



A Physical Exercise In Schizophrenia

Tanjung Ayu Sumekar^{1,2,3*}, Hang Gunawan Asikin¹

¹Department of Psychiatry, Faculty of Medicine, Universitas Diponegoro, Semarang, Indonesia

²Department of Physiology, Faculty of Medicine, Universitas Diponegoro, Semarang, Indonesia

³Department of Psychiatry, Diponegoro National Hospital, Universitas Diponegoro, Semarang, Indonesia



Keywords:

Cognitive function
Mental health
Physical exercise
Psychosocial rehabilitation
Schizophrenia

ABSTRACT

Background: Schizophrenia is a mental disorder characterized by positive and negative symptoms, with antipsychotics effectively addressing the former but less so the latter. Recent studies suggest that physical exercise may help alleviate negative and cognitive symptoms, though its role is not well established.

Objective: This review examines the role of physical exercise as a complementary intervention in the psychosocial rehabilitation of individuals with schizophrenia.

Methods: A narrative literature review was conducted, focusing on research exploring the effects of various exercise types on psychiatric symptoms, cognitive function, and physical health in individuals with schizophrenia.

Results: Physical exercise was found to improve cognitive function, reduce negative symptoms, and mitigate the metabolic side effects of antipsychotic medications. Neurobiological changes, such as increased neurogenesis and synaptic plasticity, were also observed, contributing to better mental health and quality of life. Aerobic and anaerobic exercises were particularly effective in reducing psychiatric symptoms and enhancing social integration.

Conclusion: Physical exercise offers significant benefits in schizophrenia care and should be integrated into multidisciplinary treatment strategies. Future research should focus on optimizing exercise protocols and assessing their long-term clinical impact.

*) Correspondence to:
tanjung.sumekar@fk.undip.ac.id

Article history:

Received 10-01-2025
Accepted 29-05-2025
Available online 30-07 2025

DIMJ, 2025, 6(1), 28-35 DOI: <https://doi.org/10.14710/dimj.v6i1.25701>

1. Introduction

Schizophrenia is a prevalent mental disorder affecting approximately 1% of the global population, resulting in around 16.8 million cases of disability worldwide.¹ It is associated with low recovery rates and increased mortality compared to the general population. The pathophysiology of schizophrenia is often attributed to dopaminergic dysregulation, characterized by heightened activity in the mesolimbic pathway and reduced signaling in the mesocortical pathway.²

Effective management of schizophrenia requires a multimodal approach, including psychopharmacological therapy, psychotherapy, and psychosocial rehabilitation. Antipsychotics are the cornerstone of treatment, primarily addressing positive symptoms but often falling short in alleviating negative and cognitive symptoms.³ Consequently, many individuals experience persistent symptoms and relapses, emphasizing the need for comprehensive interventions that incorporate psychosocial rehabilitation to enhance medication adherence and quality of life.

Psychosocial rehabilitation helps individuals with mental illness regain optimal functioning in their communities through programs such as social skills training, vocational training, and occupational therapy,

including physical exercise.⁴ Notably, 70-75% of individuals with schizophrenia are physically inactive, increasing their risk for chronic medical conditions like metabolic and cardiovascular diseases.⁵ Furthermore, low physical activity levels correlate with more severe negative symptoms and poor functional outcomes.^{6,7}

Evidence suggests that physical exercise can alleviate depressive symptoms and may counteract the metabolic side effects of antipsychotics, promoting both physical and mental well-being.⁸ Although the potential of physical exercise as a complementary therapy for schizophrenia remains underexplored, studies indicate significant improvements in various symptoms.^{9,10} This review examines the role of physical exercise within psychosocial rehabilitation, providing insights into its impact on the comprehensive management of individuals with schizophrenia.

Physical Exercise

Physical activity refers to any bodily movement produced by the contraction of skeletal muscles that increases energy expenditure, while physical exercise is a planned, structured, and repetitive activity aimed at improving or maintaining physical fitness. Physical fitness refers to the body's functional state and its ability to endure physical exertion.¹¹ Engaging in regular physical exercise offers numerous benefits, including weight management,

enhanced bone density, increased muscle strength, improved joint mobility, and a strengthened immune system. Additionally, individuals who engage in moderate to high levels of physical activity have lower mortality rates compared to inactive individuals.¹⁰ The biological effects of physical exercise include changes in cardiovascular, respiratory, metabolic, musculoskeletal, molecular, and immunological functions, alongside brain structure and function modifications. Key cardiovascular improvements include increased aerobic capacity (VO₂), lactate threshold, and muscle work efficiency. Exercise also influences metabolic parameters such as glucose levels, cholesterol, and body mass index (BMI). Clinical studies suggest that physical exercise enhances the production of neurotransmitters, including serotonin, endorphins, and dopamine, promotes neuroplasticity, and fosters the growth of brain structures such as the hippocampus.¹²

