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Evaluation of Educational Attainment among School Children from Vulnerable Communities after Interventions of Effortless Walking Versus Strenuous Sporting Activity

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Abstract

Background: This study investigates the impact of effortless walking (aerobic exercise) versus strenuous sporting activity (anaerobic exercise) on educational attainment among elementary school children. The focus is on how different intensities of physical activity affect cognitive functions like memory, concentration, and higher-order thinking skills.

Materials and Methods: The research included 50 fourth-grade students. They underwent tests measuring concentration, recall, understanding, application, and analysis of knowledge, first without exercise, then after effortless walking, and finally following strenuous exercise.

Results: Effortless walking significantly improved concentration (255% increase), recall (54.3% increase), understanding (42% increase), application (33% increase), and analysis of knowledge (66% increase). In contrast, strenuous exercise often resulted in a decrease in these cognitive functions compared to effortless walking.

Conclusion: The study concludes that short periods of non-strenuous exercise like effortless walking before lessons significantly enhance cognitive functions and educational performance in elementary school children, suggesting the integration of aerobic exercise into school routines could be beneficial for academic achievement.

Key words: education; effortless walking; aerobic exercise; strenuous exercise; anaerobic exercise; cognition; memory; learning

1.Introduction

Movement and human health

There is extensive evidence that supports the positive effects of physical exercise on cognition and learning via enhanced executive functions and spatial memory [1-4] Renewed focus on the importance of exercise in the prevention of childhood obesity has forced schools to re-evaluate the participation of school children in sporting activity [4]. Aerobic exercise and physical activity have been shown to be effective in the prevention of cortical atrophy and cognitive impairment in adults, and in reducing the risk of developing dementia [5]. In this article, the effects of exercise on classroom learning are investigated and reviewed. The focus here is on elementary school children (aged 9-10 years). The importance of this research is the role free of low-cost interventions that enhance cognition and educational attainment – key determinants of health and well-being for individuals and communities as a whole [6].

1.2 How Movement affects the brain

Exercise enhances the performance of tasks that require attention, organization, and planning [7-8]. During strenuous activity the brain releases endorphins. These, together with dopaminergic biochemical processes enhance the concentration, cognition and executive functions such as decision making. This process is mediated through the limbic system of the brain that familiarises individuals with their environment [1]. The hippocampus augments the formation of memories. The more physically fit an individual, the larger the hippocampus and better that individual's spatial memory. Specific exercises may also contribute to nerve protection and synaptic plasticity due to increased levels of brain-derived neurotrophic factor (BDNF) [4]. Anaerobic metabolism associated with strenuous exercise requires cerebral neurons to rely on lactate. The lactate pathway, unique to the brain, allows the brain to convert lactate to pyruvate [9-10].

During strenuous exercise, the body's demand for energy often exceeds what can be supplied through aerobic metabolism alone. As a result, muscle cells and other tissues may rely more heavily on anaerobic metabolism, which can lead to an increase in lactate production. Lactate, traditionally considered a byproduct of anaerobic glycolysis, is now recognized as an important substrate for energy production, particularly in the brain under certain conditions [10-14]. Lactate produced in the muscles during intense exercise can be transported to the brain via the bloodstream. Once in the brain, lactate can be taken up by neurons and other brain cells. This uptake is facilitated by specific monocarboxylate transporters (MCTs) that allow lactate to cross cell membranes [10,11,13]. Within neurons, lactate can be converted back into pyruvate by the enzyme lactate dehydrogenase (LDH). Pyruvate can then enter the tricarboxylic acid (TCA) cycle after being converted into acetyl-CoA, ultimately contributing to ATP production, which is essential for cellular energy [13-15].

