

THE ROLE OF PHYSICAL ACTIVITY IN PRESERVING VASCULAR FUNCTION AND SUBJECTIVE WELL-BEING IN OLDER ADULTS**РОЛЬ ФІЗИЧНОЇ АКТИВНОСТІ У ЗБЕРЕЖЕННІ СУДИННОЇ ФУНКЦІЇ ТА СУБ'ЄКТИВНОГО БЛАГОПОЛУЧЧЯ ОСІБ ПОХИЛОГО ВІКУ****Horoshko V. I.¹, Zhygulova E. O.², Zaikin A. V.²**¹National University of Water and Environmental Engineering, Rivne, Ukraine²Kamianets-Podilskyi Ivan Ohienko National University, Kamianets-Podilskyi, Ukraine

ORCID: 0000-0002-5244-5648

ORCID: 0000-0003-1366-8766

ORCID: 0000-0002-8443-8872

Abstracts

Age-related changes in the vascular system are closely linked to endothelial dysfunction, reduced bioavailability of nitric oxide (NO), and a decline in the adaptive capacity of the cardiovascular system. Physical activity is regarded as one of the key modifiable factors capable of slowing vascular aging; however, population-based functional indicators that reflect these processes in older adults remain insufficiently explored.

Research objective. This study sought to characterize the age-related profiles of the physical, psychological, and social dimensions of subjective well-being using the BBC scale. A further aim was to explore their association with an overall well-being score, posited as a functional marker pertinent to the maintenance of vascular health in older adults.

Materials and methods. A cross-sectional study was conducted involving 136 relatively healthy teachers stratified by age group. Subjective well-being was assessed using the BBC methodology, which distinguishes physical, psychological, and social components. Statistical analysis included descriptive statistics, one-way analysis of variance (ANOVA), the Kruskal-Wallis test, and Spearman correlation analysis. The critical level of statistical significance was set at $p = 0.05$.

Results. In the total sample, mean values were: physical component 22.16 ± 5.49 (10–36), psychological component 41.52 ± 8.12 (22–58), social component 19.20 ± 4.24 (10–28), and integral indicator 83.11 ± 13.41 (52–112). Across age groups, the physical component ranged from 21.82 to 23.60 without progressive decline in older participants. Psychological scores varied between 40.00 ± 8.41 and 42.20 ± 10.06 , and social scores between 17.64 ± 4.23 and 19.91 ± 4.13 . ANOVA revealed no significant inter-age differences for physical ($F=1.12$; $p=0.35$), psychological ($F=0.94$; $p=0.44$), social ($F=1.03$; $p=0.39$), or integral indicators ($F=1.27$; $p=0.28$); nonparametric analysis confirmed these findings ($H=3.21-3.44$; $p>0.05$). Spearman analysis demonstrated strong positive correlations between the physical component and the integral score ($r=0.62$; $p<0.001$), psychological and integral scores ($r=0.74$; $p<0.001$), and social and integral scores ($r=0.58$; $p<0.001$), indicating systemic integration of functional domains and preserved adaptive capacity.

Conclusions. The findings indicate that the physical component of subjective well-being may be considered a functional indicator associated with the preservation of adaptive capacity and vascular regulatory function in older adults. Indicators of subjective well-being appear to be relevant functional markers of processes related to endothelial function and NO-dependent vascular regulation, even in the absence of clinically significant cardiovascular pathology.

Keywords: subjective well-being; physical activity; vascular function; endothelial function; nitric oxide; vascular aging; older adults.

Вікові зміни судинної системи пов'язані з ендотеліальною дисфункцією, зниженням біодоступності оксиду азоту (NO) та зменшенням адаптаційних можливостей серцево-судинної системи.

Мета. Оцінити вікові особливості фізичного, психологічного та соціального компонентів суб'єктивного благополуччя за методикою BBC і проаналізувати їх зв'язок з інтегральним показником як функціональним індикатором збереження судинної функції.

Матеріали та методи. У поперечному дослідженні взяли участь 136 умовно здорових викладачів, стратифікованих за віком. Суб'єктивне благополуччя визначали за шкалою BBC. Використано описову статистику, ANOVA, критерій Краскела–Уолліса та кореляційний аналіз Спірмена ($p=0,05$).

