SIEMKO, Jakub, RULEWSKA, Natalia Maria, GRABOWSKI, Filip, NESKA, Dagmara, PRYSTACKA-SZAR, Dominika, STADLER-SZAJDA, Justyna, CZYŻNIKIEWICZ, Adrianna, STOŁOWSKI, Wenancjusz, BUJAK, Magdalena and WAŚNIOWSKA, Magdalena. The role of physical activity in the treatment of depression. Journal of Education, Health and Sport. 2025;80:57828. eISSN 2391-8306.
https://doi.org/10.12775/JEHS.2025.80.57828
https://apcz.umk.pl/JEHS/article/view/57828

The journal has had 40 points in Minister of Science and Higher Education of Poland parametric evaluation. Annex to the announcement of the Minister of Education and Science of 05.01.2024 No. 32318. Has a Journal's Unique Identifier: 201159. Scientific disciplines assigned: Physical culture sciences (Field of medical and health sciences); Health Sciences (Field of medical and health sciences).
Punkty Ministerialne 40 punktów. Załącznik do komunikatu Ministra Nauki i Szkolnictwa Wyższego z dnia 05.01.2024 Lp. 32318. Posiada Unikatowy Identyfikator Czasopisma: 201159. Przypisane dyscypliny naukowe: Nauki o kulturze fizycznej (Dziedzina nauk medycznych i nauk o zdrowiu); Nauki o zdrowiu (Dziedzina nauk medycznych i nauk o zdrowiu).
The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 15.01.2025. Revised: 02.03.2025. Accepted: 02.04.2025. Published: 05.04.2025.

The role of physical activity in the treatment of depression

Jakub Siemko

Ludwika Błażka Provincial Multi-Specialist Hospital in Inowrocław

https://orcid.org/0009-0009-9318-9458

Natalia Maria Rulewska

Provincial Specialist Hospital in Ciechanów St. Powstańców Wielkopolskich 2, 06-400 Ciechanów, Poland

https://orcid.org/0009-0008-4515-7403

Filip Grabowski

Provincial Specialist Hospital in Ciechanów St. Powstańców Wielkopolskich 2, 06-400 Ciechanów, Poland

https://orcid.org/0009-0007-0466-2764

Dagmara Neska

Ludwika Błażka Provincial Multi-Specialist Hospital in Inowrocław St. Poznańska 97, 88-100 Inowrocław, Poland

https://orcid.org/0009-0003-1900-954X

Dominika Prystacka-Szar

Ludwik Rydygier Memorial Specialized Hospital in Krakow Osiedle Złotej Jesieni 1, 31-820 Kraków

https://orcid.org/0009-0003-6533-4247

Justyna Stadler-Szajda

Ludwika Błażka Provincial Multi-Specialist Hospital in Inowrocław St. Poznańska 97, 88-100 Inowrocław, Poland

https://orcid.org/0000-0002-1742-1835

Adrianna Czyżnikiewicz

Ludwika Błażka Provincial Multi-Specialist Hospital in Inowrocław St. Poznańska 97, 88-100 Inowrocław

https://orcid.org/0009-0007-4541-7175

Wenancjusz Stołowski

Ludwika Błażka Provincial Multi-Specialist Hospital in Inowrocław St. Poznańska 97, 88-100 Inowrocław

https://orcid.org/0009-0009-0317-1212

Magdalena Bujak

Krakow University Hospital St. Macieja Jakubowskiego 2, 30-688 Krakow

https://orcid.org/0009-0008-9274-3595

Magdalena Waśniowska

Stefana Żeromskiego Specialist Hospital in Kraków Os. Na Skarpie 66, 31-913 Kraków

https://orcid.org/0009-0006-0614-8307

Abstract

Introduction: Depression contributes significantly to the overall global societal and personal burden of disease. Despite the developments in treatment strategies, the effectiveness of both medication and psychotherapy is not optimal. As theoretical knowledge expands, so does the need for other practical evidence-based interventions. Among them, physical activity (PA) shows a potential therapeutic role.

Aim: The aim of this article is to explore the role of PA in the treatment of depression and establish whether it is reasonable to think of physical exercise as a therapeutic intervention in a clinical setting.

Review methods: A comprehensive analysis of research papers available on PubMed and Google Scholar was undertaken using the search terms encompassing the following keywords:

depressive symptoms / depression / neuropsychiatry / physical activity / exercise / physical health / running therapy / treatment.

Conclusion: Physical activity is known to help improve mental health. Exercise therapy is therefore a valuable option in mental health care, both in terms of mental and physical health, and should be considered standard practice for people with depression and/or anxiety disorders. All types of PA and exercise are beneficial. Putting an emphasis on this element of lifestyle when developing intervention plans, treatment programs, and health policy guidelines plays a key factor in providing a multi-dimensional approach to mental healthcare.