1.3 The relationship between movement and cognitive abilities

Short periods of walking cause an increase in the secretion of BDNF which plays an important role in increasing hippocampal volume. Aerobic exercise was found to increase hippocampal volume by up to 2% This increase in volume was directly related to improvements in memory performance, with significant correlations found for both the left and right hemispheres of the hippocampus [5]. The mechanism by which exercise increases BDNF levels may involve the ketone body β-hydroxybutyrate (BHB), which is elevated during exercise and has been shown to activate BDNF transcription. However, it is noted that exercise can induce BDNF expression through BHB-independent mechanisms as well [16], The effect persists with regular exercise. This increase is due to the effect of neurotransmitters and dendritic expansion and is also critical for memory formation. Another factor affecting BDNF levels is anterior hippocampal volume. The hippocampus is rich in BDNF. Exercise causes a rapid rise in BDNF. Moderate physical activity may be a simple but important method of improving cognitive development [17]. While precise neurophysiological mechanisms are not yet understood, both acute and chronic physical exercise can induce positive effects on brain function, and this is associated with improvements in cognitive performance. No study has yet been conducted that suggests a link between prolonged physical exertion, cognition, concentration, and memory.

1.4 Study objective

The aim of this research was to investigate the effect of movement on learning by testing two aspects of cognition: (1) attention (2) recall and retrieval of information.

2. Methods

2.1. Participants

To address the query regarding the determination of the study size and the protocol, the authors followed ethical guidelines as stipulated by the Research Committee of Oranim Academic College, Israel. The study was conducted in compliance with the Ministry of Education of Israel, which waived the requirement for individual consent per child. Instead, written consent was obtained collectively through the parents after the school provided verbal information about the study's focus on cognition and learning.

The sample size included 50 grade four elementary school children, aged between 9-10 years, featuring a gender distribution of 26 males. The cohort was homogenized by the socio-economic status of the participants, all of whom were identified as Arab, encompassing both Christians and Muslims, and classified as 'middle-class' according to the criteria established by Hollingshead and Redlich [18]

2.2. Procedure

The "Simon" type memory and "Feature detection " type concentration tasks (18) were used with a science (chemistry) quiz based on Bloom's taxonomy of critical thinking developed by the National Center for Science Teaching at Tel Aviv University (www.matar.ac.il) and the Ministry of Education in Israel. The science quiz contained open and closed chemistry questions categorized in terms of lower-order and higher-order thinking [19].

Each pupil performed the memory and concentration tasks and took the chemistry quiz three times. In the first week, the pupils performed the three tests (memory, concentration, and Bloom's test) without exercise beforehand (resting-basal status) at 10 am on alternate days of the week. In the second week, the pupils performed the three tests after 10 minutes of effortless walking. In the third week, the pupils performed the three tests after 30 minutes of running or cycling (strenuous exercise). In all three weeks the pupils undertook the three tests in the same order but the questions in the chemistry test were different each week (although within the same categories and at the same educational level). Each pupil participant served as his/her own control. The research design and criteria were based on recent research on the effect of movement on cognitive performance [18]

2.3 Statistical analysis

The statistical analyses were tailored to the nature of the data collected in the study. Quantitative comparisons between the experimental groups and the control group, focusing on memory, concentration, and cognition, were performed using the SPSS software. Since the analysis involved comparing averages and percentages of change between paired groups, paired t-tests were employed for this purpose. A paired t-test, also known as a dependent t-test in SPSS, compares the means between two related groups on the same continuous, dependent variable [20].

3. Results

3.1 Concentration and Recall

The comparative effects of effortless walking versus physical exertion on concentration are presented in Table 1.

Variable	Resting-Basal	Effortless walking 10 min	Exertion Physical activity 30 min	Percent change %	t-test
Concentration	16.33±1.64	41.66±2.84		255%	6.782***
Concentration	16.33±1.64		17.66±1.15	7.7%	0.324*
Concentration		41.66±2.84	17.66±1.15	-57.6%	5.576***

*N.S ****p<0.001*

Table 1: The effect of rest versus effortless walking and strenuous exercise on the ability to concentrate (scores out of 20)

The level of concentration at rest was 16.33 +1.64. This increased by 255% as a result of 10 minutes of effortless walking. Strenuous exercise did not significantly affect concentration, but did decrease concentration significantly (by 57.6%) compared to effortless walking.