Schizophrenia

Schizophrenia is a complex mental disorder characterized by both positive and negative symptoms that significantly impair social and occupational functioning. Positive symptoms include delusions, hallucinations, and disorganized behavior, while negative symptoms involve apathy and social withdrawal. With a lifetime prevalence of 0.30% to 0.66%, schizophrenia ranks as the fifth leading cause of disability.^{2,3} The disorder is often associated with disturbances in brain development and persistent disability, possibly linked to impaired neural plasticity.²

Individuals with schizophrenia typically have a shorter life expectancy due to poor physical health. Approximately 70-75% of patients are classified as physically inactive, contributing to an increased prevalence of respiratory dysfunction, cardiovascular diseases, and diabetes, with cardiovascular mortality rates nearly double those of the general population.^{2,12} This poor physical health is exacerbated by the side effects of antipsychotic medications, inactivity, smoking, and limited access to healthcare.² Despite the benefits of antipsychotic therapy, individuals with schizophrenia face challenges in restoring their physical health. Second-generation antipsychotics, commonly prescribed for their lower risk of extrapyramidal side effects, are associated with metabolic disturbances.³

The Impact of Physical Exercise on Schizophrenia

Several studies have highlighted the positive impacts of physical exercise on both physical and mental health.¹³ Physical exercise is a method to counteract metabolic disorders caused by the side effects of antipsychotic medication in individuals with schizophrenia. It has also been recognized as an effective strategy to enhance brain health. Exercise-induced cellular and structural changes in the brain, including increased neurogenesis, synaptogenesis, dendritic remodeling, and synaptic

plasticity, are believed to play a significant biological role. Additionally, physical exercise is recommended as an adjunct therapy for depression and anxiety, as increased physical activity is linked to elevated serotonin synthesis, reducing the risk of depression.^{14,15}

Recent research indicates that lifestyle, particularly regular physical activity, has neurobiological effects on neurogenesis, the neuroimmune system, and the HPA axis. Individuals with schizophrenia tend to exercise less frequently than the general population.¹⁶ Previous studies suggest that structured exercise programs yield beneficial effects on both physical and mental health parameters, with regular physical activity being a recommended supplementary intervention for individuals with schizophrenia.^{17,18}

While the exact brain adaptation mechanisms related to physical exercise remain unclear, several accepted explanations for the psychological changes induced by exercise have been identified. These include biochemical changes, such as increased levels of neurotransmitters like serotonin, endorphins, and dopamine. Neuroanatomical changes, including an increase in hippocampal volume, have also been observed. Additionally, physiological improvements, such as enhanced cardiovascular function and better neuromuscular communication, contribute to these changes. Furthermore, exercise is associated with psychological benefits like enhanced social support, a greater sense of autonomy, improved perceived competence, and a positive body image.

Physical exercise alters neurotransmitter release and reduces the serotonergic stress response in healthy individuals. Increased epinephrine levels are also observed during physical activity. Changes in serotonin circuits through exercise can help prevent the dysregulation of serotonin reuptake in patients with depression. One study explained that stress affects the balance of neurotransmitters like serotonin, dopamine, and norepinephrine, and such abnormalities can be mitigated by activating brain-derived neurotrophic factor (BDNF) during physical exercise. The release of serotonin in the anterior and ventromedial hypothalamic nuclei induces feelings of pleasure, improves mood, creates a sense of satisfaction, increases energy levels, and boosts red blood cell production.

Physical exercise is now widely recognized as an effective intervention to maintain or even improve brain health, particularly in cognitive functions among the elderly. Clinical studies have shown that increased physical activity reduces the risk of neurodegenerative diseases such as Alzheimer's and Parkinson's.¹⁹

The hippocampus, a brain region involved in learning and memory, demonstrates the most significant effects of exercise on brain structure. Animal studies reveal that exercise enhances hippocampal structure and functional plasticity by promoting adult neurogenesis in the

hippocampal dentate gyrus, increasing dendritic complexity, spine density, and synaptic plasticity.^{8,20}

Research shows that hippocampal neurogenesis contributes to cognitive function improvement. Van Praag et al. demonstrated that wheel running in mice not only boosted hippocampal neurogenesis but also improved performance in the Morris water maze and selectively enhanced long-term potentiation (LTP). This early research indicates that physical activity enhances both hippocampal neurogenesis and synaptic plasticity, facilitating learning and memory.²¹ Exercise over three months has been associated with increased blood volume in the dentate gyrus, as seen through functional magnetic resonance imaging (fMRI), and improved cognitive function. Physical exercise also increases cerebral blood flow, blood-brain barrier permeability, and angiogenesis. The correlation between angiogenesis, neurogenesis, and cognitive improvements following exercise suggests that these benefits are due to enhanced hippocampal angiogenesis and neurogenesis.⁸