Keywords
depression; physical activity; neuropsychiatry; treatment; physical health; running; hiking; mind-body exercise; resistance training.

Introduction

Depression is one of the major leading causes of disability worldwide [1]. It is estimated that 970 million people of all ages are affected by depression, and almost one in two (44%) will experience a mental health disorder in their lifetime [2]. Depression can have several negative consequences, such as a prevalent sad mood and/or loss of interest, affecting thoughts, feelings, behaviors, and physical health and impairing social and occupational functioning [3,4]. In addition to the mental health-related aspects of depression, there is significant evidence showing that people suffering from depression experience considerably poorer physical health [5]. For example, people with depression present increased prevalence of cardiometabolic disease [6], diabetes [7], and cardiovascular disease [8], and experience premature mortality by 10 years compared with the general population [9]. The annual global costs of mental health disorders have been estimated at $2.5 trillion (USD), which is projected to increase to $6 trillion (USD) by 2030 [10]. Despite the significant growth in social awareness, depression continues to be frequently under-diagnosed and inadequately treated [11].

Pathophysiology of Depression

The challenge in diagnosing and treating depression lies mainly in the fact that the precise mechanisms underlying the pathophysiology of depression remain unknown [12]. Be it the mid-

20th century monoamine hypothesis proposed as an explanation of how antidepressants work [13], the supposed hypothalamic–pituitary–adrenal axis changes [14,15,16] the inflammation theory linking peripheral cytokine concentrations with brain function [17], hypotheses of a protective role of neurogenesis within the general theory of neuroplasticity [18], or the modern-day epigenetic findings explaining how some genes are activated by environmental factors, therefore shining a light on how the environment might have a role in the modification of brain neurobiology [19,20]—they all fail to satisfactorily explain all aspects of the disease. These limitations are reflected in clinical practice and support the notion of a necessity for an individual approach to each case.

Treatment of Depression

At present the evidence-based treatment options consist mainly of antidepressants and psychotherapies. The problem at hand with both of these options is adherence—some evidence suggests that only about half of the people taking antidepressants achieve a clinically significant response (a decrease of 50% or more on depressive symptoms) [21], with dropout rates ranging from 15% to 132% higher than placebo [22]. But even for those following the pharmacological treatment the outcomes do not seem to be sufficient. The treatment-prevalence paradox describing a situation that can be widely observed in Western countries since 1980, where increased availability of supposedly effective treatments does not correspond with the decline in the incidence of depression is reinforcing the view that addressing the high rates of depression through symptom recognition and treatment with antidepressants is unlikely to be effective. The absolute long-term effectiveness of antidepressants in real-world settings is disappointingly modest [23]. On the other hand, the clinical relevance of the effects of psychotherapies, though being comparable to that of antidepressant medications, remain open to debate [24]. Furthermore modern analyzes show that response and remission rates under usual care are low, the vast majority of patients do not respond to treatment or achieve remission, and outcomes are unlikely to have improved over time. Despite the increasing availability of evidence-based therapies, no significant improvement in response or remission rates over time is found [25].

Within this frame arises the need to broaden the spectrum of possible interventions.
Physical activity is a recognized factor that has a beneficial preventive and therapeutic effect on many lifestyle diseases, including mental illnesses, such as affective and anxiety disorders.

The positive effects of physical exercise have been well documented in many systematic reviews and meta-analyses [26,27,28,29,30,31].

Physical activity—neuropsychiatric perspective

From a neuropsychiatric perspective, the benefits of regular physical exercise include mechanisms such as reducing cortisol concentration in the mechanism of regulation of the hypothalamic-pituitary-adrenal axis [32], modulation the noradrenergic and serotoninergic systems [33], the production of neurotrophic factor influencing neuroplasticity [34] the improvement in vascular function and oxygenation of the brain tissue [35,36]. Reduced oxygen supply to areas involved in mood regulation may result in chronic ischemia of these regions and increase the risk of mental disorders [37]. Chronic white matter ischemia in the course of microvascular diseases often manifests clinically as depressive disorders [35]. Furthermore, physical activity is being studied as a factor playing a role in protecting the hippocampal volume of the brain [38] and regenerating hippocampal neurons by decreasing glucocorticoid receptors [39,40], both of which lead to alleviation of symptoms of depression. Lastly, concurrent with previous findings showing the role of endurance training in alleviating anxiety disorders [39,41] and expanding on the neurobiological understanding of said mechanism, currently conducted research has shown a link between physical exercise-induced improvement of brain RNA methylation leading to a therapeutic effect in the treatment of stress-induced anxiety [42].

