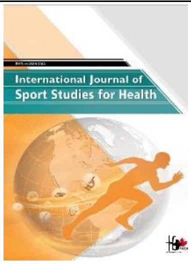
International Journal of Sport Studies for Health

Journal Homepage



Exploring the Impact of Functional Exercise Rehabilitation on Neuroplastic Biomarker Changes in Cardiovascular Disorders

Armin. Gorouhi[1*], Adebayo. Clement Olaide[2], Daniel. López-López[1], Fernando. Iellamo[3], Hadi. Nobari[4]

[1] Department of Health Sciences. Faculty of Nursing and Podiatry. Industrial Campus of Ferrol. University of A Coruna, Spain
[2] School of Public Health. Imperial College of Londen, England
[3] Department of Clinical Sciences and Translational Medicine, Tor Vergata University, Rome, Italy
[4] LFE Research Group, Department of Health and Human Performance, Faculty of Physical Activity and Sport Science (INEF), Universidad Politécnica de Madrid, Madrid, Spain

*** Corresponding author email address**: armingoroohi@gmail.com

A r t i c l e I n f o

Article type:
Review Article

How to cite this article:
Gorouhi, A., Olaide, A. C., López-López, D., Iellamo, F., & Nobari, H.. (2025). Exploring the Impact of Functional Exercise Rehabilitation on Neuroplastic Biomarker Changes in Cardiovascular Disorders. *International Journal of Sport Studies for Health*, *8*(2), 35-39.
http://dx.doi.org/10.61838/kman.intjssh.8.2.5

A B S T R A C T

This narrative review explores the interconnected roles of neuroplasticity, cardiovascular health, and functional exercise rehabilitation. By reviewing recent literature, the study identifies how various exercise interventions—including aerobic training, resistance training, balance exercises, and combined modalities—affect neuroplastic biomarkers like brain drive eutrophic factor (BDNF) relevant to cardiovascular disorders. Evidence suggests that physical activities such as aerobic training enhance (BDNF) expression, improving cognitive functions and cardiovascular health. Balance and proprioception exercises effectively induce cortical changes, enhancing stability and motor control. Moreover, multimodal rehabilitation approaches integrating cognitive and physical training have shown superior outcomes in stroke rehabilitation, suggesting their potential application in broader cardiovascular conditions. Overall, this review highlights the importance of a holistic and integrated rehabilitation approach in improving neuroplasticity and cardiovascular outcomes, advocating for personalized rehabilitation strategies tailored to individual patient needs.

Keywords: *Functional Exercise, Rehabilitation, Neuroplastic Biomarkers, Cardiovascular Disorders,*

1. Introduction

In the realm of healthcare, the intricate interplay between neuroplasticity, cardiovascular health, and functional exercise rehabilitation has garnered increasing attention (1). As researchers and clinicians delve deeper into understanding these connections, it becomes evident that a narrative approach can elucidate the multifaceted

Article history:
Received 02 February 2025
Revised 09 March 2025
Accepted 14 March 2025
Published online 01 April 2025

relationships between these domains. In this narrative review, we embark on a journey through the scientific landscape, exploring how different types of exercise interventions influence neuroplastic biomarker changes within the cardiovascular system. Several studies have shown that learning new tasks triggers brain plasticity (2), leading to structural modifications and improved cognitive function, further underscoring the intricate relationship between neuroplasticity and cardiovascular health (3). Physical activity, including aerobic and resistance training, has emerged as a modifiable factor in promoting cardiovascular and brain health. Exercise interventions have been shown to enhance neuroplasticity and cognitive function, offering potential therapeutic benefits for individuals with cardiovascular disorders (4). Physical activity can induce BDNF expression, enhancing synaptic performance and promoting circuit repair and reorganization through neuroplasticity, particularly in aging populations (5). The influence of physical activity on immune function has been a cornerstone in exercise science and it is observed that aerobic exercises lead to reduce the interleukin 6, interleukin 8, and tumor necrosis factor (TNF) in inflammation process (6, 7). Aerobic exercise, in particular, has been associated with increased BDNF levels, which may contribute to improved brain structure and function and in the study of Mackay it is shown clearly (8). Early studies demonstrated a correlation between physical fitness and brain function, showing that older athletes had faster reaction times on cognitive tests compared to age-matched inactive controls (9). Qualitative changes are necessary to trigger structural modifications in the brain for the brain to modify its structure, triggering plastic changes shortly after training begins (10). Depending on the direction, acceleration, and force of movement into space for accessing or stepping, cortical neurons fire at various rates. These neurons can indicate various motions in response to changing stimuli and practice (11). Cortical and spinal levels of sensory feedback, such as proprioception, have a significant impact on motor skill via changing sensorimotor coordination (11, 12).