Individuals with schizophrenia often show reduced hippocampal volume, which correlates with neuronal atrophy and decreased neuropil. However, whether hippocampal volume remains constant or progressively shrinks is unclear. Some studies suggest that antipsychotic therapy does not restore reduced hippocampal volume in schizophrenia.^{2,8} Nonetheless, certain research indicates that treatment is associated with hippocampal volume increases, which correlate with symptom improvement, implying that hippocampal plasticity persists in schizophrenia.^{8,17}

Figure 1 shows exercise's beneficial effects on cognitive function suggest it may prevent cognitive decline in neurodegenerative diseases.¹⁹ Physical activity is known to counteract age-related declines in hippocampal cell proliferation, neurogenesis, LTP, and neurotrophin levels.²²

In recent years, physical exercise has emerged as an affordable, accessible, and effective strategy for healthy aging, showing potential as a preventative therapy for cognitive decline related to neurodegenerative diseases. A meta-analysis revealed that one to twelve months of exercise in healthy adults improved memory function, processing speed, and attention.²³ Therefore, regular exercise may reduce the risk of dementia and preserve cognition in later life, highlighting its role in preventing cognitive decline. An observational study showed that regular physical exercise lowers the risk of Alzheimer's and other forms of dementia compared to non-exercisers. Physical activity benefits cognitive function, particularly in tasks involving the prefrontal cortex and hippocampus. Animal studies have shown that exercise enhances structural plasticity (e.g., neurogenesis and dendritic remodeling) and functional plasticity (e.g., synaptic plasticity) in the hippocampus.¹⁴

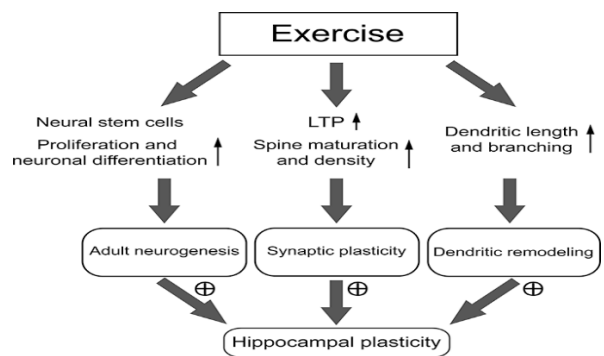


Figure 1. Potential mechanisms mediating hippocampal plasticity induced by physical exercise.²⁴

Adult neurogenesis is a key component of brain plasticity. Abnormalities in olfactory neurons and hippocampal granule cells in schizophrenia suggest that disrupted neurogenesis may contribute to impaired neuronal plasticity. While the mechanisms for modulating olfactory neurogenesis in humans remain unclear, hippocampal neurogenesis in healthy individuals can be stimulated by physical exercise.²⁰

Running distance is often used as a measure of physical fitness in animal studies, with a positive correlation between running distance and hippocampal neurogenesis. However, running distance is not the only factor influencing hippocampal neurogenesis induced by exercise. Additional variables, such as genetic background, the age of test subjects, whether running is voluntary or forced, group size, and the duration of the running program, can all affect neurogenesis. Despite variations across studies, increased neurogenesis is consistently reported in the literature.²⁴ Long-term voluntary wheel running (two to four months) in C57 mice significantly improves neuronal survival, synaptic plasticity, and performance in the Morris water maze. Other researchers have identified distinct stages where voluntary running affects cell proliferation and differentiation. In male C56B/L adult mice, short-term voluntary running leads to a peak in cell proliferation after three days, with subsequent normalization.

Synaptic plasticity refers to changes in the way neurons communicate as a result of previous experiences. Two key forms of synaptic plasticity in the hippocampus are long-term potentiation (LTP), where synaptic responses to a primary input are enhanced following a memory-forming episode, and long-term depression (LTD), where synaptic responses decrease, often associated with memory erasure. Physical exercise has been shown to influence hippocampal plasticity. In a study by van Praag et al. (1999), voluntary running in female rats led to greater LTP in the dentate gyrus after just one week of running.²⁴

In addition to promoting neurogenesis in the dentate gyrus, voluntary running can enhance dendritic complexity and spine density in hippocampal subregions, including the dentate gyrus, CA1, CA3, and the entorhinal cortex (EC).