Physical activity — in practice

In 2020, the World Health Organization recommended training involving all major muscle groups and engaging in varied and multi-component PA. Both resistance exercises and aerobic exercises performed at least 3 days a week and lasting 150-300 minutes a week provide benefits [43]. It is worth noting that some studies show that moderate and light physical exercise seems to have a preventive effect on depressive disorders, and heavy exercise may paradoxically increase the risk of their occurrence [44], while others state that light PA (walking, yoga) still provides clinically meaningful effects, but the expected effects are stronger for vigorous exercise (running, interval training) [45]. Moreover, a meta-analysis done by Pearce et al. showed significant mental health benefits even when engaging in activity at levels below the public health recommendations [46]. One of such activities showing certain clinical promise is moderate hiking—a cost-effective intervention that helps people to meet physical activity guidelines in an outdoor setting [47]. Moderate hiking is a viable, effective, and well-tolerated form of fitness program even in high-risk suicidal patients providing systemic training effects

without increasing cytokines previously associated with elevated risk of suicidality [48]. The so-called mind-body exercises emphasizing the coordination of body and breath in a mindful practice may also be useful. According to a meta-analysis by Li et al., tai chi, health qigong, and yoga are capable of reducing levels of depression and anxiety via the means of strengthening the breathing muscles and increasing the body's intake of oxygen [49]. Open water swimming is also worth mentioning, as clinicians report that it is safe for patients with depression when done under supervision, and regular participation may improve sleep and well-being, effectively reducing symptoms of depression [50]. A case report of such an intervention states that within a month of open water swimming female patient was able to reduce her medication and no longer required drug treatment after 4 months of subsequent activity [51]. The more strenuous physical activity, such as running, also has extensive clinical research providing insight into its potential use in the treatment of depression [52,53]. The results of the study by Verhoeven et al. showed that although antidepressants and running therapy did not differ statistically significantly on mental health outcomes in a sample of patients with depression and anxiety disorders, the interventions had significantly different and often contrasting effects on several physical health outcomes, with more favorable results for people taking part in the exercises. Antidepressant users showed reductions in heart rate variability and increases in waist circumference, blood pressure, and triglyceride levels, suggesting an increase in metabolic syndrome and higher cardiovascular risk. The runner group showed a decrease in both metabolic syndrome components and heart rate, which in turn indicated a protective effect on cardiovascular events. This study demonstrated the importance of exercise in patients with depression and anxiety disorders and caution in the use of antidepressants in physically unhealthy patients [54]. Resistance training, no different than previously mentioned forms of PA, proves across multiple studies to be an effective intervention in the field of affective disorders such as depression—both in older adults aged 60 years and more [55] and in young people [56]. Using one's own body weight, training with the use of machines, using resistance bands, free resistance training, electrostimulation, vibration plates—all forms of resistance training when performed regularly result in a substantial reduction in depressive symptoms [57]. Another comparative study of the effectiveness of exercise, antidepressants, and their combination in treating non-severe depression shows no difference between exercise and pharmacological interventions in reducing depressive symptoms in adults with moderate (non-severe) depression and suggests that these results support the use of exercise as an alternative or complementary treatment for moderate depression in adults, highlighting that European, Canadian, Australian, and British treatment guidelines recommend the use of exercise as an

alternative treatment for moderate depression. These guidelines recommend exercise programs consisting of 30-60 minute sessions of moderate intensity, performed 2-3 times per week for 9-12 weeks and led in groups by a competent professional [58].

Conclusion

Physical activity is known to help improve mental health. Exercise therapy is therefore a valuable option in mental health care, both in terms of mental and physical health, and should be considered standard practice for people with depression and/or anxiety disorders. However, despite the evidence, it has not been widely adopted as a first-line treatment. Furthermore, social awareness of the importance of exercise does not translate into practice, which is indirectly evidenced by the increase in the number of overweight or obese people in recent decades. All types of physical activity and exercise are beneficial. Putting an emphasis on this element of lifestyle when developing intervention plans, treatment programs, and health policy guidelines plays a key factor in providing a multi-dimensional approach to mental healthcare [59]. Of equal importance is understanding that social support from health care workers, friends, and family plays an important role in encouraging patients to take up physical exercise [60].

Author's contribution

Conceptualization: Jakub Siemko, Filip Grabowski

Methodology: Filip Grabowski, Dagmara Neska, Magdalena Waśniowska

Software: not applicable;

Verification: Natalia Rulewska, Wenancjusz Stołowski, Magdalena Bujak

Formal analysis: Dominika Prystacka-Szar, Adrianna Czyżnikiewicz

Research: Wenancjusz Stołowski, Magdalena Bujak, Filip Grabowski, Adrianna Czyżnikiewicz

Resources: Adrianna Czyżnikiewicz, Dagmara Neska

Writing- rough preparation: Justyna Stadler-Szajda, Magdalena Waśniowska

Writing- review and editing: Jakub Siemko, Magdalena Waśniowska, Magdalena Bujak

Visualization: Natalia Rulewska, Dominika Prystacka-Szar , Justyna Stadler-Szajda

Supervision: Jakub Siemko

Project administration: Jakub Siemko

Funding acquisition: not applicable.