The effect of exercise on memory is shown in Table 2

Variable	Resting-Basal	Effortless walking 10 min	Exertion Physical activity 45 min	Percent change %	t-test
Recall	5.96± 0.82	9.23 ±1.55		54.3 %	3.898 ***
Recall	5.96± 0.82		6.06 ±0.19	1.6%	0.291*
Recall		9.23 ±1.55	6.06 ±0.19	- 34.3%	6.265***

*N.S, ***p<0.001

Table 2: The effect of rest versus effortless walking and strenuous exercise on memory (recall) (scores out of 20)

The basal level of recall or memory at rest was 5.96 +0.82. This increased significantly by 54.3% after 10 minutes of effortless walking. Strenuous exercise did not result in any significant change compared to rest but decreased recall significantly (34.3%) when compared to effortless walking.

3.2 Results of Bloom's taxonomy tests of critical thinking

The effect of rest versus effortless walking and strenuous exercise on remembering information (knowledge) is shown in Table 3.

Variable	Resting-Basal	Effortless walking 10 min	Exertion Physical activity 30 min	Percent change %	t-test
Knowledge	16.66 ±1.07	21.36 2.07±		28.6%	3.21**
Knowledge	16.66 ±1.07		15.00± 2.10	-1.5%	0.41*
Knowledge		21.36 2.07±	15.00± 2.10	-42.4%	4.41**

*N.S, **p<0.005 (n=50)

Table 3: The effect of rest versus effortless walking and strenuous exercise on knowledge, (scores out of 20) .

The basal knowledge score at rest was 16.66 + 1.07. This increased by 28.6% after effortless walking for 10 minutes (21.36 + 2.07). After 30 minutes of strenuous exercise there was no significant change in knowledge score compared to the score at rest, but when compared to effortless walking there was a significant decrease in score (by 42.4%).

The effect of movement on the pupils' level of understanding are seen in Table 4.

Variable	Resting-Basal	Effortless walking 10 min	Exertion Physical activity 30 min	Percent change %	t-test
Understanding	10.00 ±2.96	14 ±2.17		42%	4.682**
Understanding	10.00 ±2.96		10.66 1.99±	6.1%	1.278 *
Understanding		14 ±2.17	10.66 1.99±	25.3%	3.756 **

*N.S, **p<0.005 , (n=50)

Table 4: Effect of rest versus effortless walking and strenuous exercise on understanding (scores out of 20).

The level of understanding at rest was 10.00 + 2.96. Scores in understanding increased significantly (by 42%) as a result of 10 minutes effortless walking. Strenuous exercise did not result in a significant change in score compared to resting level scores but decreased scores significantly (by 25.3%) when compared to effortless walking.

Effects on the application of knowledge are seen in Table 5.

Variable	Resting-Basal	Effortless walking 10 min	Exertion Physical activity 30 min	Percent change %	t-test
Applying	13.00 ±1.23	17.33±2.91		33.07%	3.626 **
Applying	13.00 ±1.23		13.66+1.80	1.04%	0.24*
Applying		17.33±2.91	13.66+1.80	-21.17%	2.041**

**N.S, **p<0.05,* (n=50)

Table 5 : Effect of rest versus effortless walking and strenuous exercise on applying knowledge (scores out of 20).

The application of knowledge score at rest was 13.00 +1.23. This increased significantly (by 33%) as a result of effortless walking. Strenuous exercise did not significantly affect scores compared to rest but scores decreased significantly (by 21.1%) compared to effortless walking.

The effects on knowledge analysis are shown in Table 6.

Variable	Resting-Basal	Effortless walking 10 min	Exertion Physical activity 30 min	Percent change %	t-test
Analyzing	10.60±2.60	17.60±2.95	.	66%	5.789 ***
Analyzing		17.60±2.95	9.66±2.50	-45.1%	4.09***
Analyzing	10.60±2.60		9.66±2.50	-8.86%	0.516*

*N.S, ****p<0.001,* (n=50)

Table 6 Effect of rest versus effortless walking and strenuous exercise on analysing knowledge (scores out of 20).