Retroviral labeling in rats showed that running accelerates the maturation of newborn dentate gyrus neurons and promotes their functional integration into existing neural circuits. Furthermore, voluntary running increases both spine density and dendritic length of granule cells in the dentate gyrus, particularly boosting cells with higher dendritic complexity. While two months of running enhanced spine density in CA1 and layer III of the EC, structural changes in CA3 required a longer duration, with significant dendritic and spine increases observed only after four weeks of running.²⁵

Figure 2 shows that physical exercise stimulates the release of crucial neurotrophic factors, such as brain-derived neurotrophic factor (BDNF), insulin-like growth factor 1 (IGF-1), and vascular endothelial growth factor (VEGF). Recent theories suggest that physical activity induces the release of a variety of factors from skeletal muscles (e.g., neurotrophins, myokines, cytokines) and from adipose tissue (adipokines) into the bloodstream. These peripheral molecules, particularly myokines, cytokines, and adipokines, are believed to enhance brain health by promoting neurogenesis, synaptic plasticity, and dendritic remodeling, thereby improving hippocampal plasticity.^{22,24}

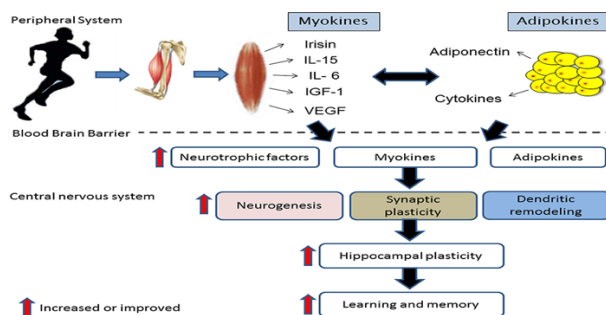


Figure 2. The effects of physical exercise on cognitive function.²⁴

Physiological Effects

Figure 3 illustrates the biological and psychological effects of physical exercise on patients with mental disorders. Physical exercise significantly enhances cardiovascular and metabolic function in patients with mental disorders. Previous studies have shown that physical activity interventions lead to reduced serum glucose, cholesterol, and cortisol levels, along with increased HDL levels and insulin production. Additionally, these interventions have been associated with reductions in metabolic syndrome and body weight, which is especially critical for schizophrenia patients, given the weight gain and metabolic syndrome linked to antipsychotic therapy.¹² Research has indicated that fat mass and obesity contribute to chronic inflammation, a known risk factor for psychiatric disorders.²⁶ Inactivity can lead to visceral fat accumulation, a source of systemic inflammation; however, regular

physical exercise can counteract this effect by exerting anti-inflammatory benefits. Contracting skeletal muscles produce myokines, which have endocrine effects on visceral fat. Furthermore, yoga has been shown to lower sympathetic nervous system activity, reduce blood pressure, and decrease stress hormones like cortisol. A study by Abdel-Baki et al. found significant reductions in waist circumference and resting heart rate, along with increased maximal oxygen consumption (VO₂ max), in schizophrenia patients participating in aerobic interval training.²⁷

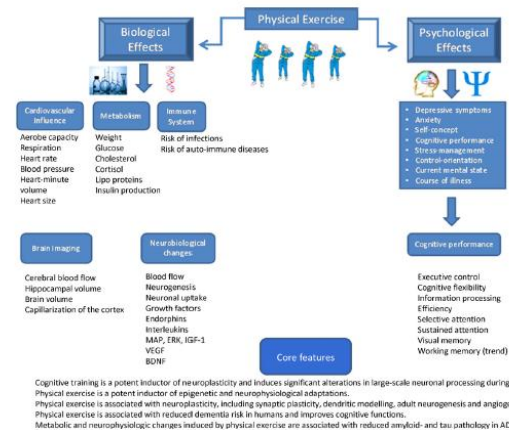


Figure 3. The biological and psychological effects of physical exercise.¹⁰

Types of Physical Exercise in Schizophrenia

Physical exercise can be categorized into three main types based on their physiological effects: aerobic, anaerobic, and flexibility exercises. Aerobic exercise involves activities that engage large muscle groups and increase oxygen consumption, such as swimming, brisk walking, cycling, and jogging. These exercises are effective when performed for 20 to 45 minutes at a pace that allows for conversation.

In contrast, anaerobic exercise consists of high-intensity activities, like weightlifting and sprinting, that lead to lactate production due to insufficient oxygen delivery to the muscles, typically sustained for shorter durations. Flexibility exercises aim to enhance the range of motion in joints, reducing the risk of injury, with common forms including yoga and Tai Chi.