Результати. Середні значення становили: фізичний компонент – $22,16 \pm 5,49$ (10–36), психологічний – $41,52 \pm 8,12$ (22–58), соціальний – $19,20 \pm 4,24$ (10–28), інтегральний показник – $83,11 \pm 13,41$ (52–112). У вікових групах фізичний компонент варіював у межах 21,82–23,60 без прогресивного зниження у старших осіб. Психологічні та соціальні показники також залишалися стабільними. За ANOVA ($F=1,12$; $p=0,35$) та критерієм Краскела–Уолліса ($H=3,21$;



$p=0,52$) статистично значущих міжвікових відмінностей не виявлено ($p>0,05$). Встановлено сильний позитивний зв'язок між фізичним та інтегральним показниками ($r=0,62$; $p<0,001$), ще більш виражений – між психологічним та інтегральним ($r=0,74$; $p<0,001$), а також значущий зв'язок соціального компоненту з інтегральним індикатором ($r=0,58$; $p<0,001$), що свідчить про інтегрованість функціональних доменів.

Висновки. Фізичний компонент суб'єктивного благополуччя може розглядатися як функціональний маркер збереження адаптаційних і судинно-регуляторних механізмів у осіб похилого віку та опосередковано відображати NO-залежну регуляцію судин.

Ключові слова: суб'єктивне благополуччя; фізична активність; судинна функція; ендотеліальна функція; оксид азоту; судинне старіння; люди похилого віку.

Introduction. Cardiovascular disease remains the leading cause of morbidity, disability, and mortality among older adults. Age-related structural and functional alterations of the vascular wall, including reduced arterial elasticity, increased vascular stiffness, and endothelial dysfunction, contribute to diminished exercise tolerance, limitations in daily activities, and a decline in quality of life. Amidst global population aging, the preservation of vascular and physical function has become a matter of substantial medical and social importance. Alongside pharmacological treatment, physical activity is widely recognized as a key factor in the prevention of cardiovascular disease and in slowing the progression of age-related cardiovascular changes. According to current recommendations issued by the World Health Organization (WHO) and the European Society of Cardiology (ESC), regular physical exercise is associated with improved hemodynamic parameters, reduced arterial stiffness, enhanced exercise tolerance, and overall optimization of functional status. Yet, the magnitude of the protective effects of physical exercise on vascular function in older adults, alongside its influence on functional and psychosocial indicators, remains a subject of ongoing scientific debate. A comprehensive approach to evaluating the effects of physical activity is therefore particularly important. This kind of approach must analyze not only physical condition, but also psychological and social dimensions closely linked to subjective well-being. This perspective is consistent with the International Classification of Functioning, Disability and Health (ICF), which emphasizes activity and participation in everyday life. Within this framework, assessment of the protective effects of physical activity in older adults allows vascular function to be considered as one component of overall functional capacity. Although research on physical activity has expanded considerably, data focusing specifically on older adults remain limited, particularly with respect to integrated assessments that simultaneously address physical, psychological, and social domains. Hence, there is a clear need for studies that demonstrate the protective effects of physical activity on vascular function within the broader context of overall functional status in older adults [8, 16].

Blood vessels play a central role in the transport of blood and circulating factors such as oxygen, nutrients, and metabolic products. Their functional integrity depends on the coordinated interaction of endothelial cells (ECs), vascular smooth muscle cells (VSMCs), and components of the extracellular matrix (ECM) [7]. The endothelium performs both barrier and regulatory functions by controlling vascular permeability and thromboresistance, modulating inflammatory responses, and regulating vascular tone. Vascular smooth muscle cells provide the mechanical

properties of the vessel wall and enable adaptation to hemodynamic load. In response to injury or chronic stimuli, VSMCs may shift toward a synthetic phenotype, leading to vascular remodeling and increased arterial stiffness [3].

Age-related changes in the vascular wall are associated with the accumulation of molecular and cellular damage, as well as with cellular aging processes, including mitochondrial dysfunction, DNA damage, telomere shortening, and activation of cell cycle regulators (p.53/ p.21/ p.16). These mechanisms exacerbate a pro-oxidant and pro-inflammatory tissue environment. Within the vascular bed, this manifests as endothelial dysfunction, reduced bioavailability of nitric oxide (NO), increased oxidative stress, low-grade inflammation, phenotypic switching of vascular smooth muscle cells, collagen accumulation, and elastin degradation. Collectively, these processes contribute to arterial stiffness, hypertension, atherosclerosis, and heart failure, which dominate the morbidity and mortality profile of older adults [1, 5, 16].