Analytical skill scores at rest were 10.60 + 2.60. These significantly increased (by 66%) after effortless walking. Compared to resting scores, there was no significant change after strenuous exercise, but strenuous exercise decreased analytical skills significantly (by 45.1%) when compared to effortless walking.

Table 7 shows the effects on evaluation of knowledge.

Variable	Resting-Basal	Effortless walking 10 min	Exertion Physical activity 30 min	Percent change %	t-test
Evaluating	10.6±0.91	15.30±2.60		44.3%	5.23***
Evaluating	10.6±0.91		9.88±0.60	-0.72%	1.361 *
Evaluating		15.30±2.60	9.88±0.60	-35.4% %	4.46***

**N.S, ***p<0.001,* (n=50)

Table 7: Effect of rest versus effortless walking and strenuous exercise on evaluation of knowledge (scores out of 20).

Evaluation skill scores at rest were 10.60 + 0.91. These increased significantly (by 44.3%) after effortless walking. Strenuous exercise did not significantly affect evaluation scores compared to those at rest but in comparison to effortless walking significantly reduced scores (by 35.4%).

4. Discussion

This study is one of the first of its kind to examine the effect of effortless walking (aerobic exercise) and strenuous (anaerobic) exercise on lower and higher order cognitive skills among school pupils in the classroom. This study showed that 10 minutes of effortless walking before class consistently improved concentration, recall and higher order thinking compared to no exercise or strenuous exercise. Complementary research has identified that various activities, including physical movement, musical engagement, adherence to a Mediterranean diet, and interactive computer games, are associated with enhanced scholastic performance (referenced in studies 18, 21, 22, 23). These results suggest that incorporating regular periods of aerobic exercise into the school routine could be instrumental in boosting academic learning outcomes (as supported by references 1, 18, 21, 22, 23). Such an intervention offers a cost-effective and relatively straightforward strategy with the potential for significantly amplifying educational achievement.

4.1 Mechanisms by which aerobic exercise improves brain function

The differential effects of aerobic versus anaerobic exercise reveal the importance of the intensity of exercise on brain connectivity [24]. Exercise increases the volume of the hippocampal area in the brain by up to 2%, producing new neurons, allowing people to remember familiar environments and to perform tasks that require attention, organization, and planning [1,18] known as activity dependent plasticity [25]. The findings of the present study show that effortless walking does not cause a change in lower-order thinking skills (at the level of recall, knowledge and understanding according to Bloom's taxonomy), but only in high-order thinking (application, analysis, and synthesis). Bloom's taxonomy is a hierarchical learning pyramid with several stages, arranged according to the complexity of brain function. In order to move from stage to stage in learning, it is necessary to develop brain architecture. Thus, ascending the hierarchical pyramid depends on brain plasticity, and higher-order cognitive skills cannot be reached until lower-order cognitive skills are achieved [1]. While genetic polymorphisms account for variation in BDNF-hippocampal dependent differences in cognitive function among individuals, the effects of aerobic exercise on BDNF secretion mean that learning and memory may be enhanced by positive environmental factors [25].