All authors have read and agreed with the published version of the manuscript.

Funding statement

The study did not receive special funding.

Informed Consent Statement

Not applicable.

Conflict of Interest Statement:

The authors report no conflict of interest.

References

1. Global Burden of Disease. (2019). Global Health Data Exchange (GHDE). *Global Burden of Disease Study 2019 (GBD 2019).*
2. Australian Bureau of Statistics . National study of mental health and wellbeing, 2021-2011. Australian Government, 2022.
3. American Psychiatric Association. Diagnostic and Statistical Manual of Mental Disorders, 5th ed.; American Psychiatric Association: Arlington, VA, USA, 2013.
4. Odone A, Landriscina T, Amerio A, Costa G. The impact of the current economic crisis on mental health in Italy: evidence from two representative national surveys. Eur J Public Health. 2018 Jun 1;28(3):490-495. doi: 10.1093/eurpub/ckx220. PMID: 29293996.
5. Moussavi, S., Chatterji, S., Verdes, E., Tandon, A., Patel, V., & Ustun, B. (2007). Depression, chronic diseases, and decrements in health: results from the World Health Surveys. *The Lancet*, *370*(9590), 851-858.
6. Vancampfort, D., Stubbs, B., Mitchell, A. J., De Hert, M., Wampers, M., Ward, P. B., ... & Correll, C. U. (2015). Risk of metabolic syndrome and its components in people with schizophrenia and related psychotic disorders, bipolar disorder and

major depressive disorder: a systematic review and meta-analysis. *World psychiatry*, *14*(3), 339-347.

7. Vancampfort, D., Correll, C. U., Galling, B., Probst, M., De Hert, M., Ward, P. B., ... & Stubbs, B. (2016). Diabetes mellitus in people with schizophrenia, bipolar disorder and major depressive disorder: a systematic review and large scale meta-analysis. *World Psychiatry*, *15*(2), 166-174.
8. Correll, C. U., Solmi, M., Veronese, N., Bortolato, B., Rosson, S., Santonastaso, P., ... & Stubbs, B. (2017). Prevalence, incidence and mortality from cardiovascular disease in patients with pooled and specific severe mental illness: a large-scale meta-analysis of 3,211,768 patients and 113,383,368 controls. *World psychiatry*, *16*(2), 163-180.
9. Charlson, F. J., Diminic, S., Lund, C., Degenhardt, L., & Whiteford, H. A. (2014). Mental and substance use disorders in sub-Saharan Africa: predictions of epidemiological changes and mental health workforce requirements for the next 40 years. *PloS one*, *9*(10), e110208.
10. Marquez PV, Saxena S. Making Mental Health a Global Priority. Cerebrum. 2016 Jul 1;2016:cer-10-16. PMID: 28058091; PMCID: PMC5198754.
11. Peveler R, Carson A, Rodin G. Depression in medical patients. BMJ. 2002 Jul 20;325(7356):149-52. doi: 10.1136/bmj.325.7356.149. PMID: 12130614; PMCID: PMC1123674.
12. Tian H, Hu Z, Xu J, Wang C. The molecular pathophysiology of depression and the new therapeutics. MedComm (2020). 2022 Jul 21;3(3):e156. doi: 10.1002/mco2.156. PMID: 35875370; PMCID: PMC9301929.
13. Segal DS, Kuczenski R, Mandell AJ. Theoretical implications of drug-induced adaptive regulation for a biogenic amine hypothesis of affective disorder. Biol Psychiatry. 1974 Oct;9(2):147-59. PMID: 4154114.
14. Goodyer IM, Herbert J, Tamplin A, Altham PM. Recent life events, cortisol, dehydroepiandrosterone and the onset of major depression in high-risk adolescents. Br J Psychiatry. 2000 Dec;177:499-504. doi: 10.1192/bjp.177.6.499. PMID: 11102323.
15. Harris TO, Borsanyi S, Messari S, Stanford K, Cleary SE, Shiers HM, Brown GW, Herbert J. Morning cortisol as a risk factor for subsequent major depressive disorder in adult women. Br J Psychiatry. 2000 Dec;177:505-10. doi: 10.1192/bjp.177.6.505. PMID: 11102324.