Physical exercise is regarded as one of the most important factors supporting vascular homeostasis during aging. Through hemodynamic stimuli, particularly shear stress, physical activity activates endothelial nitric oxide synthase (eNOS) and NO production, attenuates oxidative and inflammatory signaling, modulates cytokine production (including IL-6 and subsequent anti-inflammatory cascades), promotes the mobilization of endothelial progenitor cells, and improves vascular reactivity. Clinical studies have demonstrated that regular aerobic exercise is associated with the preservation of endothelial function in older adults [6, 11, 15, 16]. At the same time, the selection of an optimal exercise regimen for this population requires an individualized approach, as excessive intensity may be associated with increased risk and reduced tolerance.

Given that age-related vascular dysfunction affects not only hemodynamics but also functional capacity, activity, and participation, the use of integrated indicators that reflect physical status in combination with psychological and social components appears justified. In this context, the BBC methodology represents a practically meaningful tool for assessing functional profile and subjective well-being across different age groups, allowing the potential «protective effects» of physical activity to be interpreted beyond the scope of clinical and laboratory markers alone.

The aim of the study is to assess age-related characteristics of the physical, psychological, and social components of subjective well-being using the BBC methodology, and to analyze their relationship with the integral indicator of subjective well-being as a functional marker reflecting the role of physical activity in maintaining vascular function in older adults.

Materials and methods. The study employed a single-point (cross-sectional) observational design aimed at examining age-related characteristics of physical, psychological, and social components of functioning, as well as their relationship with the integral indicator of subjective well-being as a functional marker relevant to the concept of preserving vascular function. The survey was conducted among 136 relatively healthy academic and teaching staff members from higher education institutions aged 20 years and older. Participants were stratified into five age groups: 20-30 years, 31-40 years, 41-50 years, 51-60 years, and 61 years and older, which enabled comparative analysis of the studied indicators across age categories.

The study included individuals without clinically significant cardiovascular disease in acute or decompensated stages, without acute somatic conditions at the time of examination, and who provided voluntary informed consent. Exclusion criteria comprised diagnosed cardiovascular disease, severe concomitant pathology (oncological, endocrine, or neurological), as well as refusal to participate. In accordance with its observational design, the study did not involve pharmacological interventions, placebo administration, randomization, or masking.

Functional status and subjective well-being were assessed using the BBC methodology, which allows comprehensive evaluation of physical, psychological, and social components of functioning, as well as calculation of an integral indicator of subjective well-being. The physical component reflected subjective assessment of physical well-being and functional capacity; the psychological component characterized psycho-emotional status and adaptive abilities; and the social component reflected the level of social activity and interpersonal interaction. Assessment was performed using a standardized scoring scale, followed by calculation of mean values for each component and for the integral indicator.

Statistical analysis of the obtained data was performed using contemporary mathematical statistics software. Quantitative variables are presented as arithmetic mean and standard deviation ($M \pm \text{STD}$). Data distribution was assessed using the Shapiro-Wilk test. Intergroup differences by age were evaluated using one-way analysis of variance (ANOVA) for parametric data and the Kruskal-Wallis test for nonparametric data. Relationships between the components assessed by the BBC methodology were analyzed using Spearman correlation coefficients. The critical level of statistical significance was set at $p = 0.05$, and the actual values of the relevant statistical tests and achieved significance levels are reported.

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki of the World

Medical Association, the Convention on Human Rights and Biomedicine, and current Ukrainian health care legislation. All participants were informed about the aims and procedures of the study and provided written voluntary informed consent prior to participation.

The research followed the basic principles of bioethics, in particular, the principles of integrity, confidentiality, fairness, and consent of research participants. The research was conducted considering ethical standards that guarantee the protection of the rights and well-being of research participants. All actions and procedures related to the research were in accordance with the principles of bioethics and the legislation of Ukraine, which regulates the conduct of scientific research. The study was carried out in compliance with the basic provisions of the «Rules of ethical principles of scientific medical research with human participation», approved by the Declaration of Helsinki (1964-2013), ICH GCP (1996), EEC Directive №609 (dated 24.11.1986), Orders of the Ministry of Health of Ukraine №690 (dated 23.09.2009), No. 944 (dated 14.12.2009), №616 (dated 03.08.2012). All the participants were informed about the goals, organization, methods of examination and signed an informed consent to participate in the completely anonymous study.

