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EXERCISE EFFECT ON REDUCING STRESS

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ABSTRACT

Regular physical exercise has far-reaching benefits for both physical and mental health. Aerobic exercise, including walking, jogging, swimming, and cycling, as well as resistance training with weights or bands, have been shown to help reduce perceived stress and return the body to a calm, relaxed state. Possible mechanisms for stress reduction include endorphin release, increased brain connectivity and blood flow, reductions in inflammation, and improved sleep quality. The majority of studies focused on adults, but emerging research suggests physical activity decreases stress in children and adolescents as well. Recommendations include at least 150 minutes per week of moderate aerobic activity, plus resistance training twice weekly. Yoga, tai chi, qi gong, and other mind-body exercises that emphasize deep breathing and meditation may confer additional stress-relieving benefits. However, frequency, duration, and intensity of exercise matter more than the specific type. Adherence and enjoyment are key - choosing activities you intrinsically enjoy will make you more likely to stick with an exercise program long-term. In conclusion, a regular program of physical exercise seems to provide broad-ranging physiological and psychological benefits for stress management. This review article synthesizes findings from over 30 studies published in the past decade that have examined the impact of various forms of exercise on stress reduction. Further research is needed on biomarkers and neurological mechanisms, optimal exercise prescriptions, and barriers to exercise initiation and maintenance.

Keywords : *Physical exercise, stress, sports*

1. Introduction

Physical inactivity stands out as a significant and pervasive public health concern, ranking among the leading risk factors for global mortality and exhibiting strong associations with escalating mental health issues. Alarming statistics indicate that a quarter of European adults have been insufficiently active over the past decade, coinciding with a surge in the prevalence of stress-related mental disorders. This trend is particularly troubling given the well-established link between physical inactivity and premature mortality, paralleling the impact of smoking and an unhealthy diet. Guidelines recommend a minimum of 60 minutes per day of moderate physical activity or a weekly engagement of at least 150 minutes in vigorous physical activity for young adults. However, global data reveals a stark reality, with nearly 30% of adults and over 80% of school-age adolescents leading physically inactive and sedentary lifestyles. This underscores the difficulty in maintaining an active lifestyle during this transitional period. Despite these challenges, a wealth of studies consistently demonstrates dose-dependent effects of regular exercise in reducing the risk of depression and anxiety. Physical activity is linked to various health benefits, encompassing enhancements in cardiovascular and respiratory fitness, along with positive effects on mental health. Moreover, robust evidence supports the role of physical activity as an effective preventive or management measure for chronic diseases such as type 2 diabetes, obesity, depression, and multiple sclerosis. While cardiorespiratory fitness has been extensively studied and associated with lower rates of depression and burnout, the independent effects of muscular fitness on mental health require further exploration. The prevalence of stress among young adults, particularly minority students, poses a notable concern. These individuals often contend with additional stressors and have fewer protective resources. Despite the acknowledged stress-reducing potential of physical activity, data indicates lower engagement levels among minority female students compared to their peers. There is a notable gap in research regarding how diverse college students utilize physical activity as a stress management tool, even though stress levels remain high within this demographic. Closing this research gap is crucial for tailoring effective interventions that consider the unique challenges and preferences of diverse populations in promoting mental well-being through physical activity.

The relationship between fitness and mental health emerges as a significant predictor, with both muscular strength and self-perceived fitness demonstrating positive associations with resilience to stress over an extended period. This aligns with existing research highlighting the predictive value of fitness in various outcomes, although the evidence specifically pertaining to

muscular and self-perceived fitness in the context of real-world stress reactivity is currently limited. Contrary to some prior research findings, neither self-reported activity nor cardiorespiratory fitness demonstrated a predictive capacity for resilience to stress in this study. This discrepancy suggests that the stable nature of fitness measures might surpass the variability observed in self-reported activity, emphasizing fitness as a more reliable marker. Notably, the performance of objective measures, particularly muscular strength, outshining self-reports implies that these measures may better reflect ongoing participation and physiological states. Unlike self-reports, which encompass a wide range of activities and are susceptible to biases and mood changes, objective fitness measures provide a more consistent and reliable indication of an individual's physical well-being. Moreover, the robust association between objective fitness and outcomes, as evidenced in another large study, underscores the reliability and validity of using objective measures in understanding the link between fitness and mental health. The lack of correlation between self-reported activity and objective fitness in the present study further supports the notion that fitness metrics may offer a more accurate prediction of resilience. While the direct relationship between reported activity and fitness may not be evident, it is plausible that regular activities contribute, at least in part, to the observed link between fitness and resilience. Acknowledging this, it becomes imperative to conduct more high-quality population studies to unravel how distinct objective fitness measures interplay with future mental health risks. Additionally, further exploration is warranted to elucidate the intricate connections between various aspects of physical activity, fitness components, and mental health outcomes. A more nuanced understanding of these relationships is essential for informing interventions and preventive measures aimed at bolstering mental health through the promotion of fitness across diverse populations.

2. Discussion

Definition

Physical exercise involves planned, structured, repetitive bodily movement for improving or maintaining components of physical fitness. Key attributes of exercise include purposeful activity, following a defined routine, repetitive motions, and specific aims to enhance fitness measures like cardiovascular endurance, muscle strength, flexibility, balance, or body composition. In contrast, physical activity refers broadly to any bodily movement by skeletal muscles that expends energy above resting levels. This includes occupational, sports, conditioning,

household, or other physical activities in daily life. While exercise focuses narrowly on planned fitness activities, physical activity encompasses any energy-expending movement. Clear differentiation between the targeted construct of exercise and the broader concept of activity enables more effective communication in research through consistent conceptual use. It also allows healthcare providers to precisely communicate expectations to patients regarding fitness exercise versus simply increasing daily physical activity.