16. Knorr U, Vinberg M, Kessing LV, Wetterslev J. Salivary cortisol in depressed patients versus control persons: a systematic review and meta-analysis. Psychoneuroendocrinology. 2010 Oct;35(9):1275-86. doi: 10.1016/j.psyneuen.2010.04.001. Epub 2010 May 5. Erratum in: Psychoneuroendocrinology. 2011 Oct;36(9):1427-9. PMID: 20447770.
17. Bollen J, Trick L, Llewellyn D, Dickens C. The effects of acute inflammation on cognitive functioning and emotional processing in humans: A systematic review of experimental studies. J Psychosom Res. 2017 Mar;94:47-55. doi: 10.1016/j.jpsychores.2017.01.002. Epub 2017 Jan 4. PMID: 28183402.
18. Kraus C, Castrén E, Kasper S, Lanzenberger R. Serotonin and neuroplasticity - Links between molecular, functional and structural pathophysiology in depression. Neurosci Biobehav Rev. 2017 Jun;77:317-326. doi: 10.1016/j.neubiorev.2017.03.007. Epub 2017 Mar 22. PMID: 28342763.
19. Klengel T, Mehta D, Anacker C, Rex-Haffner M, Pruessner JC, Pariante CM, Pace TW, Mercer KB, Mayberg HS, Bradley B, Nemeroff CB, Holsboer F, Heim CM, Ressler KJ, Rein T, Binder EB. Allele-specific FKBP5 DNA demethylation mediates gene-childhood trauma interactions. Nat Neurosci. 2013 Jan;16(1):33-41. doi: 10.1038/nn.3275. Epub 2012 Dec 2. PMID: 23201972; PMCID: PMC4136922.
20. Bigdeli TB, Ripke S, Peterson RE, Trzaskowski M, Bacanu SA, Abdellaoui A, Andlauer TF, Beekman AT, Berger K, Blackwood DH, Boomsma DI, Breen G, Buttenschøn HN, Byrne EM, Cichon S, Clarke TK, Couvy-Duchesne B, Craddock N, de Geus EJ, Degenhardt F, Dunn EC, Edwards AC, Fanous AH, Forstner AJ, Frank J, Gill M, Gordon SD, Grabe HJ, Hamilton SP, Hardiman O, Hayward C, Heath AC, Henders AK, Herms S, Hickie IB, Hoffmann P, Homuth G, Hottenga JJ, Ising M, Jansen R, Kloiber S, Knowles JA, Lang M, Li QS, Lucae S, MacIntyre DJ, Madden PA, Martin NG, McGrath PJ, McGuffin P, McIntosh AM, Medland SE, Mehta D, Middeldorp CM, Milaneschi Y, Montgomery GW, Mors O, Müller-Myhsok B, Nauck M, Nyholt DR, Nöthen MM, Owen MJ, Penninx BW, Pergadia ML, Perlis RH, Peyrot WJ, Porteous DJ, Potash JB, Rice JP, Rietschel M, Riley BP, Rivera M, Schoevers R, Schulze TG, Shi J, Shyn SI, Smit JH, Smoller JW, Streit F, Strohmaier J, Teumer A, Treutlein J, Van der Auwera S, van Grootheest G, van Hemert AM, Völzke H, Webb BT, Weissman MM, Wellmann J, Willemsen G, Witt SH, Levinson DF, Lewis CM, Wray NR, Flint J, Sullivan PF, Kendler KS. Genetic effects influencing risk for major depressive disorder in China and Europe. Transl

Psychiatry. 2017 Mar 28;7(3):e1074. doi: 10.1038/tp.2016.292. PMID: 28350396; PMCID: PMC5404611.