Research results. The study analyzed the physical, psychological, and social components, as well as the integral indicator of subjective well-being, using the BBC methodology in a sample of 136 relatively healthy academic and teaching staff members from different age groups. The summarized results are presented in Tables 1-5. Mean values of the physical component were comparable across all age groups, whereas the psychological and social components demonstrated relative stability irrespective of age [9, 10, 12, 14]. The integral indicator of subjective well-being showed a tendency toward higher values in older age groups.

According to the results of one-way analysis of variance and the Kruskal-Wallis's test, no statistically significant intergroup differences were identified ($p > 0.05$). Correlation analysis revealed strong positive associations among the BBC components of subjective well-being, with the most pronounced relationship observed between the psychological component and the integral indicator of subjective well-being.

The physical component of BBC, reflecting the level of physical functioning and exercise tolerance, demonstrates age-related variability without a pronounced decline in older age groups. This pattern may be interpreted as a functional marker of preserved adaptive capacity of the cardiovascular system in relatively healthy individuals (Table 2).

Table 1

Indicators of BBC components in different age groups ($M \pm \text{STD}$)

Age group	n	Physical	Psychological	Social	Integral
20-30	11	21.91±7.45	40.00±8.41	17.64±4.23	79.55±14.74
31-40	40	22.25±5.41	41.98±8.44	19.48±4.25	83.70±13.24
41-50	45	22.04±5.03	41.96±7.91	19.91±4.13	83.91±12.57
51-60	28	21.82±5.77	40.46±7.41	18.64±4.12	80.93±13.89
≥61	10	23.60±5.68	42.20±10.06	19.40±4.62	85.20±16.41

Note. M – arithmetic mean; STD – standard deviation.

Table 2

Descriptive statistics of BBC indicators in the total sample

Indicator	M	STD	Min	Max
Physical component	22.16	5.49	10	36
Psychological component	41.52	8.12	22	58
Social component	19.20	4.24	10	28
Integral indicator	83.11	13.41	52	112

Note. M – sample mean; STD – standard deviation; Min – minimum value; Max – maximum value.

Table 3

Results of one-way analysis of variance (ANOVA)

Indicator	F	p
Physical component	1.12	0.35
Psychological component	0.94	0.44
Social component	1.03	0.39
Integral indicator	1.27	0.28

Note. F – Fisher's criterion value of one-way analysis of variance (ANOVA); p – achieved level of statistical significance. The critical level of significance was taken as $p = 0.05$.

Table 4

Results of the Kruskal-Wallis' test

Indicator	H	p
Physical component	3.21	0.52
Psychological component	2.87	0.58
Social component	3.05	0.55
Integral indicator	3.44	0.49

Note. H – value of the Kruskal-Wallis' criterion; p – achieved level of statistical significance. The critical level of significance was taken as $p = 0.05$.

Parametric and nonparametric analyses consistently demonstrated the absence of statistically significant age-related differences, underscoring the stability of functional status within the studied cohort.

Table 5

Correlations between BBC components

Pair of indicators	r	p
Physical – Integral	0.62	<0.001
Psychological – Integral	0.74	<0.001
Social – Integral	0.58	<0.001

Note. r – Spearman's correlation coefficient; p – achieved level of statistical significance. The critical level of significance was taken as $p = 0.05$.

Descriptive statistics indicated the absence of extreme values and sufficient sample homogeneity, supporting the use of the obtained indicators as reliable functional markers of general condition associated with vascular homeostasis (Table 3).

According to the results of ANOVA, no statistically significant inter-age differences were found ($p > 0.05$), which indicates the relative stability of the functional components of subjective well-being in different age groups.

Significant correlations between the physical component and the integral indicator of subjective well-being confirm the importance of physical functioning as a key functional factor relevant to the maintenance of vascular function during aging.

Discussion. Our data show that in a cohort of relatively healthy older adults, preservation of the integral level of subjective well-being occurs alongside age-related variability in the physical component, suggesting its potential as a functionally meaningful indicator of the body's adaptive capacity [2, 4, 13]. The age-related variability of the physical BBC component of subjective well-being observed in Table 1 likely reflects relatively preserved cardiovascular reserves, particularly the ability to maintain adequate vascular

reactivity and hemodynamic adaptation in the absence of clinically manifest cardiovascular disease.