To achieve optimal benefits, aerobic exercises should be performed regularly—3 to 5 days a week for at least 20 minutes at moderate intensity, defined as 60%–80% of the maximum heart rate. Research indicates that non-competitive aerobic exercises, such as jogging, swimming, and cycling, are particularly beneficial for individuals with schizophrenia. Low-impact aerobic activities, characterized by gentle movements, can help maintain brain function, enhance neurotransmitter metabolism, and elevate serotonin levels while also reducing hallucinations.⁹

Various studies, including those by Kang et al. and Behere et al., highlight the efficacy of Tai Chi and yoga programs in alleviating symptoms and improving quality of life in schizophrenia patients.^{19,22,28} In addition, both aerobic and strength training exercises have been shown to reduce psychiatric symptoms, anxiety, and psychological distress.²⁹

Various studies have explored the impact of physical exercise interventions on schizophrenia, highlighting the diverse benefits across different types of exercises. Table 1 summarizes key findings from these studies, illustrating the effects of various physical activities, such as aerobic exercise, strength training, yoga, and Progressive Muscle Relaxation (PMR), on psychiatric symptoms, cognitive function, and quality of life in individuals with schizophrenia.

Community-based exercise programs have demonstrated significant improvements in aerobic capacity, muscle strength, and mental health following 12 weeks of supervised sessions.³⁰ Behere et al. conducted a study involving 91 schizophrenia patients on antipsychotic therapy, providing a supervised yoga program for one month, followed by two months of home practice. The yoga, a calisthenic style with light intensity, significantly improved both positive and negative symptoms, as well as quality of life. The study also noted improvements in Facial Emotion Recognition Deficit (FERD), a component of social cognition that affects interpersonal communication and social interaction, often linked to poor overall functioning in schizophrenia.²⁹

Furthermore, Progressive Muscle Relaxation (PMR), which involves cycles of muscle tension and relaxation, has proven effective in reducing anxiety and psychological distress.

Table 1. Physical exercise interventions on Schizophrenia

Study	Participants	Experimental vs Control Intervention	Duration	Frequency and Intensity	Outcomes
Vancampfort et al. ³¹	52 inpatients with schizophrenia, mean age 35.6 years	PMR control (reading condition) vs	25 minutes	Single session	Reduction in anxiety and psychological distress post-PMR but not after control condition
Vancampfort et al. ³²	40 inpatients with schizophrenia or schizoaffective disorder, mean age 32.77 years	Aerobic exercise vs yoga vs control (rest)	30 minutes and 20 minutes cycling	Single session, self-selected aerobic exercise	Reduction in anxiety and psychological distress after yoga and aerobic exercise, but not after control condition
Pajonk et al. ³¹	16 outpatients with	Aerobic exercise	3 months	30 minutes, 3 times per week, heart	Improvement in short-term memory;

	schizophrenia	(cycling) vs table football		rate at lactate levels 1.5-2 mmol/L	hippocampal volume and maximal oxygen consumption per kg increased post-exercise; short-term memory and maximal oxygen consumption correlate with hippocampal volume
Behere et al.	66 outpatients with schizophrenia	Aerobic exercise and muscle strengthening vs yoga vs control	3 months	60-minute sessions in 1-4 weeks under supervision, followed by 3 months unsupervised	Significant reduction in positive and negative symptom scores at 2 and 4 months post-yoga; reductions post-aerobic exercise and muscle strengthening were not significant
Marzolini et al. ³⁰	13 inpatient and outpatients with schizophrenia or schizoaffective disorder, mean age 44.6 years	Aerobic exercise with muscle strengthening vs usual care	12 weeks	60 minutes, 2 times per week	Higher 6-minute walk scores and muscle strength vs control
Chen et al. ³³	14 inpatients with schizophrenia, mean age 40 years	PMR vs usual care	11 days	40 minutes per day	Anxiety decreased after 11 days and one week thereafter
Duraisswamy et al. ³⁴	41 inpatients and outpatients with schizophrenia, ages 18-55 years	Aerobic exercise and muscle strengthening vs yoga	16 weeks	60 minutes, 5 times per week for 1-3 weeks under supervision, followed by 3 months unsupervised	Positive and negative symptoms decreased; aerobic exercise and muscle strengthening significantly improved physical and psychological quality of life after yoga
Beebe et al.	10 outpatients with schizophrenia, ages 40-63 years	Aerobic exercise (treadmill walking)	16 weeks	25-50 minutes, 3 times per week until week 3, 10 minutes warm-up, 5-30 minutes moderate-intensity walking, and 10 minutes cool-down	Decrease in body fat percentage vs 6MWT scores
Ball et al.	11 outpatients with	Walking mile	1 week	5-10 minutes, 3 times per week	Body weight decreased compared to