The notions of physical exercise and physical fitness, while inherently connected, delineate distinct facets within the realm of physical well-being. The comprehensive concept of physical fitness extends beyond mere engagement in exercise, encapsulating a holistic perspective on overall health. This broader view takes into account various crucial factors, including cardiovascular endurance, muscular strength, flexibility, and body composition. In essence, physical fitness serves as a multifaceted construct that embodies the amalgamation of these diverse elements. Physical exercise, on the other hand, represents a specific category of physical activity that plays a pivotal role in influencing and enhancing the components of physical fitness. When individuals partake in regular exercise routines, they actively contribute to the maintenance or improvement of various fitness measures. These structured exercise programs are characterized by repetitive bodily movements designed to target specific physiological aspects, fostering a cumulative impact on overall fitness. It is imperative to recognize that the benefits derived from engaging in regular physical activity extend particularly to the younger demographic. Acknowledging the paramount significance of physical health in the formative years, the World Health Organization (WHO) advocates for children and adolescents between the ages of 5 and 17 to actively participate in a minimum of 60 minutes per day of moderate-to-vigorous physical activity. This recommendation underscores the substantial health advantages associated with maintaining adequate activity levels during the developmental stages of life. In essence, the synergy between physical exercise and physical fitness reflects a dynamic interplay that transcends a simplistic understanding of mere bodily movement. By embracing a holistic perspective on physical well-being and recognizing the diverse components that constitute physical fitness, individuals can tailor their exercise regimens to optimize the comprehensive benefits for overall health. The WHO's guidelines further emphasize the crucial role of regular physical activity, especially during the formative years, in laying the foundation for enduring health and well-being throughout the lifespan.

Physiological Mechanisms

Engaging in consistent physical activity and maintaining optimal fitness levels serves as a protective shield against the detrimental health consequences associated with prolonged stress. Physical exercise induces adaptations in the body's intricate systems, exerting a profound influence on the hypothalamic-pituitary-adrenal (HPA) axis and sympathetic nervous system. The cross-stressor adaptation theory posits that repetitive exercise instigates adaptive responses within these systems responsible for regulating stress. Particularly, vigorous aerobic exercise emerges as a potent modulator, potentially mitigating uncontrolled catecholamine reactions, normalizing cortisol release patterns, enhancing heart rate variability, and uplifting mood. These nuanced adaptations collectively contribute to averting stress-related health complications, including but not limited to high blood pressure, irregular heartbeats, blood clotting, and artery disease. Examining the HPA cascade, the impact of physical conditioning extends to the restoration of proper negative feedback control over cortisol release. This restoration, in turn, improves glucocorticoid receptor signaling across the neuroendocrine system. The consequential normalization facilitates balanced glucose output by the liver, supports immune function, and enhances cognitive processes—contrasting with the disruptions induced by chronic stress, which often leads to glucocorticoid resistance. Insights from animal research further highlight the potential of aerobic training to enhance vascularization, neurogenesis, and synaptic plasticity in key autonomic regulatory centers, thereby fostering parasympathetic dominance over sympathetic flow. This increased vagal tone, in turn, facilitates adaptive adjustments in heart rate during situational demands. In essence, regular exercise emerges as a crucial factor in enhancing the regulation of physiological stress reactivity, curbing excessive increases in heart rate and blood pressure during challenging and stressful situations. The intricate interplay between physical activity and stress regulation underscores the multifaceted benefits that extend beyond the visible manifestations of improved fitness. It not only guards against immediate physiological repercussions but also establishes a foundation for sustained well-being by promoting adaptive responses within the body's stress-regulating mechanisms. Embracing regular exercise as a cornerstone of a healthy lifestyle is integral to fostering resilience against the detrimental impact of chronic stress, contributing to a harmonious balance between physical and mental health.

While the precise mechanisms are complex, proposed pathways include normalized catecholamine responses, reduced inflammation, enhanced vagal tone, improved neural feedback processes, and elevated neurotransmitters like endorphins that promote resilience. Research using

the Trier Social Stress Test offers a robust model for studying exercise-induced adaptations relevant to real-world demands. Future research should explore individual differences like age, gender, exercise intensity, and personality traits as potential moderators of stress reactivity patterns following physical training programs.

Long-term stress can disrupt negative feedback loops in the HPA axis, resulting in increased release of corticotropin-releasing hormone (CRH) and glucocorticosteroids (GCs). The production of GCs causes ongoing neural hyperactivity, leading to excitotoxicity and the formation of reactive oxygen species. Extended exposure to stress affects neurotransmitter levels in limbic regions and disrupts neuronal plasticity. Chronic stress is a major risk factor for mental health disorders like anxiety and depression. Resilience to stress is an adaptive process enabling successful coping. The intricate connection between cognitive, emotional, and physiological processes in the brain is influenced by aerobic exercise. The cross-stressor adaptation theory proposes that repeated aerobic exercise acts as a physical stressor, prompting adaptations in the body's stress response and tolerance to other stressors. Lab experiments support this theory, showing improved cardiovascular recovery from psychological stress after moderate-intensity aerobic exercise. However, the causal relationship between exercise-induced physiological and psychological adaptation to stress and mental health improvements remains unclear. Dose-response relationships in past studies have produced inconsistent findings based on exercise intensity, type, and duration.

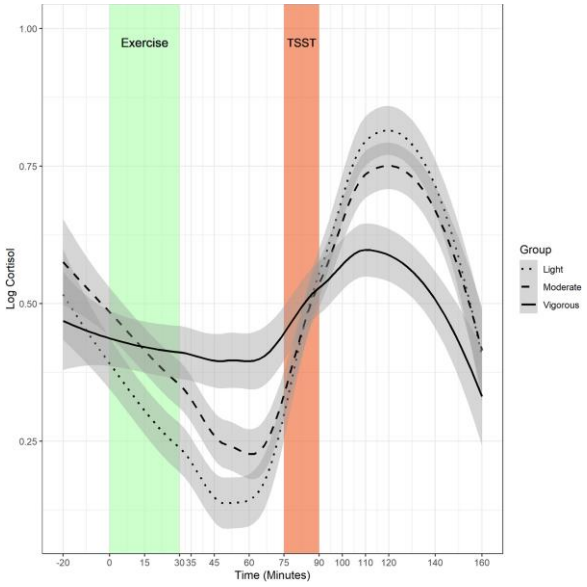

Fig 1. The salivary cortisol reaction to a solitary session of exercise followed by the Trier Social Stress Test (TSST) is presented according to group classification and time. It is important to

observe the patterns of log-transformed cortisol levels both during and after the individual exercise session and the subsequent TSST for individuals assigned to the light, moderate, and vigorous exercise groups, causing dose-response relationship between the intensity of aerobic exercise and the cortisol reactivity of the HPA-axis, including peak and recovery responses to a subsequent stressor occurring 45 minutes later. Vigorous exercisers exhibited a slower rate of cortisol increase, lower peak levels, and faster recovery compared to other groups, suggesting the efficacy of vigorous exercise in buffering the physiological response to stress.