Moreover, balance and strength training have been shown to enhance cortical thickness and gray matter volume, highlighting the multifaceted benefits of exercise on neuroplasticity and cardiovascular outcomes (13). Strength, power, running, and other functional capabilities are all enhanced by improvements in balance and proprioception (14), which are beneficial for stability as well. Increased instability exercises combined with coordination training should encourage motor control changes (15).

Furthermore, dancing has been shown to result in greater gray matter density (GMD) compared to repetitive strength training. Furthermore, the amount of BDNF in the dance group has begun to grow (16).

2. Method

As a narrative review, the outcomes were gathered through PubMed, google scholar, research Gate and web of science. The keywords on searches were functional rehabilitation, exercise rehabilitation, neuroplasticity biomarker and cardiovascular disorders. All selected studies were published in English and focused on the role of exercise rehabilitation in injury prevention and recovery. The relationships between neuroplasticity biomarkers, rehabilitation, and cardiovascular disease were analyzed separately and in combination, as summarized in Table 1.

Table 1. Different stage of studies consideration

Row	Description
1	Neuroplasticity biomarker VS Cardiovascular disease
2	Rehabilitation VS cardiovascular disease
3	Rehabilitation VS neuroplasticity biomarker

3. Neuroplasticity biomarker VS cardiovascular disease

According to accurate consideration on relationship between neuroplasticity biomarkers and cardiovascular parameters, studies have investigated that some biomarkers may effect on cardiac activity (11). BDNF is recognized as a key biomarker that indirectly influences cardiac function through its effects on the autonomic nervous system. studies have shown that the autonomic nervous system is influenced (17). after BDNF releasing and sympathetic nervous system control hypertension and heart beat so on. In the study of Schaare, the effect of gray matter volume on hypertension and cardiovascular system have shown. Gray matter volume plays a significant role in autonomic functions, including the regulation of blood pressure (18).

4. Rehabilitation VS Cardiovascular disease

There are different types of rehabilitation which can influence on cardiovascular system in direct and indirect way (4). The main impact of physical activity which may insert in rehab program on cardiac system, would be stimulating autonomic nervous system to control blood pressure (19). One of the most common cardiac diseases which creates secondary disorders is hypertension which it can be controlled by rehabilitation. Although rehab program may have several positive points for cardiac patients, it has been done under observation of medications to prevent any risky interaction. For this purpose, high-intensity exercises are generally excluded from rehabilitation programs for cardiac patients due to safety concerns (20). and some other ones would be altered due to patients inability to perform.

5. Rehabilitation VS Neuroplasticity

There is some sort of researches in this area which shows the impact of rehab program on neuroplasticity biomarkers (6). Marcori's review article emphasizes the importance of physical activity programs involving continuous cognitive and motor learning for inducing neuroplastic alterations in gray matter density (GMD) in elderly individuals (17). This aligns with the idea that certain types of exercise, such as functional exercise rehabilitation, can positively impact brain structures (21).

Draganski's study reinforces the idea that novel motor input, such as juggling, can lead to alterations in gray matter density in specific brain regions. However, the transient nature of these changes suggests that continued practice is necessary to maintain the observed alterations, indicating the dynamic nature of neuroplasticity (12).