21. Pigott, H. E. (2015). The STAR* D trial: it is time to reexamine the clinical beliefs that guide the treatment of major depression. *The Canadian Journal of Psychiatry*, *60*(1), 9-13.
22. Cipriani, A., Furukawa, T. A., Salanti, G., Chaimani, A., Atkinson, L. Z., Ogawa, Y., ... & Geddes, J. R. (2018). Comparative efficacy and acceptability of 21 antidepressant drugs for the acute treatment of adults with major depressive disorder: a systematic review and network meta-analysis. *The Lancet*, *391*(10128), 1357-1366.
23. Mulder RT, Jorm AF. The impact of antidepressants and human development measures on the prevalence of sadness, worry and unhappiness: cross-national comparison. BJPsych Open. 2023 Oct 10;9(6):e182. doi: 10.1192/bjo.2023.576. PMID: 37814546; PMCID: PMC10594156.
24. Cuijpers, P., Turner, E. H., Mohr, D. C., Hofmann, S. G., Andersson, G., Berking, M., & Coyne, J. (2014). Comparison of psychotherapies for adult depression to pill placebo control groups: a meta-analysis. Psychological Medicine, 44(4), 685–695. doi:10.1017/S0033291713000457.
25. Cuijpers P, Miguel C, Harrer M, Ciharova M, Karyotaki E. The outcomes of mental health care for depression over time: A meta-regression analysis of response rates in usual care. J Affect Disord. 2024 Aug 1;358:89-96. doi: 10.1016/j.jad.2024.05.019. Epub 2024 May 4. PMID: 38710332.
26. Gianfredi V, Blandi L, Cacitti S, Minelli M, Signorelli C, Amerio A, Odone A. Depression and Objectively Measured Physical Activity: A Systematic Review and Meta-Analysis. Int J Environ Res Public Health. 2020 May 25;17(10):3738. doi: 10.3390/ijerph17103738. PMID: 32466242; PMCID: PMC7277615.
27. Bailey AP, Hetrick SE, Rosenbaum S, Purcell R, Parker AG. Treating depression with physical activity in adolescents and young adults: a systematic review and meta-analysis of randomised controlled trials. Psychol Med. 2018 May;48(7):1068-1083. doi: 10.1017/S0033291717002653. Epub 2017 Oct 10. PMID: 28994355.
28. Tian J, Kang Y, Liu P, Yu H. Effect of Physical Activity on Depression in Patients with Parkinson's Disease: A Systematic Review and Meta-Analysis. Int J Environ Res Public Health. 2022 Jun 3;19(11):6849. doi: 10.3390/ijerph19116849. PMID: 35682432; PMCID: PMC9180645.

29. Bourke M, Patten RK, Klamert L, Klepac B, Dash S, Pascoe MC. The acute affective response to physical activity in people with depression: A meta-analysis. J Affect Disord. 2022 Aug 15;311:353-363. doi: 10.1016/j.jad.2022.05.089. Epub 2022 May 21. PMID: 35605707.
30. Ashdown-Franks G, Firth J, Carney R, Carvalho AF, Hallgren M, Koyanagi A, Rosenbaum S, Schuch FB, Smith L, Solmi M, Vancampfort D, Stubbs B. Exercise as Medicine for Mental and Substance Use Disorders: A Meta-review of the Benefits for Neuropsychiatric and Cognitive Outcomes. Sports Med. 2020 Jan;50(1):151-170. doi: 10.1007/s40279-019-01187-6. PMID: 31541410.
31. Cempa K, Jurys T, Kluczyński S, Andreew M. Physical activity as a therapeutic method for non-pharmacological treatment of schizophrenia: A systematic literature review. Psychiatr Pol. 2022 Aug 31;56(4):837-859. English, Polish. doi: 10.12740/PP/140053. Epub 2022 Aug 31. PMID: 37074832.
32. Beserra AHN, Kameda P, Deslandes AC, Schuch FB, Laks J, Moraes HS. Can physical exercise modulate cortisol level in subjects with depression? A systematic review and meta-analysis. Trends Psychiatry Psychother. 2018 Oct-Dec;40(4):360-368. doi: 10.1590/2237-6089-2017-0155. PMID: 30570106.
33. Meeusen R, De Meirleir K. Exercise and brain neurotransmission. Sports Med. 1995 Sep;20(3):160-88. doi: 10.2165/00007256-199520030-00004. PMID: 8571000.
34. Szuhany KL, Bugatti M, Otto MW. A meta-analytic review of the effects of exercise on brain-derived neurotrophic factor. J Psychiatr Res. 2015 Jan;60:56-64. doi: 10.1016/j.jpsychires.2014.10.003. Epub 2014 Oct 12. PMID: 25455510; PMCID: PMC4314337.
35. van Agtmaal MJM, Houben AJHM, Pouwer F, Stehouwer CDA, Schram MT. Association of Microvascular Dysfunction With Late-Life Depression: A Systematic Review and Meta-analysis. JAMA Psychiatry. 2017 Jul 1;74(7):729-739. doi: 10.1001/jamapsychiatry.2017.0984. PMID: 28564681; PMCID: PMC5710252.
36. Taylor WD, Aizenstein HJ, Alexopoulos GS. The vascular depression hypothesis: mechanisms linking vascular disease with depression. Mol Psychiatry. 2013 Sep;18(9):963-74. doi: 10.1038/mp.2013.20. Epub 2013 Feb 26. PMID: 23439482; PMCID: PMC3674224.
37. Gianfredi V, Blandi L, Cacitti S, Minelli M, Signorelli C, Amerio A, Odone A. Depression and Objectively Measured Physical Activity: A Systematic Review and

Meta-Analysis. Int J Environ Res Public Health. 2020 May 25;17(10):3738. doi: 10.3390/ijerph17103738. PMID: 32466242; PMCID: PMC7277615.