Aerobic exercise increases cortical activation via the secretion of BDNF. BDNF-related synaptic connections (generating memories and enhancing neuroplasticity) have been detected within seconds. BDNF has been shown to contribute to the expansion of dendrites in rodents and humans [5,7,8,26]. The effect is mediated through cell proliferation or increased dendritic expansion, increasing volume in the hippocampus. These effects are most prominent in early childhood [3]. BDNF synthesis and action is complex. BDNF enhances neuroplasticity via a number of mechanisms including synaptogenesis, neurogenesis, dendritic spine growth, long term potentiation and stimulation of protein synthesis, and in various timeframes; thus, the exact mechanisms regarding exercise are unclear [3]. Increased serum lactate levels in anaerobic exercise or after intravenous infusion of lactate at rest increase serum BDNF levels. BDNF crosses the blood brain barrier in both directions and may thus be measured in the serum [27]. In adults, it seems that exercise and/or training temporarily elevate basal BDNF and possibly upregulate cellular processing of BDNF (i.e. synthesis, release, absorption and degradation). From that point of view, exercise and/or training would result in a higher BDNF synthesis following an acute exercise bout (i.e. compared with untrained subjects). Subsequently, more BDNF could be released into the blood circulation which may, in turn, be absorbed more efficiently by central and/or peripheral tissues where it could induce a cascade of neurotrophic and neuroprotective effects. [28,29]. Similarly, lactate generated during anaerobic exercise also crosses the blood brain barrier. Information about the function of lactate as a signaling molecule is emerging. Lactate and BDNF do interact during exercise but the role of lactate in enhancing or diminishing learning is not clear [5]. Current thinking is that strenuous exercise reduces concentration and impairs higher-order skills and memory [18,27]. The gene known as Sirtuin 1, which has anti-aging properties, plays a crucial role in regulating the secretion of BDNF, a factor essential for cognitive function, hippocampal health, and synaptic plasticity [30-33]. It is imperative to investigate whether aerobic exercise during the school day can enhance plasma Sirtuin 1 levels, thereby influencing BDNF secretion. The interplay between Sirtuin 1 activators and inhibitors may be significant concerning BDNF levels and potentially beneficial for classroom learning [30-33]. Future research should consider examining the effects of aerobic exercise on Sirtuin 1 plasma concentrations and its subsequent impact on learning outcomes, taking into account the delicate balance between activators and inhibitors of Sirtuin 1.

4.2 Implications for the school timetable

In our view, exercise programmes are built into school timetables worldwide. Exercise plays a large role in school activities, whether competitive sport or classes in physical fitness. This research, focusing on elementary school learning, has shown that a short period of non-strenuous exercise before lessons begin, enhances what is learned in class and performance in assessment of what has been learned. Effortless walking requires only a safe place to walk, is of no cost, and, if shown to consistently improve learning, should become routine practice before all classroom learning (and before assessment). The aim is to improve environmental factors that stimulate and enhance learning. Other factors include music, adequate sleep and a nurturing environment in which to grow and learn. While not all these factors may be mitigated within the school timetable, exercise fits in well during classroom breaks.

4.3 Limitations

While the literature supports the importance of movement in the form of effortless walking in significantly improving children's performance in continuous mory tests that require cognitive-motor interaction and tests to identify attention-related features [1], exact mechanisms remain unclear. As 75% of serum BDNF derives from the brain, serum BDNF levels may be measured and future research in the classroom may include the measurement of brain activity via the collection of BDNF levels or cortical activity using EEG analysis. Similarly, the measurement of serum lactate levels may have a role in further uncovering the mechanism by which aerobic exercise is beneficial to learning while strenuous exercise is determinantal, but, even if invasive blood tests are feasible in children, the information yield should be interpreted with caution. Laboratory studies in rodents indicate positive benefits of lactate [25]. The exact balance of metabolic conditions that stimulate classroom learning requires substantially more research. Mechanisms of interaction between peripheral and central structures, muscle, liver and glucose metabolism should be understood. While the role of BDNF in exercise induced neuroplasticity in adults has been well researched [27], the effects on child development warrant further enquiry. Long lasting neurochemical effects have not been researched, thus, we recommended repeated classroom routine after exercise requires further research.

