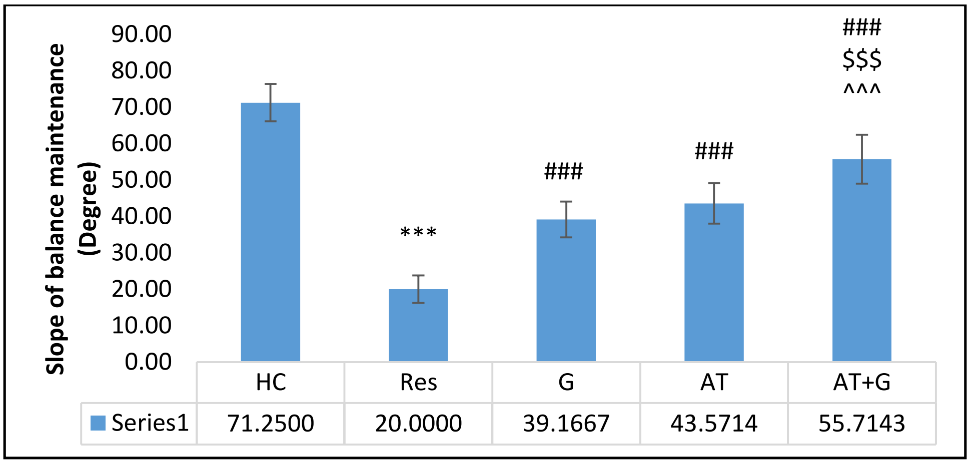

Figure 3. Slope of balance maintenance in rats in the research groups

*** (P=0.001) Significant decrease compared to HC group, ### (P=0.001) Significant increase compared to Res group, $$$ (P=0.001) Significant increase compared to G group, ^^^ (P=0.001) Significant increase compared to AT group

4. Discussion

The present study aimed to investigate the effect of eight weeks of AT and garlic supplementation (G) on inflammatory markers of brain tissue and sensorimotor function in rats with PD. The results of the present study showed that in the Res group, TLR and CRP values were significantly higher and the slope of maintaining equilibrium was significantly lower than in the HC group. However, in the AT group, TLR and CRP values were significantly lower and the slope of equilibrium maintenance was significantly higher than in the Res group. Data suggest that the induction of PD in various ways can lead to the activation of the alpha-synuclein protein, which can lead to the activation of natural killer cells in microglia. Further, after activation of M2-type macrophages, Toll-like proteins with subunits 2 and 4 (TLR2/4) are first activated. These proteins, in turn, lead to the activation of NF-kB, which then transcribes inflammatory factors such as TNF-α, IFN-γ, IL-1β, and CRP (14,18). Since systemic inflammation is associated with damage to central and peripheral neurons, data suggest that neuromuscular function is impaired following PD induction (14,19). A study showed that inducing PD disease in an animal model led to disruption of regulatory T cells, disruption of M1 and M2 type macrophages, and these inflammatory disorders subsequently led to damage to peripheral neurons and ultimately caused impairment of motor function (20).