38. Schaeffer E, Roeben B, Granert O, Hanert A, Liepelt-Scarfone I, Leks E, Otterbein S, Saraykin P, Busch JH, Synofzik M, Stransky E, Bartsch T, Berg D. Effects of exergaming on hippocampal volume and brain-derived neurotrophic factor levels in Parkinson's disease. Eur J Neurol. 2022 Feb;29(2):441-449. doi: 10.1111/ene.15165. Epub 2021 Nov 14. PMID: 34724287.
39. Wegner M, Helmich I, Machado S, Nardi AE, Arias-Carrion O, Budde H. Effects of exercise on anxiety and depression disorders: review of meta- analyses and neurobiological mechanisms. CNS Neurol Disord Drug Targets. 2014;13(6):1002-14. doi: 10.2174/1871527313666140612102841. PMID: 24923346.
40. Berchtold NC, Kesslak JP, Cotman CW. Hippocampal brain-derived neurotrophic factor gene regulation by exercise and the medial septum. J Neurosci Res. 2002 Jun 1;68(5):511-21. doi: 10.1002/jnr.10256. PMID: 12111841.
41. Larun L, Nordheim LV, Ekeland E, Hagen KB, Heian F. Exercise in prevention and treatment of anxiety and depression among children and young people. Cochrane Database Syst Rev. 2006 Jul 19;(3):CD004691. doi: 10.1002/14651858.CD004691.pub2. PMID: 16856055.
42. Yan L, Wei JA, Yang F, Wang M, Wang S, Cheng T, Liu X, Jia Y, So KF, Zhang L. Physical Exercise Prevented Stress-Induced Anxiety via Improving Brain RNA Methylation. Adv Sci (Weinh). 2022 Aug;9(24):e2105731. doi: 10.1002/advs.202105731. Epub 2022 Jun 1. PMID: 35642952; PMCID: PMC9404392.
43. Bull FC, Al-Ansari SS, Biddle S, Borodulin K, Buman MP, Cardon G, Carty C, Chaput JP, Chastin S, Chou R, Dempsey PC, DiPietro L, Ekelund U, Firth J, Friedenreich CM, Garcia L, Gichu M, Jago R, Katzmarzyk PT, Lambert E, Leitzmann M, Milton K, Ortega FB, Ranasinghe C, Stamatakis E, Tiedemann A, Troiano RP, van der Ploeg HP, Wari V, Willumsen JF. World Health Organization 2020 guidelines on physical activity and sedentary behaviour. Br J Sports Med. 2020 Dec;54(24):1451-1462. doi: 10.1136/bjsports-2020-102955. PMID: 33239350; PMCID: PMC7719906.
44. Guo Z, Li R, Lu S. Leisure-time physical activity and risk of depression: A dose-response meta-analysis of prospective cohort studies. Medicine (Baltimore). 2022

Jul 29;101(30):e29917. doi: 10.1097/MD.0000000000029917. PMID: 35905243; PMCID: PMC9333473.

45. Noetel M, Sanders T, Gallardo-Gómez D, Taylor P, Del Pozo Cruz B, van den Hoek D, Smith JJ, Mahoney J, Spathis J, Moresi M, Pagano R, Pagano L, Vasconcellos R, Arnott H, Varley B, Parker P, Biddle S, Lonsdale C. Effect of exercise for depression: systematic review and network meta-analysis of randomised controlled trials. BMJ. 2024 Feb 14;384:e075847. doi: 10.1136/bmj-2023-075847. Erratum in: BMJ. 2024 May 28;385:q1024. doi: 10.1136/bmj.q1024. PMID: 38355154; PMCID: PMC10870815.
46. Pearce M, Garcia L, Abbas A, Strain T, Schuch FB, Golubic R, Kelly P, Khan S, Utukuri M, Laird Y, Mok A, Smith A, Tainio M, Brage S, Woodcock J. Association Between Physical Activity and Risk of Depression: A Systematic Review and Meta-analysis. JAMA Psychiatry. 2022 Jun 1;79(6):550-559. doi: 10.1001/jamapsychiatry.2022.0609. PMID: 35416941; PMCID: PMC9008579.
47. Mitten D, Overholt JR, Haynes FI, D'Amore CC, Ady JC. Hiking: A Low-Cost, Accessible Intervention to Promote Health Benefits. Am J Lifestyle Med. 2016 Jul 9;12(4):302-310. doi: 10.1177/1559827616658229. PMID: 32063815; PMCID: PMC6993091.
48. Neunhäuserer D, Sturm J, Baumgartlinger MM, Niederseer D, Ledl-Kurkowski E, Steidle E, Plöderl M, Fartacek C, Kralovec K, Fartacek R, Niebauer J. Hiking in suicidal patients: neutral effects on markers of suicidality. Am J Med. 2013 Oct;126(10):927-30. doi: 10.1016/j.amjmed.2013.05.008. Epub 2013 Aug 13. PMID: 23953873.
49. Li Z, Liu S, Wang L, Smith L. Mind-Body Exercise for Anxiety and Depression in COPD Patients: A Systematic Review and Meta-Analysis. Int J Environ Res Public Health. 2019 Dec 18;17(1):22. doi: 10.3390/ijerph17010022. PMID: 31861418; PMCID: PMC6981896.
50. Hjorth P, Sikjær MG, Løkke A, Jørgensen AM, Jørgensen N, Kaasgaard DM, Rasmussen MRV. Cold water swimming as an add-on treatment for depression: a feasibility study. Nord J Psychiatry. 2023 Oct;77(7):706-711. doi: 10.1080/08039488.2023.2228290. Epub 2023 Jun 28. PMID: 37381680.
51. van Tulleken C, Tipton M, Massey H, Harper CM. Open water swimming as a treatment for major depressive disorder. BMJ Case Rep. 2018 Aug