References

1. Bassuk, S. S., Church, T. S., & Manson, J. E. (2013). Why exercise works magic. *Scientific American*, *309*(2), 74-79.
2. Keeley, T. J., & Fox, K. R. (2009). The impact of physical activity and fitness on academic achievement and cognitive performance in children. *International review of sport and exercise psychology*, *2*(2), 198-214.
3. Müller, P., Duderstadt, Y., Lessmann, V., & Müller, N. G. (2020). Lactate and BDNF : key mediators of exercise induced neuroplasticity? *Journal of Clinical Medicine*, *9*(4), 1136.
4. Peiris, D. L. I. H. K., Duan, Y., Vandelanotte, C., Liang, W., Yang, M., & Baker, J. S. (2022). Effects of In-Classroom Physical Activity Breaks on Children's Academic Performance, Cognition, Health Behaviours and Health Outcomes: A Systematic Review and Meta-Analysis of Randomised Controlled Trials. *International Journal of Environmental Research and Public Health*, *19*(15), 9479.
5. Erickson, K. I., Voss, M. W., Prakash, R. S., Basak, C., Szabo, A., Chaddock, L., ... & Kramer, A. F. (2011). Exercise training increases size of hippocampus and improves memory. *Proceedings of the national academy of sciences*, *108*(7), 3017-3022.
6. Qu, S., Chattopadhyay, S. K., Hahn, R. A., & Community Preventive Services Task Force. (2016). High School Completion programs: a community guide systematic economic review. *Journal of Public Health Management and Practice*, *22*(3), E47-E56.
7. Ratey, J. J., & Loehr, J. E. (2011). The positive impact of physical activity on cognition during adulthood: a review of underlying mechanisms, evidence and recommendations.
8. Hong, M., Kim, M., Kim, T. W., Park, S. S., Kim, M. K., Park, Y. H., ... & Shin, M. S. (2020). Treadmill exercise improves motor function and short-term memory by enhancing synaptic plasticity and neurogenesis in photothrombotic stroke mice. *International Neurourology Journal*, *24*(Suppl 1), S28.
9. Hargreaves, M., & Spriet, L. L. (2020). Skeletal muscle energy metabolism during exercise. *Nature metabolism*, *2*(9), 817-828.
10. Li, X., Yang, Y., Zhang, B., Lin, X., Fu, X., An, Y., ... & Yu, T. (2022). Lactate metabolism in human health and disease. *Signal transduction and targeted therapy*, *7*(1), 305.
11. Proia, P., Di Liegro, C. M., Schiera, G., Fricano, A., & Di Liegro, I. (2016). Lactate as a Metabolite and a Regulator in the Central Nervous System. *International journal of molecular sciences*, *17*(9), 1450.
12. Xue, X., Liu, B., Hu, J., Bian, X., & Lou, S. (2022). The potential mechanisms of lactate in mediating exercise-enhanced cognitive function: A dual role as an energy supply substrate and a signaling molecule. *Nutrition & Metabolism*, *19*(1), 1-16.
13. Rabinowitz, J. D., & Enerbäck, S. (2020). Lactate: the ugly duckling of energy metabolism. Nature metabolism, 2(7), 566-571.
14. Dienel, G. A. (2012). Brain lactate metabolism: the discoveries and the controversies. *Journal of Cerebral Blood Flow & Metabolism*, *32*(7), 1107-1138.
15. Melkonian, E. A., & Schury, M. P. (2019). Biochemistry, anaerobic glycolysis.
16. Sleiman, S. F., Henry, J., Al-Haddad, R., El Hayek, L., Abou Haidar, E., Stringer, T., ... & Chao, M. V. (2016). Exercise

promotes the expression of brain derived neurotrophic factor (BDNF) through the action of the ketone body β-hydroxybutyrate. *elife*, *5*, e15092.