On the other hand, it is believed that various moderate-intensity exercise activities can lead to an increase in myokines, improvement in L-DOPA, BDNF, reduction in inflammation, increase in dopamine, serotonin, and norepinephrine type 2 receptors, and this is associated with a decrease in oxidative stress in peripheral nerves and can lead to the development of motor function (7). Data also indicate that exercise can lead to improved microglia function through the mechanism of adiponectin activation. This protein induces its anti-inflammatory effects through activation of peroxisome proliferator-activated receptor gamma (PPAR-γ). Apelin 13 also increases after exercise, leading to inhibition of astrocyte activity, NFkB, and ultimately a decrease in the expression of IL-1β, TNF-α, an increase in IL-10, and IL-1 receptor agonist (21). Along with the present study, the results of a study showed that exercise can inhibit the TLR/MyD88/IκBα pathway by reducing α-synuclein expression. Subsequently, NF-κB is inhibited, and this occurs with decreased levels of IL-1β, TNF-α, increased IL-10, TGF-β, decreased apoptotic factors, and increased neurotrophins in PD (21). Researchers also showed that exercise training can lead to improved motor function, development of motor balance, and quality of life in patients with PD (21). In another study, the results showed improved balance, improved flexibility, and improved joint flexibility in PD patients following 6 months of walking training for 180 minutes per week (22). In one study, the results showed that 10 weeks of high-intensity interval training and moderate-intensity continuous training both improved peak oxygen consumption, walking balance, and motor balance in patients with PD (23). Therefore, the present study confirmed the results of other studies in terms of anti-inflammatory effects and improving sensory-motor function. In group G, TLR and CRP values were significantly lower and the slope of equilibrium maintenance was significantly higher than in group Res. So, G, as an antioxidant drug, primarily leads to the inhibition of oxidative stress and free radicals; since the main factor inducing apoptosis and inflammation in neurons is the increase in ROS, garlic, due to its content of isoflavones such as S-allylcysteine, can participate in the structure of antioxidant enzymes and increase transcription and formation of SOD.As a result, this leads to increased GSH, modulation of 6-hydroxydopamine (6-OHDA), modulation of mitogen-activated protein kinase with P38 subunit (P38MAPK), TNF-α, IL-6 and IL-1β (24). In this original study, which was consistent with the present study and was conducted on animal models of PD, the results showed that garlic reduced the aforementioned inflammatory factors, modulated acetylcholinesterase activity, and reduced MDA; although in this study, higher doses such as 100 and 200 mg/kg sometimes showed more favorable effects (25). In another study conducted on the SH-SY5Y cell line, the results showed that S-allylcysteine extracted from black garlic led to a decrease in TNF-α/IL1/IL8, a decrease in DNA damage markers, and a decrease in 6-OHDA (25). In another study, which was also consistent with the present study, the results showed a decrease in TNF-α, CRP, and improved walking balance in patients with rheumatoid arthritis (26). Therefore, this study also confirmed previous studies in terms of confirming the effectiveness of garlic supplementation in reducing inflammation and oxidative stress.

In the AT+G group, TLR and CRP values were significantly lower and the slope of equilibrium maintenance was significantly higher than in the Res group. In the context of the simultaneous effect of exercise and garlic supplementation, consistent with this study, our previous study showed that the combination of aerobic exercise and garlic could lead to a decrease in FN-γ, an increase in IL-4, and motor balance in rats with PD (16). In the study by Hosseinzadeh et al., the results showed that aerobic exercise and garlic led to an increase in GPx and a decrease in MDA in the brain tissue of PD rats (15). In addition, a study showed that consuming garlic extract and aerobic exercise led to a decrease in TLR4 in liver tissue and improved metabolic indices in rats fed a high-fat diet (27). The few studies that researchers found on the simultaneous effect of exercise and garlic indicate a favorable combined effect of these two interventions on the inflammatory system. However, exercise seems to be effective in improving motor function through mechanisms such as reducing α-synuclein expression, inhibiting the TLR/MyD88/IκBα pathway, increasing myokines, increasing cerebral blood flow, improving L-DOPA, BDNF, and improving neurotrophins and neurotransmitters.It also activates adiponectin, activates PPAR-γ, increases apelin 13, inhibits astrocyte activity, NFkB, and ultimately reduces the expression of IL-1β, TNF-α, increases IL-10, and IL-1 receptor agonist (18). Garlic also leads to a decrease in TNF-α, IL-6, and IL-1β through the pathway of increasing SOD, increasing GSH, decreasing 6-OHDA, and modulating P38MAPK (24,25). The more favorable effect of combining these two interventions (exercise and garlic supplementation) on inflammatory factors and improving motor function could be due to the enhancement of the effect of these two interventions. Considering the consideration of two inflammatory proteins and the effect of NF-kB and P38MAPK on the inflammatory signaling pathway, the lack of evaluation of this protein was one of the limitations of the present study. Therefore, it is suggested that this signaling pathway be evaluated in future studies. Considering the role of myokines, which increase during exercise, on the central nervous system and inflammatory factors in the nervous system, the lack of evaluation of myokines seems to be another limitation of the present study. Therefore, it is suggested that the role of myokines and the relationship between neuromuscular neurotransmitters be evaluated in future studies.

5. Conclusion

However, it seems that AT and G alone have effects on reducing inflammation in brain tissue and improving sensory-motor function in conditions that induce PD, but the combining these two interventions can enhance each other's effects and produce better results than either alone. Therefore, the simultaneous use of these two interventions in conditions of neurological disorders is recommended.

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Conflict of interests: The authors declare no conflicts of interest.