The reference to Lövdén's ideas about plasticity and flexibility adds theoretical support to the concept that changes in behaviour, particularly those involving motor practice, can stimulate physiological mechanisms that influence processing efficiency in the brain (22).

6. Rehabilitation

6.1 Categorization of Rehabilitation Models

To provide clarity and coherence, we categorize rehabilitation models based on their physiological mechanisms and clinical applications. Aerobic rehabilitation interventions focus on enhancing cardiovascular fitness and neuroplasticity through sustained, rhythmic movements (23). Combined approaches integrate multiple modalities to target cognitive, motor, and cardiovascular domains concurrently, capitalizing on synergistic effects (24). Balance and strength training interventions emphasize neuromuscular coordination and muscular strength, fostering resilience in both the musculoskeletal and cardiovascular systems (7, 14, 15). By categorizing interventions, we aim to elucidate the diverse pathways through which exercise influences neuroplastic biomarker changes in cardiovascular disorders.

Table 2. Summary of Rehabilitation Interventions and Their Effects on Neuroplastic Biomarker Changes

Rehabilitation Intervention	Key Findings
Aerobic Exercise	- Increased BDNF levels - Improved cardiovascular parameters - Enhanced neuroplasticity
Combined Approach	- Synergistic effects on cognitive function and cardiovascular health - Superior outcomes compared to single-modal interventions
Balance and Strength Training	- Promotion of cortical thickness changes - Improvement in neuromuscular coordination and muscular strength

6.2 Aerobic Rehabilitation Interventions

Aerobic exercise stands as a cornerstone in the realm of rehabilitation, offering a myriad of benefits for cardiovascular health and neuroplasticity. Studies have shown that aerobic training induces favorable changes in neurotrophic factors such as brain-derived neurotrophic factor (BDNF), which play crucial roles in synaptic plasticity and cognitive function (29). Moreover, aerobic rehabilitation interventions have been associated with improvements in cardiovascular parameters, including blood pressure regulation and vascular function (6). By promoting neuroplasticity and cardiovascular health in tandem, aerobic exercise emerges as a promising strategy for enhancing overall well-being (20).

6.3 Combined Rehabilitation Approaches

In recent years, researchers have explored the synergistic effects of combining aerobic exercise with other modalities, such as cognitive training or strength exercises (16). This combined approach aims to capitalize on the complementary mechanisms of different interventions to maximize benefits for both neuroplasticity and cardiovascular health (23). Preliminary evidence suggests that combined rehabilitation interventions may yield superior outcomes compared to single-modal interventions, highlighting the importance of a holistic approach in promoting optimal health outcomes (20). In a study of ploughman, the effect of combined activities with decision making required tasks on improvements in fluid intelligence. were considered; low intensity activities and aerobic training for an active phase, computer games and cognitive training were chosen as decision-making tasks were chosen. Ploughman findings suggest that combining aerobic and cognitive training may enhance fluid intelligence in chronic stroke patients. Moreover, changes in serum IGF-1 levels indicate potential physiological mechanisms underlying cognitive improvement (24). These findings highlight the benefits of integrating aerobic and cognitive training into stroke rehabilitation programs.

6.4 Balance and Strength Training

Beyond traditional aerobic exercises, balance and strength training have gained recognition for their potential to enhance neuroplasticity and cardiovascular function. These interventions target specific motor pathways and musculoskeletal systems, leading to structural adaptations within the brain and improvements in functional capacity (24). Moreover, balance training has been shown to promote cortical thickness changes, indicating its potential to bolster neuroplasticity in individuals with cardiovascular disorders. By incorporating diverse modalities into rehabilitation programs, clinicians can tailor interventions to address the unique needs of each patient while fostering holistic improvements in health (7). Ann Kathrin Rogge and colleagues conducted a study focusing on the efficiency of physical activity, particularly balance training, in enhancing cognitive abilities and brain structural plasticity. The research aimed to investigate whether balance training could promote structural plasticity by depleting the sensory-motor system and vestibular self-motion perception. Moreover, a correlation was found between improvements in balance performance and cortical thickness changes in the precentral gyrus and occipital clusters. These findings suggest that balance training induces structural plasticity in the brain, leading to improvements in both cognitive abilities and motor skills (15).