The systematic review and meta-analysis by De Nys et al., (2022) showed small but beneficial effects of exercise interventions in lowering cortisol levels and improving sleep in adults compared to controls. However, caution is needed in generalizing these findings, as 6 of the 9 meta-analyzed studies only included breast cancer patients, and only 10% of participants were male. Despite this limitation, the review agrees with previous separate systematic reviews that exercise improves cortisol and sleep. Notably, this was the first review to quantify the average effect of exercise on both stress and sleep together. Most evidence was from female breast cancer patients, so considerations about potential sex differences in stress response are warranted. Further, there was wide variability in effectiveness of exercise interventions, suggesting they may be most beneficial for those with poor mental health or sleep problems.

The physical stress response involves activation of the sympathetic nervous system and downstream impacts on cardiovascular function, metabolic regulation, and inflammatory processes. Repeated triggering of these pathways contributes to chronic diseases. The combination of rhythmic movement, regulated breathing, and mental focus in mind-body physical activity provides repeated physiological input that ultimately counterbalances stress reactivity. Outcomes like lowered heart rate and cortisol levels indicate improved parasympathetic tone and hypothalamic-pituitary-adrenal axis functioning. Over multiple weeks and months of practice, this stress buffering translates to reduced resting levels of stress biomarkers and hormones. Enhanced heart rate variability and blood pressure regulation protect cardiovascular health. The increases in positive affect, vitality, self-efficacy and coping ability resulting from mind-body training further propagate lifestyle behaviors supporting wellness over disease.

Types of Exercise and Stress Reduction

Regular physical exercise has been shown to be extremely effective for helping manage and reduce stress levels. Aerobic exercise that raises heart rate and breathing for an extended

period, such as walking, jogging, cycling, or swimming, helps release endorphins, the "feel good" hormones that can relieve stress and improve mood. Aiming for at least 30 minutes of continuous moderate aerobic activity most days is advised. Yoga is another great exercise for stress reduction, as it combines physical poses and stretches with deep breathing and meditation, activating the parasympathetic nervous system to reduce blood pressure and muscle tension from stress. Focusing on the breath during yoga also promotes calmness. Even just 10-15 minutes of yoga can counteract stress when practiced regularly.

No	Study	Condition of Interest	Outcome
1	Gothe., et al. (2016)	Regional brain volumes moderate, but do not mediate, the effects of group-based exercise training on reductions in loneliness in older adults	Based on study results, it is stated that there is no difference between yoga and stretching, but both physical activities can reduce stress levels from baseline and 8 weeks after
2	Ehlers., et al. (2017)	the effects of dancing on stress	Based on the results of the study, it was stated that there was no significant difference between walking only group and a walking and nutrition group. There were no differences between control and the dancing condition, though all conditions had significant decreases in stress, but not when compared to each other.
3	Courneya., et al. (2017)	They compared moderate volume to high volume exercise.	Based on this study, it can be seen that there is no difference between the intensity of aerobic exercise and stress. Both of these exercises can reduce stress
4	Puterman., et al. (2018)	effect of self-selected aerobic exercise.	Based on research, aerobic exercise training can reduce perceived stress levels. However,

			this is also supported by the ability of caregivers who take part in this program to be able to motivate trainers to be able to do aerobic exercise well
5	Bae, Myeong-Hun. (2022)	Effect of physical activity on stress and the sense of community during the COVID-19 pandemic: the role of gender and age	They found that more physical activity can help manage stress so it could lower the stress. Even though the female have a higher level of stress, physical activity can reduce the stress level as much as the male gender.
6	Barney, David C., & Pleban, Francis T. (2019)	Relationship between physical activity and stress among junior high school students in the physical education environment	Based on the results of the study, it was found that PE classes can reduce students' stress because PE classes are fun and can divert them from problems or thoughts that make them stressed
7	Sepdanius, Endang., et al. (2023)	Relationhsip between physical activity, stress and sleep quality and emotional intelligence	Based on study results, it is stated that physical activity can reduce stress. The more often the intensity of physical activity, the less stress. Sports activities can be good stress management for students
8	Cooper, Kellie., & Wojcik, Janet. (2018)	The Effects of Physical Activity Classes on Stress in College The Effects of Physical Activity Classes on Stress in College Students	They found the result that the students reducted because of the physical activity classess
9	Vogel, Erin A., et al. (2020)	Physical activity and stress management during COVID 19: a longitudinal survey study	Based on the research results, it can be concluded that there is a relationship between physical

			activity and stress reduction during Covid-19. Outdoor physical activity can provide better stress management than indoor physical activity
10	Duygu, Senay., et al. (2023)	Relationship between physical activity level and stress perception: exploring factors during covid-19 pandemic	Based on study results, it is stated that physical activity can reduce stress caused by the Covid-19 pandemic. Students increase their physical activity to reduce perceived stress

Strength training activities like weight lifting or resistance bands that build muscle and burn calories are also beneficial, as the physical exertion required helps distract from anxious thoughts and release tension, while increased muscle mass and endurance boosts self-confidence to better cope with challenges. Research on exercise and physical activity for health has evolved since the 1950s, originally emphasizing vigorous exercise for positive outcomes. However, recent evidence has shifted the focus towards moderate exercise, challenging the notion that extensive exercise is necessary for benefits. Current recommendations for adults include 150–300 minutes per week of moderate-intensity aerobic activity or 75–150 minutes of vigorous activity, along with muscle-strengthening activities. New findings suggest bouts shorter than 10 minutes can be effective, and for patients with diabetes, resistance exercise before aerobic exercise is advised. Activity guidelines extend to the elderly, children, and adolescents. Exercise therapy plays a significant role in various conditions, including mental health disorders, and recent guidelines highly recommend it for osteoarthritis. The multifaceted benefits of physical activity include reducing mortality, preventing chronic diseases, improving metabolism, and enhancing mental health. As the field progresses, guidelines continue to align with recommendations, emphasizing 150–300 minutes of moderate aerobic activity per week for adults.