References

1. Ben-Shlomo Y, Darweesh S, Llibre-Guerra J, Marras C, San Luciano M, Tanner C. The epidemiology of Parkinson's disease. Lancet. 2024; 403(10423): 283-292. doi: 10.1016/S0140-6736(23)01419-8
2. Tylutka A, Żabiński P, Walas Ł, Zembron-Lacny A. Neuroinflammation as a Link in Parkinson’s and Alzheimer’s Diseases: A Systematic Review and Meta-Analysis. Aging Dis. 2025; 16(6): 2. doi: 10.14336/AD.2024.1174
3. Abdel Amir Nasser A, Jalali Dehkordi KH, Radhi Nasser M, Taghian F, Chitsaz, A. The effects of multimodal exercise program on functional capacity and quality of life in elderly patients with Parkinson's Disease. Elderly Health J. 2025: 10(2): 122-128. doi: 10.18502/ehj.v10i2.17366
4. Ghanbari P, Khajehzadeh S, Sayyed A, Raeisi D, Salehi O. The effect of high intensity interval training with beetroot (Beta vulgaris) juice supplementation on serotonin and dopamine receptors expression, anxiety and depression in middle-aged diabetic rats. Avicenna J Phytomedicine. 2022; 12(6): 627. doi: 10.22038/AJP.2022.20895.