7. Conclusion

In conclusion this narrative review has explored" or this review has highlighted. the intricate relationship between functional exercise rehabilitation, neuroplasticity, and cardiovascular health. Functional exercises influence neuroplasticity and gray matter, which play a key role in autonomic nervous system function, thereby impacting the cardiovascular system through mechanisms such as blood pressure regulation. By adopting a holistic approach and incorporating diverse rehabilitation modalities, such as aerobic training, balance exercises, and combined cognitive-physical interventions, clinicians can optimize outcomes for patients with cardiovascular disorders. As we continue to unravel the complexities of this relationship, integrating evidence-based interventions into clinical practice holds the key to promoting health and well-being across the lifespan. For example, in addressing the link between childhood trauma and adult mental health disorders, clinicians can implement trauma-informed care, provide access to cognitive-behavioral therapy (CBT), and use mindfulness-based interventions to help individuals develop healthier coping mechanisms and reduce long-term psychological distress.

Authors' Contributions

All authors equally contributed to this study. This study is part of a master's thesis project conducted under the supervision of professors from the University of Tor Vergata, Italy, and the Polytechnic University of Madrid, Spain.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

Acknowledgments

We would like to express our gratitude to all individuals helped us do the project.

Declaration of Interest

The authors report no conflict of interest.

Funding

According to the authors, this article has no financial support.