21;2018:bcr2018225007. doi: 10.1136/bcr-2018-225007. PMID: 30131418; PMCID: PMC6112379.

52. Kruisdijk FR, Hendriksen IJ, Tak EC, Beekman AT, Hopman-Rock M. Effect of running therapy on depression (EFFORT-D). Design of a randomised controlled trial in adult patients [ISRCTN 1894]. BMC Public Health. 2012 Jan 19;12:50. doi: 10.1186/1471-2458-12-50. PMID: 22260713; PMCID: PMC3299590.
53. Chen C, Du S, Shao Q, Fu X, Jin L, Zhou S, Li Y. The effects of aerobic exercise for depression: An umbrella review of systematic reviews and meta-analyses. J Bodyw Mov Ther. 2024 Oct;40:2161-2172. doi: 10.1016/j.jbmt.2024.10.068. Epub 2024 Oct 28. PMID: 39593579.
54. Verhoeven JE, Han LKM, Lever-van Milligen BA, Hu MX, Révész D, Hoogendoorn AW, Batelaan NM, van Schaik DJF, van Balkom AJLM, van Oppen P, Penninx BWJH. Antidepressants or running therapy: Comparing effects on mental and physical health in patients with depression and anxiety disorders. J Affect Disord. 2023 May 15;329:19-29. doi: 10.1016/j.jad.2023.02.064. Epub 2023 Feb 23. PMID: 36828150.
55. Khodadad Kashi S, Mirzazadeh ZS, Saatchian V. A Systematic Review and Meta-Analysis of Resistance Training on Quality of Life, Depression, Muscle Strength, and Functional Exercise Capacity in Older Adults Aged 60 Years or More. Biol Res Nurs. 2023 Jan;25(1):88-106. doi: 10.1177/10998004221120945. Epub 2022 Aug 13. PMID: 35968662.
56. Marinelli R, Parker AG, Levinger I, Bourke M, Patten R, Woessner MN. Resistance training and combined resistance and aerobic training as a treatment of depression and anxiety symptoms in young people: A systematic review and meta-analysis. Early Interv Psychiatry. 2024 Aug;18(8):585-598. doi: 10.1111/eip.13528. Epub 2024 May 6. PMID: 38710640.
57. Augustin N, Bendau A, Heuer S, Kaminski J, Ströhle A. Resistance Training in Depression. Dtsch Arztebl Int. 2023 Nov 10;120(45):757-762. doi: 10.3238/arztebl.m2023.0196. PMID: 37656468; PMCID: PMC10745562.
58. Recchia F, Leung CK, Chin EC, Fong DY, Montero D, Cheng CP, Yau SY, Siu PM. Comparative effectiveness of exercise, antidepressants and their combination in treating non-severe depression: a systematic review and network meta-analysis of randomised controlled trials. Br J Sports Med. 2022 Dec;56(23):1375-1380. doi:

10.1136/bjsports-2022-105964. Epub 2022 Sep 16. PMID: 36113975; PMCID: PMC9685718.

59. White RL, Babic MJ, Parker PD, Lubans DR, Astell-Burt T, Lonsdale C. Domain-Specific Physical Activity and Mental Health: A Meta-analysis. Am J Prev Med. 2017 May;52(5):653-666. doi: 10.1016/j.amepre.2016.12.008. Epub 2017 Jan 30. PMID: 28153647.

60. Quirk H, Hock E, Harrop D, Crank H, Peckham E, Traviss-Turner G, Machaczek K, Stubbs B, Horspool M, Weich S, Copeland R. Understanding the experience of initiating community-based group physical activity by people with serious mental illness: A systematic review using a meta-ethnographic approach. Eur Psychiatry. 2020 Oct 22;63(1):e95. doi: 10.1192/j.eurpsy.2020.93. PMID: 33087211; PMCID: PMC7681136.