5. Agahi MRH, Mosallanejad Z, Salehi OR. The effects of resistance training and spirulina on the performance of the antioxidant system with emphasis on mir125b, mir146a and cognitive function in stanazolol-induced neurotoxicity in rats. ChemBiol Interaction. 2022; 366: 110112. doi: 10.1016/j.cbi.2022.110112
6. Salehi OR, Sheikholeslami-Vatani D, Hosseini SA. Psycho-physiological effects of high intensity interval training and vitamin E consumption in elderly trimethyltin-treated Alzheimer's rats. Metab Exerc. 2021; 11(2): 57-76.doi.org/10.22124/jme.2023.23953.251
7. Tuon T, Souza PS, Santos MF, Pereira FT, Pedroso GS, Luciano TF, et al. Physical training regulates mitochondrial parameters and neuroinflammatory mechanisms in an experimental model of Parkinson’s disease. Oxid Med Cell Long. 2015; 2015(1): 261809. doi: 10.1155/2015/261809
8. Szymura J, Kubica J, Wiecek M, Pera J. The immunomodulary effects of systematic exercise in older adults and people with Parkinson’s disease. J Clin Med. 2020; 9(1): 184. doi: 10.3390/jcm9010184.
9. Hosseini SA, Salehi OR, Farzanegi P, Farkhaie F, Darvishpour AR, Roozegar S. Interactive effects of endurance training and royal jelly consumption on motor balance and pain threshold in animal model of the alzheimer disease. Arch Neurosci. 2020; 7(2): e91857. doi: 10.5812/ans.91857
10. Lohrasbi M, Taghian F, Dehkordi KJ, Hosseini SA. Interactive effects of endurance training with royal jelly consumption on motor balance in an experimental encephalomyelitis model. J Nutrition Fasting Health. 2022; 10(1): 44-50. doi: 10.22038/jnfh.2022.61748.1367
11. Bautista-Perez SM, Silva-Islas CA, Sandoval-Marquez OU, Toledo-Toledo J, Bello-Martínez JM, Barrera-Oviedo D, et al. Antioxidant and anti-inflammatory effects of garlic in ischemic stroke: Proposal of a new mechanism of protection through regulation of neuroplasticity. Antioxidant. 2023; 12(12): 2126. doi: 10.3390/antiox12122126.
12. Patel M, Goyal L, Raj K, Singh S. Chapter 62 - Neuroprotective role of garlic constituents against neurological disorders. Natural Molecule Neuroprotection Neurotoxicit. 2024: 1507-1523. doi:10.1016/B978-0-443-23763-8.00038-5
13. Arreola R, Quintero-Fabián S, López-Roa RI, Flores-Gutiérrez EO, Reyes-Grajeda JP, Carrera-Quintanar L, et al. Immunomodulation and anti-inflammatory effects of garlic compounds. J Immunol Res. 2015: 2015(1): 401630. doi: 10.1155/2015/401630
14. Massaro Cenere M, Tiberi M, Paldino E, D’Addario SL, Federici M, Giacomet C, et al. Systemic inflammation accelerates neurodegeneration in a rat model of Parkinson’s disease overexpressing human alpha synuclein. npj Parkinson's Disease. 2024; 10(1), 213. doi: 10.1038/s41531-024-00824-w
15. Hosseinzadeh M, Abbasi Daloii A, Hoseini SA, Abdi, A. The effects of aerobic training and garlic supplementation on superoxide dismutase, glutathione peroxidase and malondialdehyde of brain tissue in aged rats with Parkinson’s Disease. J Mazandaran Uni Med Sci. 2023; 33(1): 25-35.
16. Khosravi MR, Hosseini SA, Hasanpoor G, Roozbehani M. The effect of eight weeks of aerobic training and garlic supplementation on IFN-γ and IL-4 gene expression in the brain tissue of rats with Parkinson’s disease. Feyz Med Sci J. 2024; 28(3): 244-252. doi: 10.48307/FMSJ.2024.28.3.244
17. Khodaee E, Fatemi S, Rajaei Z, Samarghandian S, , Hadjzadeh M. Effect of MK-801, a non-competitive NMDA receptor antagonist, on motor deficits induced by focal cerebral ischemia in the rat. North Khorasan University of Medical Sciences 2013; 4 (4) :585-592
18. Wang H, Liu Y, Zhao J, Guo X, Hu M, Chen Y. Possible inflammatory mechanisms and predictors of Parkinson's disease patients with fatigue (Brief Review). Clin Neurol Neurosurgery. 2021; 208: 106844. doi: 10.1016/j.clineuro.2021.106844.
19. Xie F, Shen B, Luo Y, Zhou H, Xie Z, Zhu S, et al. Repetitive transcranial magnetic stimulation alleviates motor impairment in Parkinson’s disease: association with peripheral inflammatory regulatory T-cells and SYT6. Molecul Neurodegeneration. 2024; 19(1), 80.doi: 10.1186/s13024-024-00770-4
20. Mitchell AK, Bliss RR, Church FC. Exercise, neuroprotective exerkines, and Parkinson’s Disease: Narrative Rev Biomolecul. 2024; 14(10): 1241. doi: 10.3390/biom14101241.
21. Clarkin CM, Ward-Ritacco CL, Mahle, L. Exercise-induced functional changes in people with Parkinson’s Disease following external cueing and task-based intervention. Rehab Res Practice. 2024; 2024(1): 6188546. doi: 10.1155/2024/6188546.
22. Mak MK, Wong-Yu IS, Cheung RT, Ho SL. Effectiveness of balance exercise and brisk walking on alleviating non-motor and motor symptoms in people with mild-to-moderate Parkinson's Disease: A randomized clinical trial with 6-month follow-up. Arch Phys Med Rehabil. 2024;105(10):1890-1899. doi: 10.1016/j.apmr.2024.05.031.
23. Kathia MM, Duplea SG, Bommarito JC, Hinks A, Leake E, Shannon J, et al. High-intensity interval versus moderate-intensity continuous cycling training in Parkinson’s disease: a randomized trial. J Appl Physio. 2024; 137(3): 603-615. doi: 10.1152/japplphysiol.00219.2024.
24. Yousefsani BS, Ghobadi A, Shirani K. Uncovering the neuroprotective powers of Allium sativum: exploring its potential to alleviate malathion-associated Parkinson's-like behavioral symptoms in a rat model. J Med Plants. 2024; 23(89): 68-82. doi:10.61186/jmp.23.89.68
25. Yeni Y, Cicek B, Yildirim S, Bolat İ, Hacimuftuoglu A. Ameliorating effect of S-Allyl cysteine (Black Garlic) on 6-OHDA mediated neurotoxicity in SH-SY5Y cell line. Toxicol Report. 2024; 13: 101762.doi:10.1016/j.toxrep.2024.101762
26. Moosavian SP, Paknahad Z, Habibagahi Z, Maracy M. The effects of garlic (Allium sativum) supplementation on inflammatory biomarkers, fatigue, and clinical symptoms in patients with active rheumatoid arthritis: A randomized, double-blind, placebo-controlled trial. Phytotherap Res. 2020; 34(11): 2953-2962. doi: 10.1002/ptr.6723.
27. Khabiri P, Rahimi MR, Rashidi I, Nedaei SE. Impacts of an 8-week regimen of aged garlic extract and aerobic exercise on the levels of Fetuin-A and inflammatory markers in the liver and visceral fat tissue of obese male rats. Clin Nutr ESPEN. 2023; 58: 79-88. doi: 10.1016/j.clnesp.2023.09.004.