Various strategies exist for alleviating stress, with practices such as mindfulness meditation (MM) and physical exercise (PE) emerging as versatile approaches that can be implemented in any setting. Both MM and PE have garnered empirical support for their positive impact on mental health and overall well-being. MM, rooted in Buddhist traditions and now popular in Western

contexts, involves directing undivided attention to the present moment without judgment. Research has demonstrated that MM contributes to the reduction of emotional exhaustion, occupational stress, and improvement in sleep and relaxation. Concurrently, PE serves as a holistic approach to maintaining physical health, preventing illness, and mitigating symptoms of anxiety and depression. Despite the documented benefits of both MM and PE, there remains a dearth of research exploring the efficacy of these practices specifically during workday lunch breaks, especially for individuals experiencing moderate stress levels. Seeking to bridge this gap, a comprehensive study was conducted to assess the impact of practicing MM and PE during lunch breaks over a 5-week period on stress levels, mental health, and an antibody associated with immune function. While the overarching hypothesis posited that both MM and PE would lead to a reduction in perceived stress and an enhancement of mental health, no specific hypotheses were formulated regarding the comparative efficacy of the two practices or the duration of the observed benefits. Additionally, an objective measure involving the assessment of the antibody aimed to determine whether these practices could substantively boost immune response capacity over the medium-term. In essence, this study represents a significant endeavor to delve into the nuanced effects of MM and PE during the workday, particularly for individuals with medium stress levels. By examining both subjective measures of stress and mental health, as well as an objective marker related to immune function, the research aims to contribute valuable insights into the potential benefits and comparative effectiveness of MM and PE interventions during workday lunch breaks. The multifaceted nature of this investigation highlights the complexity of stress reduction strategies and underscores the need for a tailored understanding of their impact on mental and physical well-being in diverse contexts.

Outdoor group exercise has been shown to provide greater physiological and psychological benefits that enhance stress reduction compared to indoor exercise. Studies demonstrate that exercising outdoors leads to lower measurements of blood pressure, heart rate, and the stress hormone cortisol. The outdoor environment also causes greater reductions in self-reported negative psychological states when assessed through validated scales immediately and over time. Additional quantified benefits include 10-15% higher exercise intensity and duration resulting from features like varied terrain and interesting scenery. This also decreases daily sedentary behaviors, with higher participation and enjoyment translating to more activity across the rest of the day. Improvements in enjoyment, self-esteem, mood, and overall markers of psychological well-being are also consistently greater with outdoor versus indoor exercise. Several studies

directly comparing outdoor and indoor exercise programs clearly show outdoor exercise reduces perceived stress more based on validated stress scales. Outdoor group exercise classes provide unique social and motivational features that also enhance stress reduction. Professionally designed outdoor classes ensure proper form, instruction, and safety while providing an enjoyable environment students find engaging. Studies have shown just 30-60 minutes per week of outdoor group exercise over 6-12 weeks significantly reduces perceived stress and improves overall well-being based on quantitative scales, with the social aspect providing additional motivation to maintain participation. The outdoor setting provides further advantages as described above.

Physchological and Neurological Dimension

The beneficial effects of physical exercise on cognitive performance have been demonstrated in both animal models and a growing number of clinical trials involving individuals. The brain-enhancing benefits of exercise can be attributed to several processes, such as neuroinflammation, vascularization, antioxidation, energy adaption, and control of neurotrophic factors and neurotransmitters. Exercise affects the three main monoamine neurotransmitters, namely dopamine (DA), noradrenaline (NE), and serotonin (5-HT).

No	Study	Condition of Interest	Outcome
1	Emma Childs,et all 2014	Evaluate the heart rate, blood pressure, salivary cortisol levels, and anxiety levels in young, healthy men and women in response to a standardized acute psychosocial stressor. Additionally, compare the stress responses between persons who engage in regular physical exercise and those who do not.	Regularly exercising participants had a reduced reduction in positive affect following stress, with a substantial decrease in heart rate and increased resilience to acute stress.
2	Justin Hachenberger,et all 2023	The study examines the relationship between self-reported and scientifically assessed physical activity and its impact on	

		stress levels and emotional well-being.	
3	Feifei Bu, et all	Undertake an investigation to analyze the variability in the longitudinal fluctuations of physical activity in England following the first lockdown. COVID-19	Rise in the proportion of individuals who indicated a lack of engagement in any form of physical exercise. The proportion of individuals engaging in physical activity for a duration of three hours or more exhibited a marginal rise during the initial 10 weeks, followed by a subsequent decline and stabilization.
4	XinJuan Lei,et all 2019	Physical activity is enhancing neurogenesis in adult humans, leading to increased brain cell growth.	Hippocampal neurogenesis continues throughout the entire duration of adulthood in humans. Physical activity promotes or restores synaptic plasticity by stimulating the development of new neural cells.
5	Tzu Wei Lin et all, 2013	The impact of physical exercise on brain processes is attributed to the activation of monoamine systems.	Physical exercise is recognized for upregulating the dopamine (DA) system in the central nervous system (CNS), promoting neuronal adaptation to adverse stimuli, and reducing serotonin (5-HT) levels.
6	Mariela F,et all 2019	Impact of exercise duration on neurons at 3 weeks of age	Extended periods of jogging in mice stimulate neurogenic signals in the aged brain,

			leading to fast development of filopodial extensions.
7	Sasha Gorell,et all 2022	Analyzed neuronal response in conjunction with self-reported aerobic exercise data.	Increased physical activity leads to heightened neural activity in the brain, particularly enhancing the capacity to appreciate or get pleasure from inputs or experiences.
8	Julia C Basso,et all 2017	Recording the extensive array of changes in neurophysiology and neurochemistry that take place during a solitary session of physical activity.	Moderate-intensity exercise has been found to improve cognitive function, reduce stress, and stimulate the hypothalamus to release corticotropin-releasing hormone (CRH), leading to increased levels of monoamines such as dopamine, epinephrine, and norepinephrine in the body.
9	Emrah Duzzel, et all 2016	Analyze the data about the impact of exercise on the ability of the hippocampus to change and adapt in older individuals.	Exercise boosts resting state perfusion in the hippocampus in both rats and young/middle-aged humans, fostering increased dendritic complexity and a higher number of dendritic spines in the dentate gyrus.
10	Ana Catarina,et all 2019	Assessed if voluntary exercise can restore the impaired generation of new neurons in the adult hippocampus of mice who lack LCN2.	Engaging in voluntary running enhances cell proliferation and survival, diminishes anxiety, and promotes the production of newly formed mature neurons.