	schizophrenia treated with olanzapine (minimum 6 months) who gained at least 7% body weight					control, but BMI did not differ significantly; no differences in HDRS, BPRS, and SANS between baseline and week 10.
Hawkins et al.	40 inpatients with schizophrenia, mean age 35 years	PMR vs light relaxation vs thermal feedback vs PMR + thermal feedback	2 weeks	40 minutes, 5 times per week		Reduction in anxiety
Pharr and Coursey	30 inpatients with schizophrenia, mean age unspecified	PMR vs EMG biofeedback vs listening to recordings	20 minutes	7 individual sessions		No significant changes in tension-anxiety scores
Acil et al. ³⁵	15 patients with mental disorders, 15 controls	Aerobic exercise	10 weeks	3 times per week, 40 minutes per session, first 2 weeks (25 minutes/day) - 10 minutes warm-up - 25 minutes aerobic exercise - 5 minutes cool-down		Decrease in PANSS (positive and negative symptoms), reduction in BSI, improvement in QOL
Yuli et al. ⁹	15 patients with schizophrenia, 17 controls	Low-impact aerobic exercise	2 weeks	times per week, 0 minutes/session		Decrease in scores, hallucination
Kang et al. ³⁶	244 patients with schizophrenia	Tai Chi aerobic exercise	12 months	2 times per week, 30-60 minutes/session		Decrease in PANSS scores

The Denmark National Board of Health emphasizes the importance of integrating physical activity into psychiatric care for enhanced patient outcomes. Successful implementation requires management support, education for ward staff, and a collaborative approach that engages patients in physical activities, supported by tailored activity plans and resources designed for psychiatric settings.

2. Conclusion

This review highlights the benefits of physical exercise for individuals with schizophrenia, emphasizing its positive impact on mental health. Although guidelines for optimal exercise dosage are limited, moderate-intensity physical activity for 30 minutes on several days a week is

recommended. Individuals are encouraged to seek guidance from healthcare providers regarding their exercise routines. Physicians play a crucial role in promoting physical activity by educating patients about its mental, physical, and social benefits. A multidisciplinary approach is necessary, as both psychiatrists and general practitioners must consider the specific needs of their patients, including potential negative symptoms and barriers to engagement. Policymakers should facilitate this by implementing multidisciplinary strategies in healthcare facilities, ensuring patients receive comprehensive care to address comorbidities and healthcare needs. Research in this area should adhere to established standards, focusing on the management of physical exercise regarding duration, frequency, and intensity. Future studies should clearly document patient demographics, adherence to exercise programs, and relevant schizophrenia outcomes, including symptomatology and broader clinical effects like healthcare utilization and relapse rates.

Ethical Approval

There is no ethical approval.

Conflicts of Interest

The authors declare no conflict of interest.

Funding

No specific funding was provided for this review.

Author Contributions

The authors contributions to this review are as follows: conceptualization, collecting literature, writing draft, review and editing: Tanjung Ayu Sumekar; Supervision: Hang Gunawan Asikin.

Acknowledgments

This work was supported by Department of Psychiatry, Faculty of Medicine, Diponegoro University.

References

1. Timmermans H. Grand Challenges in Global Mental Health. *Nature*. 2011 Jul;475:27–30. <https://doi.org/10.1371/journal.pmed.10001434>
2. Woo TUW. Neurobiology of schizophrenia onset. *Curr Top Behav Neurosci*. 2014;16:267–95. https://doi.org/10.1007/7854_2013_243
3. Howes OD, Kambeitz J, Kim E, Stahl D, Slifstein M, Abi-Dargham A, et al. The nature of dopamine dysfunction in schizophrenia and what this means for treatment: Meta-analysis of imaging studies. *Arch Gen Psychiatry*. 2012 Aug;69(8):776–86. <https://doi.org/10.1001/archgenpsychiatry.2012.169>
4. World Association for Psychosocial Rehabilitation. Psychosocial Rehabilitation: A Consensus Statement.