Physical activity is well established as one of the key modifiable factors supporting endothelial function through activation of endothelial nitric oxide synthase (eNOS) and increased bioavailability of nitric oxide (NO). Nitric oxide plays a central role in the regulation of vascular tone and in the inhibition of inflammatory processes, platelet aggregation, and smooth cell proliferation. Thus, the physical component of the BBC methodology, which reflects the level of physical functioning and tolerance to exercise load, may be considered an indirect functional marker of NO-dependent vascular regulation during the aging process.

The absence of statistically significant inter-age differences observed in both one-way analysis of variance and the Kruskal-Wallis' test (Tables 3 and 4) should not be interpreted as evidence of the absence of age-related changes per se. Instead, it points to the relative stability of functional status within a cohort of comparatively healthy individuals. This aligns with existing literature demonstrating that regular physical activity can substantially attenuate age-related declines in endothelial function and NO bioavailability, even in advanced age.

Particular attention should be given to the results of the correlation analysis (Table 5), which revealed a strong positive association between the physical BBC component of subjective well-being and the integral indicator of subjective well-being. Such a link reinforces the idea that physical functioning, psycho-emotional regulation, and social activity are systemically integrated, interrelated domains that indirectly reflect the state of vascular homeostasis. With respect to vascular aging, these interconnections may be underpinned by shared mechanisms, including NO-dependent vasodilation, reduction of oxidative stress, and suppression of chronic low-grade inflammation.

The psychological and social BBC components, which also demonstrated significant correlations with the integral indicator, may influence vascular function through neurohumoral regulatory pathways, particularly via the sympathetic-adrenal system and the hypothalamic-pituitary-adrenal axis. Chronic psycho-emotional stress is associated with reduced NO bioavailability, increased vascular stiffness, and endothelial dysfunction, whereas positive subjective well-being is regarded as a protective factor against the development of cardiovascular disorders.

Taken together, the results support the feasibility of using the integral indicator of subjective well-being and its individual components as functional markers relevant to the assessment of vascular health in older adults. The findings are consistent with current concepts regarding the role of physical activity in preserving endothelial function, maintaining NO-dependent vascular regulation, and slowing vascular aging, even in the absence of direct clinical or instrumental indicators of cardiovascular function.

The present study has several limitations. Its cross-sectional design does not allow for the establishment of causal relationships between levels of physical activity, components of subjective well-being, and vascular function. The study sample consisted of relatively healthy teachers, which may restrict the generalizability of the findings to a broader population of older adults, particularly those with established cardiovascular pathology. Furthermore, direct instrumental or biochemical markers of endothelial function, such as indices of vascular stiffness, endothelium-dependent vasodilation, or NO bioavailability, were not assessed, highlighting the need for future prospective studies incorporating comprehensive cardiovascular evaluation.

Conclusions

1. In a cohort of relatively healthy older adults, the physical component of subjective well-being demonstrates age-related variability without a pronounced decline, indicating the preservation of functional reserves and adaptive capacity of the cardiovascular system.

2. The absence of statistically significant inter-age differences in both parametric and nonparametric analyses confirms the overall stability of the integral functional state in the studied cohort, which may be attributable to the protective effects of physical activity.

3. Notably, the strong correlations identified between the physical component and the integral indicator of subjective well-being highlight the central role of physical functioning as a functional marker relevant to preserving vascular function during aging.

4. Collectively, these findings argue for the use of subjective well-being indicators as accessible functional

markers associated with endothelial function and NO-dependent vascular regulation in older adults.

Funding. This study received no external funding.

Conflict of Interest. The authors declare no actual or potential conflicts of interest related to this study.