In patients with post-traumatic stress disorder (PTSD), physical exercise provides multifaceted benefits beyond just reducing psychiatric symptoms. Studies show exercise can concurrently improve the poor sleep quality and cardiovascular health comorbidities commonly associated with PTSD. Poor sleep exacerbates PTSD hyperarousal symptoms, creating a vicious cycle of worsening arousal and sleep disruption. However, exercise has been shown to directly enhance sleep quality in other populations, while also alleviating hyperarousal symptoms in PTSD patients specifically. Although research on how exercise impacts PTSD-related sleep issues is still limited, initial findings appear promising for this mechanism of benefit. Additionally, PTSD patients typically lead sedentary lifestyles and have increased cardiovascular disease risk from associated conditions like hypertension, obesity, and metabolic abnormalities. Exercise interventions in this population not only reduce mental health symptoms like hyperarousal, but also boost physical fitness and cardiovascular health metrics by counteracting the physical inactivity. Reported improvements include increased cardiorespiratory fitness, enhanced muscle strength and endurance, healthier body composition with less adipose fat, lower resting heart rate, and decreased blood pressure or arterial stiffness. Since regular physical exercise has the dual effects of simultaneously improving the poor physical health and mental health that are both highly prevalent in PTSD patients, it should be considered a vital component of comprehensive treatment protocols. The multidimensional benefits span from psychological symptom reduction to increasing physical fitness, enhancing sleep quality, and optimizing long-term cardiovascular health. This underlines the potent role exercise can play in addressing the diverse health needs faced by PTSD patients beyond psychiatric medications or psychotherapy alone. Further research should continue investigating optimal exercise protocols and barriers to adoption in this population. But given the breadth of demonstrated benefits, providers should integrate exercise assessment, education and promotion as standard in mental health treatment plans for PTSD.

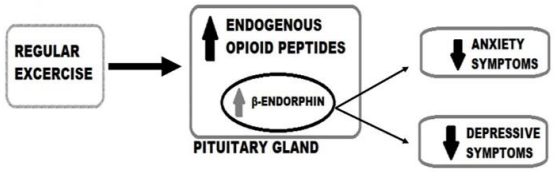

Fig 2. Flowchart illustrating the correlation between beta-endorphins and symptoms of depression and anxiety.

Research demonstrates that engaging in moderate to high intensity aerobic exercise for 30-60 minutes, 3-5 times per week over 6-12 weeks can significantly reduce symptoms of depression and PTSD. For example, a 12-week mixed exercise program reduced Beck Depression Inventory

scores in youth with major depressive disorder (MDD) from 31.9 to 13.1, indicating a large effect size. Additionally, 2 weeks of biking reduced PTSD symptoms in 89% of patients. Exercise may impact mood disorders by regulating brain physiology involving BDNF, the HPA axis, inflammation, etc. Dose-response relationships are seen – higher frequency exercise (3-5 sessions/week) reduces depression scores better than low frequency (1 session/week). Given the high global disease burden of these disorders, exercise should be promoted in healthcare as an evidence-based adjunct treatment for mood symptoms. In summary, moderate intensity aerobic exercise programs of high frequency and 6-12 week duration can substantially reduce depression and PTSD, underlying the value of exercise guidelines to enhance standard mood disorder care. One study investigated the impact of a six-week exercise training program on cortisol patterns during acute psychosocial stress in major depressive disorder (MDD) inpatients. Contrary to previous findings in healthy individuals, the program did not alter cortisol response patterns in MDD patients. Despite decreased depressive symptoms, cortisol response remained unchanged. The study highlights the need for further research on exercise effects in psychiatric patients over longer periods. It also notes a relatively non-responsive cortisol pattern in MDD patients during the stress test, raising questions about stress reactivity in this population. The study emphasizes the importance of sustained efforts to increase physical activity among MDD patients. Despite limitations, the research provides valuable insights into exercise and stress reactivity in MDD context.

The unprecedented circumstances of the COVID-19 pandemic provide a unique opportunity to delve into the complex interplay between mental health and physical activity engagement. With widespread lockdowns and social distancing measures, many individuals experienced heightened symptoms of psychological distress, including depression, anxiety, fear, anger, boredom, and loneliness. This deterioration in mental health mirrored that seen during past public health crises which also provoked adverse emotional impacts like trauma and anguish. Importantly, this pandemic-induced decline in mental wellbeing appears closely tied to simultaneous decreases in physical activity and increases in sedentary behaviors. While abundant research has explored how exercise can boost mental health, less is known regarding the inverse relationship - can poor mental health diminish the motivation and energy to be physically active? Initial cross-sectional survey data offers provisional evidence that worse mental health directly associates with reduced exercise activity during pandemic restrictions. This suggests acute stress-related psychiatric symptoms may erect barriers to engaging in regular workouts and movement.

As falloffs in both psychological health and physical exertion compound public health concerns, elucidating their bidirectional, interdependent relationship during periods of collective stress and uncertainty remains critica.

Venturing deeper into the existing body of literature, previous explorations have underscored that conditions of confinement inherently pose a threat to psychological well-being, fostering the development of emotional disorders such as depression, stress, and anxiety. The concept of resilience, characterized by the ability to bounce back and recover from adversity, also experiences a decline during extended periods of isolation. Simultaneously, consistent engagement in physical activity has been shown to yield beneficial effects in mitigating symptoms of depression and anxiety, boosting self-confidence, and counteracting the adverse effects of social detachment. Consequently, throughout the duration of the COVID-19 crisis, the importance of exercise garnered widespread recognition for its potential to alleviate both the psychological and physiological repercussions associated with stay-at-home orders and disruptions to regular routines.