References

1. Mercadante AA, Tadi P. Neuroanatomy, Gray Matter. StatPearls [Internet]. 2022.
2. Purves D, Augustine GJ, Fitzpatrick D. Neuroscience The Internal Anatomy of the Spinal Cord: Sunderland (MA): Sinauer Associates; 2001.
3. Bairey Merz CN, Elboudwarej O, Mehta P. The autonomic nervous system and cardiovascular health and disease. A complex balancing act. JACC Heart Fail. 2015;3(5):383-5. [PMID: 25951758] [DOI]
4. Iellamo F, Legramante JM, Massaro M, Raimondi G, Galante A. Effects of a Residential Exercise Training on Baroreflex Sensitivity and Heart Rate Variability in Patients With Coronary Artery Disease A Randomized, Controlled Study. 2000. [PMID: 11085961] [DOI]
5. Poletti S, Aggio V, Hoogenboezem TA, Ambrée O, de Wit H, Wijkhuijs AJM. Brain-derived Neurotrophic Factor (BDNF) and gray matter volume in bipolar disorder. European Psychiatry. 2017;40:33-7. [PMID: 27837670] [DOI]
6. Hashimoto T, Fukui K, Takeuchi H, Yokota S, Kikuchi Y, Tomita H. Effects of the BDNF Val66Met Polymorphism on Gray Matter Volume in Typically Developing Children and Adolescents. Cerebral Cortex. 2016;26(4):1795-803. [PMID: 26830347] [PMCID: PMC4785961] [DOI]
7. Behm D, Colado JC. The effectiveness of resistance training using unstable surfaces and devices for rehabilitation. International journal of sports physical therapy. 2012;7(2):226.
8. Mackay CP, Kuys SS, Brauer SG. The Effect of Aerobic Exercise on Brain-Derived Neurotrophic Factor in People with Neurological Disorders: A Systematic Review and Meta-Analysis. Neural Plast. 2017;2017:4716197. [PMID: 29057125] [PMCID: PMC5625797] [DOI]
9. Miyamoto T, Hashimoto S, Yanamoto HAUIM, Nakano Y, Sekiyama T. Response of brain-derived neurotrophic factor to combining cognitive and physical exercise. Eur J Sport Sci. 2018;18(8):1119-27. [PMID: 29842831] [DOI]
10. Woo MA, Macey PM, Fonarow GC, Hamilton MA, Harper RM. Regional brain gray matter loss in heart failure. J Appl Physiol. 2003;95:677-84. [PMID: 12716866] [DOI]
11. Amiya E, Watanabe M, Komuro I. The Relationship between Vascular Function and the Autonomic Nervous System. Ann Vasc Dis. 2014;7(2):109-19. [PMID: 24995054] [PMCID: PMC4072858] [DOI]
12. Draganski B, Gaser C, Busch V, Schuierer G, Bogdahn U, May A. Changes in grey, matter induced by training. Nature. 2004;427(6972):311-2. [PMID: 14737157] [DOI]
13. Vuorinen M, Damangir S, Niskanen E, Miralbell J, Rusanen M, Spulber G. Coronary heart disease and cortical thickness, gray matter and white matter lesion volumes on MRI. PLoS One. 2014;9(10). [PMID: 25302686] [PMCID: PMC4193798] [DOI]
14. Busch JC, Lillou D, Wittig G, Bartsch P, Willemsen D, Oldridge N. Resistance and balance training improves functional capacity in very old participants attending cardiac rehabilitation after coronary bypass surgery. J Am Geriatr Soc. 2012;60(12):2270-6. [PMID: 23176104] [DOI]
15. Rogge AK, Röder B, Zech A, Hötting K. Exercise-induced neuroplasticity: Balance training increases cortical thickness in visual and vestibular cortical regions. Neuroimage. 2018;179SP - 471:479. [PMID: 29959048] [DOI]
16. Woost L, Bazin PL, Taubert M, Trampel R, Tardif CL, Garthe A. Physical Exercise and Spatial Training: A Longitudinal Study of Effects on Cognition, Growth Factors, and Hippocampal Plasticity. Sci Rep. 2018;8(1):1-13. [PMID: 29523857] [PMCID: PMC5844866] [DOI]
17. Marcori AJ, Okazaki VHA. Motor repertoire and gray matter plasticity: Is there a link? Med Hypotheses. 2019;130. [PMID: 31383345] [DOI]
18. Schaare HL, Kharabian Masouleh S, Beyer F, Kumral D, Uhlig M, Reinelt JD. Association of peripheral blood pressure with gray matter volume in 19- to 40-year-old adults. Neurology. 2019;92(8):E758-E73. [PMID: 30674602] [DOI]
19. Iqbal AM, Jamal SF, Palatini P, Julius S. Essential Hypertension The Role of Cardiac Autonomic Function in Hypertension and Cardiovascular Disease. StatPearls [Internet]. 2022;11:199-205. [PMID: 19442329] [DOI]
20. Anazodo UC, Shoemaker JK, Suskin N, st. Lawrence KS. An investigation of changes in regional gray matter volume in cardiovascular disease patients, pre and post cardiovascular rehabilitation. Neuroimage Clin. 2013;3:388-95. [PMID: 24273722] [PMCID: PMC3814972] [DOI]
21. Phillips C. Lifestyle Modulators of Neuroplasticity: How Physical Activity, Mental Engagement, and Diet Promote Cognitive Health during Aging: Hindawi Limited; 2017. [DOI]
22. Lövdén M, Bäckman L, Lindenberger U, Schaefer S, Schmiedek F. A Theoretical Framework for the Study of Adult Cognitive Plasticity. Psychol Bull. 2010;136(4):659-76. [PMID: 20565172] [DOI]
23. Matura S, Fleckenstein J, Deichmann R, Engeroff T, Füzéki E, Hattingen E. Effects of aerobic exercise on brain metabolism and grey matter volume in older adults: results of the randomised controlled SMART trial. Transl PsychiatryVL - 7. 2017(7):e1172. [PMID: 28934191] [PMCID: PMC5538117] [DOI]
24. Ploughman M, Eskes GA, Kelly LP, Kirkland MC, Devasahayam AJ, Wallack EM. Synergistic Benefits of Combined Aerobic and Cognitive Training on Fluid Intelligence and the Role of IGF-1 in Chronic Stroke. Neurorehabil Neural Repair. 2019. [PMID: 30816066] [DOI]