17. Meijer, A., Königs, M., Pouwels, P. J., Smith, J., Visscher, C., Bosker, R. J., ... & Oosterlaan, J. (2022). Effects of aerobic versus cognitively demanding exercise interventions on brain structure and function in healthy children—Results from a cluster randomized controlled trial. *Psychophysiology*, *59*(8), e14034.
18. Mualem, R., Leisman, G., Zbedat, Y., Ganem, S., Mualem, O., Amaria, M., Kozle, A., Khayat-Moughrabi, S. and Ornai, A., 2018. The effect of movement on cognitive performance. Frontiers in public health, p.100.
19. Nagamatsu, L. S., Chan, A., Davis, J. C., Beattie, B. L., Graf, P., Voss, M. W., ... & Liu-Ambrose, T. (2013). Physical activity improves verbal and spatial memory in older adults with probable mild cognitive impairment: a 6-month randomized controlled trial. *Journal of aging research*, *2013*.
20. Afifah, S., Mudzakir, A., & Nandiyanto, A. B. D. (2022). How to calculate paired sample t-test using SPSS software: From step-by-step processing for users to the practical examples in the analysis of the effect of application anti-fire bamboo teaching materials on student learning outcomes. *Indonesian Journal of Teaching in Science*, *2*(1), 81-92.
21. Mualem, R., Jadon, N., Shance, S., Farraj, R. H., & Mansou, R. (2023). The Effect of Dietary Preferences on Academic Performance Among Kindergarten-Aged Children. *J. Neuroscience and Neurological Surgery*, *13*(3).
22. Mualem, R., Badarne, B., Biswas, S., Hnout, M., & Ganem, S. (2021). Improvements in Cognition and Educational Attainment as a Result of Integrating Music into Science Teaching in Elementary School. J. *Neuroscience and Neurological Surgery*, *8*(5).
23. Cohen,S., Hussein Farraj,R., Shance,S., Mualem,R. (2023) The Impact of Computer Games on Cognitive Performance in pupils. International Journal of Science, Engineering and Management (IJSEM). Vol 10, Issue 9, pp.96-101
24. Hong, M., Kim, M., Kim, T. W., Park, S. S., Kim, M. K., Park, Y. H., ... & Shin, M. S. (2020). Treadmill exercise improves motor function and short-term memory by enhancing synaptic plasticity and neurogenesis in photothrombotic stroke mice. *International Neurourology Journal*, *24*(Suppl 1), S28-38
25. Hariri, A. R., Goldberg, T. E., Mattay, V. S., Kolachana, B. S., Callicott, J. H., Egan, M. F., & Weinberger, D. R. (2003). Brain-derived neurotrophic factor val66met polymorphism affects human memory-related hippocampal activity and predicts memory performance. *Journal of Neuroscience*, *23*(17), 6690-6694.
26. Fernández-Rodríguez, R., Álvarez-Bueno, C., Martínez-Ortega, I. A., Martínez-Vizcaíno, V., Mesas, A. E., & Notario-Pacheco, B. (2022). Immediate effect of high-intensity exercise on brain-derived neurotrophic factor in healthy young adults: A systematic review and meta-analysis. *Journal of Sport and Health Science*, *11*(3), 367-375.
27. Hashimoto, T., Tsukamoto, H., Takenaka, S., Olesen, N. D., Petersen, L. G., Sørensen, H., ... & Ogoh, S. (2018). Maintained exercise-enhanced brain executive function related to cerebral lactate metabolism in men. *The FASEB Journal*, *32*(3), 1417-1427.
28. Tsai, C. L., Pan, C. Y., Tseng, Y. T., Chen, F. C., Chang, Y. C., & Wang, T. C. (2021). Acute effects of high-intensity interval training and moderate-intensity continuous exercise on BDNF and irisin levels and neurocognitive performance in late middle-aged and older adults. *Behavioural brain research*, *413*, 113472.
29. Kramer, A. F., & Erickson, K. I. (2007). Capitalizing on cortical plasticity: influence of physical activity on cognition and brain function. *Trends in cognitive sciences*, *11*(8), 342-348.
30. El Hayek, L., Khalifeh, M., Zibara, V., Abi Assaad, R., Emmanuel, N., Karnib, N., ... & Sleiman, S. F. (2019). Lactate mediates the effects of exercise on learning and memory through SIRT1-dependent activation of hippocampal brain-derived neurotrophic factor (BDNF). *Journal of Neuroscience*, *39*(13), 2369-2382.
31. Martins, I. J. (2016). Anti-aging genes improve appetite regulation and reverse cell senescence and apoptosis in global populations. Advances in Aging Research, 2016, 5, 9-26
32. Martins, I. J. (2017). Nutrition therapy regulates caffeine metabolism with relevance to NAFLD and induction of type 3 diabetes. *J Diabetes Metab Disord*, *4*(1), 1-9.
33. Martins, I. J. (2018). Sirtuin 1, a diagnostic protein marker and its relevance to chronic disease and therapeutic drug interventions. EC Pharmacology and Toxicology, 6(4), 209-215.

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