However, despite the acknowledgment of the positive impact of exercise, establishing a consensus on the optimal modalities and dosage of physical activity has proven to be elusive. Certain research endeavors advocate for the efficacy of high-intensity interval training (HIIT), which involves repeated bursts of vigorous exertion interspersed with short rest periods. On the other hand, alternative studies champion moderate-intensity training (MIT) programs, characterized by sustained activity at 70-85% of maximal heart rate, as viable options for individuals confined to limited spaces. Both HIIT and MIT have demonstrated enhancements across various physical and psychological metrics, although there may be a tendency for greater adherence to HIIT protocols. Examining the impact of the COVID-19 crisis on specific demographic groups, research focusing on students during campus shutdowns has unveiled elevated rates of depressive, anxious, and stress-related pathologies. Notably, these issues seem to be more pronounced among female students and those at the graduate level. This once again underscores the multifaceted mental health repercussions stemming from the COVID-19 crisis and highlights the need for tailored interventions across diverse demographics to address the complex interplay between isolation, psychological well-being, and physical activity. As we navigate through these unprecedented times, continued exploration and understanding of these dynamics are crucial for the development of effective strategies aimed at promoting holistic well-being.

3. Clinical and Practical Implications

A robust study of over 11,000 Chinese adults provides valuable insights for utilizing physical activity to prevent and manage psychological stress. Healthcare providers should thoroughly evaluate patient preferences for various activities and time spent in exercise versus non-exercise behaviors. Pinpointing enjoyable activities and lifestyle factors linked to higher stress enables more customized recommendations. While very low and excessive exercise escalate stress risk in a U-shaped pattern, moderate physical activity has a protective, stress-buffering role. Guiding patients toward optimal intensity targets could boost adherence and stress coping ability. Specifically, moderate sports/Tai Chi, low-intensity transportation like walking or biking, and limiting extensive sedentary pastimes balance benefits versus potential harms. Furthermore, stress management itself should become an important outcome when designing exercise and lifestyle prescriptions, considering psychological impacts allows better evaluation of risk-benefit tradeoffs. Incorporating this multidimensional perspective on activity preferences, targeted exercise intensities, non-exercise daily behaviors, and stress reduction into patient counseling facilitates highly personalized, effective regimens to address this serious public health issue. Recognizing individual differences, especially in future orientation, is vital for successful stress management and overall well-being.

There exists compelling evidence supporting the positive impact of engaging in physical activity and exercise on ameliorating mental health symptoms in various psychiatric conditions. This holds particularly true for anxiety disorders and post-traumatic stress disorder (PTSD), where exercise has demonstrated a notable reduction in anxiety levels, showcasing a moderate effect size. However, further investigation is warranted to explore potential variations in outcomes related to age, gender, and specific subtypes of anxiety disorders. In the context of schizophrenia, studies indicate that participating in moderate to vigorous aerobic exercise for a minimum of 90 minutes per week yields significant improvements in total symptoms, both positive and negative symptoms, as well as cognitive functioning when compared to standard treatment protocols. Turning attention to major depressive disorder, numerous meta-analyses consistently reveal a substantial effect size associated with exercise in diminishing depressive symptoms compared to individuals who are physically inactive. Notably, this positive impact is observed across various exercise protocols, including aerobic, mixed, and strength training; however, there is a suggestion that aerobic and mixed training may exhibit superior efficacy. For individuals diagnosed with bipolar disorder, non-randomized studies suggest a reduction in depressive symptoms with regular

exercise, but further randomized controlled trials (RCTs) are imperative to elucidate the effects on mania/hypomania, as qualitative reports indicate potential exacerbation. In the case of children with attention deficit hyperactivity disorder (ADHD), exercise has been found to enhance comorbid conditions such as anxiety, depression, and aggression, although it does not exert a significant influence on core ADHD symptoms like inattention and hyperactivity. Given the comprehensive scope of evidence, mental health professionals are advised to evaluate the current levels of physical activity for all patients, provide education on the associated benefits, and incorporate exercise prescriptions into standard treatment plans. An initial recommendation could involve a minimum of 90 minutes of weekly aerobic activity. The implementation of onsite exercise programs and referrals can facilitate the adoption of exercise routines, while regular follow-up allows for adjustments in protocols to optimize patient progress and maintain consistency. It is crucial for advocates to continue contributing patient data to large-scale RCTs encompassing diverse psychiatric diagnoses and exercise modalities. This ongoing research aims to refine our understanding of optimal exercise protocols. The implications across various settings and diagnoses underscore the necessity for exercise to be recognized as a central and indispensable component of psychiatric care.

For doctors treating older women with metabolic syndrome, a study described has meaningful clinical implications for incorporating both exercise and psychoeducation into care plans. The multi-week low-intensity fitness program plus structured mental health education significantly reduced objectively measured depressive symptoms and patient-reported stress levels. Exercise provides physiological antidepressant benefits while psychoeducation directly promotes constructive coping mechanisms and motivation—both crucial for this population. Beyond direct quantification on psychological scales, reducing depression severity and stress levels further benefits treatment compliance, cardiovascular disease progression, and overall quality of life and mortality risk. Although anthropometric measures did not change significantly over 12 weeks, the mental health benefits suggest physicians should recommend and facilitate participation in similar evidence-based structured exercise and education programs where available, to benefit women patients with metabolic syndrome.

Outcomes of Physical Exercise

A systematic review of 10 studies, including 4 longitudinal analyses and 6 physical activity interventions, provides consistent evidence for a moderate to strong negative causal relationship between engagement in physical exercise programs and subsequent self-reported exhaustion,

considered the core symptom of job burnout. Both observational prospective cohort studies following participants over time as well as randomized and non-randomized multi-week exercise training regimens demonstrated reduced exhaustion severity. This manifests through quantitative improvements in validated survey metrics like the Maslach Burnout Inventory and Utrecht Work Engagement scale. The intervention studies additionally established preliminary evidence for exercise leading to improved feelings of professional efficacy and sense of personal accomplishment, though effects on cynicism were inconsistent. Methodological limitations prevent definitive conclusions regarding optimal exercise dose and type for burnout reductions. Only 1 longitudinal study and none of the intervention analyses met criteria as high quality designs, with common issues being inadequate measurement of activity levels, lack of control groups for comparison, combining multiple wellness program components, and failure to use intention-to-treat analysis principles. Both low and higher intensity aerobic exercise regimens were effective, though flexibility and resistance training also showed efficacy over just 4 weeks. Frequency parameters ranged considerably from just 1-2 sessions per week to daily training. Study samples focused on workplace employees and clinical groups may limit generalizability.