- In Geneva: World Association for Psychosocial Rehabilitation; 1996.
5. Lindamer LA, McKibbin C, Norman GJ, Jordan L, Harrison K, Abeyesinhe S, et al. Assessment of physical activity in middle-aged and older adults with schizophrenia. *Schizophr Res.* 2008 Sep;104(1–3):294–301. <https://doi.org/10.1016/j.schres.2008.04.040>
 6. Vancampfort D, Knapen J, Probst M, Scheewe T, Remans S, De Hert M. A systematic review of correlates of physical activity in patients with schizophrenia. Vol. 125, *Acta Psychiatrica Scandinavica*. 2012. p. 352–62. <https://doi.org/10.1111/j.1600-0447.2011.01814.x>
 7. Vancampfort D, Probst M, Scheewe T, Knapen J, De Herdt A, De Hert M. The functional exercise capacity is correlated with global functioning in patients with schizophrenia. *Acta Psychiatr Scand.* 2012 May;125(5):382–7. <https://doi.org/10.1111/j.1600-0447.2011.01825.x>
 8. Pajonk FG, Wobrock T, Gruber ; Oliver, Scherk H, Berner D, Kaizl I, et al. Hippocampal Plasticity in Response to Exercise in Schizophrenia. *Arch Gen Psychiatry.* 2010;67(2):133–43. <https://doi.org/10.1001/archgenpsychiatry.2009.193>
 9. R Dwi Safra Yuli, Jumaini, Yesi Hasneli. Efektifitas Senam Aerobic Low Impact terhadap Penurunan Skor Halusinasi. *JOM.* 2015 Oct;2(2):97–110.
 10. Dauwan M, Begemann MJH, Heringa SM, Sommer IE. Exercise improves clinical symptoms, quality of life, global functioning, and depression in schizophrenia: A systematic review and meta-analysis. *Schizophr Bull.* 2016 May 1;42(3):588–99. <https://doi.org/10.1093/schbul/sbv164>
 11. Linda S. Pescatello, Ross Arena, Deborah Riebe, Paul D. Thompson. *ACSM's Guidelines for Exercise Testing and Prescription*. 9th ed. Philadelphia, PA: Victory Belt Publishing Inc.; 2014. 400 p.
 12. Stubbs B, Chen LJ, Chung MS, Ku PW. Physical activity ameliorates the association between sedentary behavior and cardiometabolic risk among inpatients with schizophrenia: A comparison versus controls using accelerometry. *Compr Psychiatry.* 2017 Apr 1;74:144–50. <https://doi.org/10.1016/j.comppsy.2017.01.010>
 13. Scheewe TW, Backx FJG, Takken T, Jörg F, van Strater ACP, Kroes AG, et al. Exercise therapy improves mental and physical health in schizophrenia: A randomised controlled trial. *Acta Psychiatr Scand.* 2013 Jun;127(6):464–73. <https://doi.org/10.1111/acps.12029>
 14. Kim TW, Ji ES, Kim TW, Lee SW, Lee CY, Lee SJ. Postnatal treadmill exercise attenuates prenatal stress-induced apoptosis through enhancing serotonin expression in aged-offspring rats. *J Exerc Rehabil.* 2015 Feb 28;11(1):12–9. <https://doi.org/10.12965/jer.150180>
 15. Oertel-Knöchel V, Mehler P, Thiel C, Steinbrecher K, Malchow B, Tesky V, et al. Effects of aerobic exercise on cognitive performance and individual psychopathology in depressive and schizophrenia patients. *Eur Arch Psychiatry Clin Neurosci.* 2014 Oct 1;264(7):589–604. <https://doi.org/10.1007/s00406-014-0485-9>
 16. Vancampfort D, Probst M, Scheewe T, De Herdt A, Sweers K, Knapen J, et al. Relationships between physical fitness, physical activity, smoking and metabolic and mental health parameters in people with schizophrenia. *Psychiatry Res.* 2013 May 15;207(1–2):25–32. <https://doi.org/10.1016/j.psychres.2012.09.026>
 17. Gorczynski P, Faulkner G. Exercise therapy for schizophrenia. *Cochrane Database of Systematic Reviews.* 2010 May 12. <https://doi.org/10.1002/14651858.CD004412.pub2>
 18. Vancampfort D, Probst M, Helvik Skjaerven L, Catalán-Matamoros D, Lundvik-Gyllensten A, Gómez-Conesa A, et al. Systematic Review of the Benefits of Physical Therapy Within a Multidisciplinary Care Approach for People With Schizophrenia [Internet]. 2012. Available from: <https://academic.oup.com/ptj/article/92/1/11/2735106>
 19. Falkai P, Malchow B, Schmitt A. Aerobic exercise and its effects on cognition in schizophrenia. Vol. 30, *Current Opinion in Psychiatry*. Lippincott Williams and Wilkins; 2017. p. 171–5. <https://doi.org/10.1097/YCO.0000000000000326>
 20. Vancampfort D, Probst M, De Hert M, Soundy A, Stubbs B, Stroobants M, et al. Neurobiological effects of physical exercise in schizophrenia: A systematic review. Vol. 36, *Disability and Rehabilitation. Informa Healthcare*; 2014. p. 1749–54. <https://doi.org/10.3109/09638288.2013.874505>
 21. van Praag H. Exercise and the brain: something to chew on. Vol. 32, *Trends in Neurosciences*. 2009. p. 283–90. <https://doi.org/10.1016/j.tins.2008.12.007>
 22. Kimhy D, Vakhrusheva J, Bartels MN, Armstrong HF, Ballon JS, Khan S, et al. The impact of aerobic exercise on brain-derived neurotrophic factor and neurocognition in individuals with schizophrenia: A single-blind, randomized clinical trial. *Schizophr Bull.* 2015 Jul 1;41(4):859–68. <https://doi.org/10.1093/schbul/sbv022>
 23. Rosenbaum S, Tiedemann A, Sherrington C, Curtis J, Ward PB. Physical activity interventions for people with mental illness: A systematic review and meta-analysis. *J Sci Med Sport.* 2014 Dec;18:e150. <https://doi.org/10.4088/JCP.13r08765>