References

- Horoshko, V. I., & Horoshko, A. I. (2025). Innovative technologies of mobile applications in rehabilitation practice: personalised approach to restoring body functions. *Ukraine. Nation's Health*, (3), 174–184. <https://doi.org/10.32782/2077-6594/2025.3/20>
- Horoshko, V. I., Khomenko, Y. G., & Horoshko, A. I. (2025). Influence of comprehensive physical and psychological rehabilitation on the emotional state and coping strategies of students in crisis situations. *Polski Merkuriusz Lekarski*, 53(2), 222–228. <https://doi.org/10.36740/merkur202502111>
- Ito, S. (2019). High-intensity interval training for health benefits and care of cardiac diseases - The key to an efficient exercise protocol. *World Journal of Cardiology*, 11(7), 171–188. <https://doi.org/10.4330/wjc.v11.i7.171>
- Kozakova, M., & Palombo, C. (2021). Vascular Ageing and Aerobic Exercise. *International Journal of Environmental Research and Public Health*, 18(20), 10666. <https://doi.org/10.3390/ijerph182010666>
- Kumari, R., & Jat, P. (2021). Mechanisms of Cellular Senescence: Cell Cycle Arrest and Senescence Associated Secretory Phenotype. *Frontiers in Cell and Developmental Biology*, 9. <https://doi.org/10.3389/fcell.2021.645593>
- Kutlu, Z., İbiş, S., & Aktuğ, Z. B. (2025). Effect of Respiratory Muscle Exercises Combined with Step Aerobic Exercise on Respiratory Functions. *Research in Sport Education and Sciences*, 27(2), 166–175. <https://doi.org/10.62425/rses.1627727>
- Li, Z., Zhang, Z., Ren, Y., Wang, Y., Fang, J., Yue, H., Ma, S., & Guan, F. (2021). Aging and age-related diseases: from mechanisms to therapeutic strategies. *Biogerontology*, 22(2), 165–187. <https://doi.org/10.1007/s10522-021-09910-5>
- Meng, J., Geng, Q., Jin, S., Teng, X., Xiao, L., Wu, Y., & Tian, D. (2023). Exercise protects vascular function by countering senescent cells in older adults. *Frontiers in Physiology*, 14. <https://doi.org/10.3389/fphys.2023.1138162>
- Nystoriak, M. A., & Bhatnagar, A. (2018). Cardiovascular Effects and Benefits of Exercise. *Frontiers in Cardiovascular Medicine*, 5. <https://doi.org/10.3389/fcvm.2018.00135>
- Partridge, L., Deelen, J., & Slagboom, P. E. (2018). Facing up to the global challenges of ageing. *Nature*, 561(7721), 45–56. <https://doi.org/10.1038/s41586-018-0457-8>
- Rossman, M. J., Kaplon, R. E., Hill, S. D., McNamara, M. N., Santos-Parker, J. R., Pierce, G. L., Seals, D. R., & Donato, A. J. (2017). Endothelial cell senescence with aging in healthy humans: prevention by habitual exercise and relation to vascular endothelial function. *American Journal of Physiology-Heart and Circulatory Physiology*, 313(5), H890–H895. <https://doi.org/10.1152/ajpheart.00416.2017>
- Sari, N., & Sugiharto, S. (2021). Pengaruh Senam Aerobik Low Impact Terhadap Tekanan Darah Pada Lansia dengan Hipertensi: Literature Review. *Prosiding Seminar Nasional Kesehatan*, 1, 1827–1834. <https://doi.org/10.48144/prosiding.v1i.938>
- Stojanović, S. D., Fiedler, J., Bauersachs, J., Thum, T., & Sedding, D. G. (2020). Senescence-induced inflammation: an important player and key therapeutic target in atherosclerosis. *European Heart Journal*, 41(31), 2983–2996. <https://doi.org/10.1093/eurheartj/ehz919>
- Theofilis, P., Sagris, M., Oikonomou, E., Antonopoulos, A. S., Siasos, G., Tsioufis, C., & Tousoulis, D. (2021). Inflammatory Mechanisms Contributing to Endothelial Dysfunction. *Biomedicine*, 9(7), 781. <https://doi.org/10.3390/biomed9070781>
- Zha, Y., Zhuang, W., Yang, Y., Zhou, Y., Li, H., & Liang, J. (2022). Senescence in Vascular Smooth Muscle Cells and Atherosclerosis. *Frontiers in Cardiovascular Medicine*, 9. <https://doi.org/10.3389/fcvm.2022.910580>
- Zheng, G., Qiu, P., Xia, R., Lin, H., Ye, B., Tao, J., & Chen, L. (2019). Effect of Aerobic Exercise on Inflammatory Markers in Healthy Middle-Aged and Older Adults: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Frontiers in Aging Neuroscience*, 11. <https://doi.org/10.3389/fnagi.2019.00098>