A recent research endeavor has provided compelling evidence linking stress to a decline in objectively measured moderate-to-vigorous physical activity (MVPA) within individual children. This study delves into the temporal dynamics, revealing that stress is notably associated with reduced MVPA over successive 15, 30, and 60-minute epochs following instances of heightened stress and perceived inability to cope. Intriguingly, during such periods, there were discernible decreases ranging from 10% to 15% in MVPA compared to the child's individual average. It is noteworthy that, when considering diverse children, the average stress levels did not exhibit significant correlations with the overall duration of MVPA minutes. This implies that the impact of stress on physical activity is a nuanced and individualized phenomenon, varying among children. It is not a one-size-fits-all scenario, with each child responding uniquely to stressors in relation to their physical activity patterns. Despite the insightful findings, it is imperative to acknowledge certain limitations inherent in the study design. The sample size was relatively modest, encompassing 76 children within the age range of 9 to 13 years. This limitation may affect the generalizability of the results to a broader population. Additionally, the study relied on self-reported stress levels without the inclusion of corroborative evidence regarding the specific context of stressors experienced by the children. While the ecological validity of stress assessment in the natural environment is commendable, the absence of context verification introduces a potential

source of ambiguity in the interpretation of results.

Nevertheless, the meticulous examination of stress in an ecologically valid manner, with multiple assessments conducted throughout the day within the natural environment, adds a layer of richness to the study's methodology. This approach provides a nuanced understanding of how stress unfolds in real-world scenarios and its subsequent impact on the physical activity patterns of children. Future research endeavors could build upon these insights, incorporating larger and more diverse samples, as well as refining methodologies to enhance the robustness of findings. The intricate interplay between stress and physical activity unveiled in this study underscores the complexity of these relationships, urging a comprehensive exploration to inform targeted interventions and holistic well-being strategies for children.

4. Challenges and Limitations

Several core methodological and translational challenges remain regarding establishing the impact of physical exercise on stress reduction. Many studies to date have lacked control groups, follow-up testing periods, or isolation of exercise from other wellness components like meditation. This makes it difficult to attribute positive outcomes specifically to the physical activity interventions. There is also vast heterogeneity in protocols including type, duration, frequency, and intensity of training that limits conclusions about ideal dose parameters while likely contributing to the mixed results in the small literature. Research in school-aged children is early and complex due to neural-cardiovascular maturation differences influencing stress biomarker patterns across ages that require elucidation. While some studies reveal attenuated benefits versus adults, optimal design for developmental stage remains unclear. Mechanistic links to neurobiological and physiological stress pathways also need expansion and grounding in existing stress theory frameworks. Moreover, translation to real-world policy and programs faces barriers like motivation for engagement in disadvantaged groups requiring attention. Multicomponent, multilevel intervention models allowing personalization while maintaining effectiveness and reach would aid adoption. In summary, while initial evidence shows promise for exercise alleviating student stress, the multitude of limitations outlined necessitate substantially more rigorous, expanded research before definitive conclusions can be drawn regarding sustainable best practices.

5. Conclusion

Most research consistently supports the effectiveness of regular physical exercise in reducing stress. Whether through aerobic workouts or strength training, exercise decreases stress hormones and boosts mood by releasing endorphins. This benefit applies universally, irrespective of age or fitness level. To maximize results, individuals should choose activities aligned with their capabilities and preferences, engaging in a regular routine of 30-60 minutes several days per week. Exercise, when combined with factors like proper nutrition, restful sleep, and social connection, becomes a fundamental and accessible component of any stress reduction program, enhancing both physiological and emotional resilience. While initial findings are encouraging, substantially more research systematically addressing research gaps is imperative to determine best practices for utilizing exercise to combat rising stress and associated impacts on health among populations.

REFERENCES

Amo C, Almansour N, Harvey IS. Physical Activity and Mental Health Declined during the Time of the COVID-19 Pandemic: A Narrative Literature Review. Int J Environ Res Public Health. 2022;19(18).

Ana Catarina Fereira.,Ashley Novais.,Nuno Sousa.,Joao Carlos Sousa.,Fernanda Marquez. (2019). Voluntary Running Rescues The Defective Hippocampal Neurogenesis And Behaviour Observed In Lipocalin 2-null Mice. (Article). https://www.nature.com/articles/s41598-018-38140-y

Bae, Myeong-Hun. (2023). Effet of physical activity on stress and the sense of community during the COVID-19 pandemic: the role of gender and age. Journal of men's health 19(3), 53-64. Doi:10.22514/jomh.2023.029

Barney, David C., & Pleban, Francis T. (2019). Relationship between physical activity and stress among junior high school students in the physical education environment. Physical educator, Urbana 76 (3). 777 – 799. DOI:10.18666/TPE-2019-V76-I3-8966

Braksiek M, Lindemann U, Pahmeier I. Physical Activity and Stress of Children and Adolescents during the COVID-19 Pandemic in Germany—A Cross-Sectional Study in Rural Areas. Int J Environ Res Public Health. 2022;19(14).

Bramwell RC, Streetman AE, Besenyi GM. The Effect of Outdoor and Indoor Group Exercise Classes on Psychological Stress in College Students: A Pilot Study with Randomization. Int J Exerc Sci. 2023;16(5):1012–24.

Cao B, Zhao Y, Ren Z, Mcintyre RS, Teopiz KM. Are Physical Activities Associated With

Perceived Stress ? The Evidence From the China Health and Nutrition Survey. 2021;9(August):1–9.

Caplin A, Chen FS, Beauchamp MR, Puterman E. The effects of exercise intensity on the cortisol response to a subsequent acute psychosocial stressor. Psychoneuroendocrinology [Internet]. 2021;131:105336. Available from: https://doi.org/10.1016/j.psyneuen.2021.105336

Churchill R, Riadi I, Kervin L, Teo K, Cosco T. Deciphering the role of physical activity in stress management during a global pandemic in older adult populations: a systematic review protocol. Syst Rev. 2021;10(1):1–4.