24. Yau SY, Li A, Sun X, Fontaine CJ, Christie BR, So KF. Potential Biomarkers for Physical Exercise-Induced Brain Health. In: *Role of Biomarkers in Medicine*. InTech; 2016. <https://doi.org/10.5772/62458>
25. May A, Hajak G, Gänßbauer S, Steffens T, Langguth B, Kleinjung T, et al. Structural brain alterations following 5 days of intervention: Dynamic aspects of neuroplasticity. *Cerebral Cortex*. 2007 Jan;17(1):205–10. <https://doi.org/10.1093/cercor/bhj138>.
26. Holmen TL, Egeland J, Andersen E, Mordal J, Andreassen OA, Ueland T, et al. The Association Between Cardiorespiratory Fitness and Cognition Appears Neither Related to Current Physical Activity Nor Mediated by Brain-Derived Neurotrophic Factor in a Sample of Outpatients With Schizophrenia. *Front Psychiatry*. 2019 Oct 25;10. <https://doi.org/10.3389/fpsyt.2019.00785>
27. Abdel-Baki A, Brazzini-Poisson V, Marois F, Letendre É, Karelis AD. Effects of aerobic interval training on metabolic complications and cardiorespiratory fitness in young adults with psychotic disorders: A pilot study. *Schizophr Res*. 2013 Sep;149(1–3):112–5. <https://doi.org/10.1016/j.schres.2013.06.040>.
28. Kang R, Wu Y, Li Z, Jiang J, Gao Q, Yu Y, et al. Effect of community-based social skills training and tai-chi exercise on outcomes in patients with chronic schizophrenia: A randomized, one-year study. *Psychopathology*. 2016 Nov 1;49(5):345–55. <https://doi.org/10.1159/000448195>
29. Behere R V., Arasappa R, Jagannathan A, Varambally S, Venkatasubramanian G, Thirthalli J, et al. Effect of yoga therapy on facial emotion recognition deficits, symptoms and functioning in patients with schizophrenia. *Acta Psychiatr Scand*. 2011 Feb;123(2):147–53. <https://doi.org/10.1111/j.1600-0447.2010.01605.x>
30. Marzolini S, Jensen B, Melville P. Feasibility and effects of a group-based resistance and aerobic exercise program for individuals with severe schizophrenia: A multidisciplinary approach. *Ment Health Phys Act*. 2009 Jun;2(1):29–36. <https://doi.org/10.1016/j.mhpa.2008.11.001>
31. Vancampfort D, De Hert M, Knapen J, Maurissen K, Raepsaet J, Deckx S, et al. Effects of progressive muscle relaxation on state anxiety and subjective well-being in people with schizophrenia: A randomized controlled trial. *Clin Rehabil*. 2011 Jun;25(6):567–75. <https://doi.org/10.1177/0269215510395633>
32. Vancampfort D, De Hert M, Knapen J, Wampers M, Demunter H, Deckx S, et al. State anxiety, psychological stress and positive well-being responses to yoga and aerobic exercise in people with schizophrenia: A pilot study. *Disabil Rehabil*. 2011;33(8):684–9. <https://doi.org/10.3109/09638288.2010.509458>
33. Chen WC, Chu H, Lu RB, Chou YH, Chen CH, Chang YC, et al. Efficacy of progressive muscle relaxation training in reducing anxiety in patients with acute schizophrenia. *J Clin Nurs*. 2009 Aug;18(15):2187–96. <https://doi.org/10.1111/j.1365-2702.2008.02773.x>
34. Duraiswamy G, Thirthalli J, Nagendra HR, Gangadhar BN. Yoga therapy as an add-on treatment in the management of patients with schizophrenia - A randomized controlled trial. *Acta Psychiatr Scand*. 2007 Sep;116(3):226–32. <https://doi.org/10.1111/j.1600-0447.2007.01032.x>.
35. Dogan O, Hastanesi CU, Abd P. The effects of physical exercises to mental state and quality of life in patients with schizophrenia. Vol. 15, *Journal of Psychiatric and Mental Health Nursing*. 2008. <https://doi.org/10.1111/j.1365-2850.2008.01317>
36. Bogart LM, Cowgill BO, Elliott MN, Klein DJ, Hawes-Dawson J, Uyeda K, et al. A Randomized Controlled Trial of Students for Nutrition and Exercise: A Community-based Participatory Research Study. *Journal of Adolescent Health*. 2014;55(3):415–22. <https://doi.org/10.1016/j.jadohealth.2014.03.003>.