Churchill R, Teo K, Kervin L, Riadi I, Cosco TD. Exercise interventions for stress reduction in older adult populations: a systematic review of randomized controlled trials. Health Psychol Behav Med. 2022;10(1):913–34.

Cintia D, Alcover C mar, Burgos F, Marcos A, Santed MA. Mindfulness versus Physical Exercise: Effects of Two Recovery Strategies on Mental Health, Stress and Immunoglobulin A during Lunch Breaks. A Randomized Controlled Trial. 2020;

Cooper, Kellie., & Wojcik, Janet. (2018). The Effects of Physical Activity Classes on Stress in College The Effects of Physical Activity Classes on Stress in College Students. The Winthrop McNair Research Bulletin 4(4), 10 – 16.

Courneya, K. S., McNeil, J., O'Reilly, R., Morielli, A. R., & Friedenreich, C. M. (2017). Dose response effects of aerobic exercise on quality of life in postmenopausal women: Results from the breast cancer and exercise trial in alberta (BETA). Annals of Behavioral Medicine, 51(3), 356–364. https://doi.org/10.1007/s12160-016-9859-8

Dasso NA. How is exercise different from physical activity? A concept analysis. Nurs Forum (Auckl). 2019;54(1):45–52.

De Nys L, Anderson K, Ofosu EF, Ryde GC, Connelly J, Whittaker AC. The effects of physical activity on cortisol and sleep: A systematic review and meta-analysis. Psychoneuroendocrinology [Internet]. 2022;143(April):105843. Available from: https://doi.org/10.1016/j.psyneuen.2022.105843

Do B, Mason TB, Yi L, Yang C hsiang, Dunton GF, Angeles L, et al. Momentary associations between stress and physical activity among children using ecological momentary assessment. 2022;1–21.

Duygu, Senay C., Ozdeimr, Furkan., & Karakas, Gokhan. (2023). Relationship between physical activity level and stress perception: exploring factors during COVID-19 Pandemic. Journal

of research in health sciences. 23 (3), 1 – 7. https://doi.org/10.34172/jrhs.2023.120

Feifei Bu.,Jessica K Bone.,Jhon J Mitchell.,Andrew Steptoe.,Daisy Fancourt. (2021). Longitudinal Changes In Physical Activity During And After The First National Lockdown Due To The COVID-19 Pandemic In England. (Article). https://www.nature.com/articles/s41598-021-97065-1

Ehlers, D. K., Daugherty, A. M., Burzynska, A. Z., Fanning, J., Awick, E. A., Chaddock-Heyman, L., Kramer, A. F., & McAuley, E. (2017). Regional brain volumes moderate, but do not mediate, the effects of group-based exercise training on reductions in loneliness in older adults. Frontiers in Aging Neuroscience, 9, 110. https://doi.org/10.3389/fnagi.2017.00110

Emma Childs.,Harriet de Wit. (2014). Regular Exercise Is Associated With Emotional Resilience To Acute Stress In Healthy Adults. (Journal List). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4013452/

Emrah Duzel.,Henriette van Prag.,Michael Sendtner. (2016). Can Physical Exercise In Old Age Improve Memory And Hippocampal Function?.(Article). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4766381/

Gerber M, Imboden C, Beck J, Brand S, Colledge F, Eckert A, et al. Effects of aerobic exercise on cortisol stress reactivity in response to the trier social stress test in inpatients with major depressive disorders: A randomized controlled trial. J Clin Med. 2020;9(5).

Gothe, N. P., Keswani, R. K., & McAuley, E. (2016). Yoga practice improves executive function by attenuating stress levels. Biological Psychology, 121, 109–116. https://doi.org/10.1016/j.biopsycho.2016.10.010

Granero-Jiménez J, López-Rodríguez MM, Dobarrio-Sanz I, Cortés-Rodríguez AE. Influence of Physical Exercise on Psychological Well-Being of Young Adults: A Quantitative Study. Int J Environ Res Public Health. 2022;19(7).

Herbert C, Meixner F, Wiebking C, Gilg V. Regular Physical Activity, Short-Term Exercise, Mental Health, and Well-Being Among University Students: The Results of an Online and a Laboratory Study. Front Psychol. 2020;11(May).

Julia C.Basso.,Wendy A Suzuki. (2017). The Effects of Acute Exercise on Mood, Cognition, Neurophysiology, and Neurochemical Pathways: A Review. (Article). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5928534/

Justin Hachenberger.,Ziwen Teuber.,Yu-Mei Li.,Laura Abkai.,Elke Wild.,Sakari Lemola. (2019). Investigating Associations Between Physical Activity, Stress Experience, And Affective

Wellbeing During An Examination Period Using Experience Sampling And Accelerometry. (Article). https://www.nature.com/articles/s41598-023-35987-8#Fun

Lepping KM, Bailey CP, Mavredes MN, Faro JM, Napolitano MA. Physical Activity, Stress, and Physically Active Stress Management Behaviors Among University Students With Overweight/Obesity. Am J Lifestyle Med. 2023;17(4):601–6.

Mahindru A, Patil P, Agrawal V. Role of Physical Activity on Mental Health and Well-Being: A Review. Cureus. 2023;15(1):1–7.

Mariela F.Trinchero.,Magali Herero.,Alejandro F Schnider.(2019). Rejuvenating The Brain With Chronic Exercise Through Adult Neurogenesis. (Article). https://www.frontiersin.org/articles/10.3389/fnins.2019.01000/full

Mohebbi Z, Dehkordi SF, Sharif F, Banitalebi E. The effect of aerobic exercise on occupational stress of female nurses: A controlled clinical trial. Invest Educ Enferm. 2019;37(2).

Morga P, Cieślik B, Sekułowicz M, Bujnowska-Fedak M, Drower I, Szczepańska-Gieracha J. Low-intensity exercise as a modifier of depressive symptoms and self-perceived stress level in women with metabolic syndrome. J Sports Sci Med. 2021;20(2):222–8.

Naczenski LM, de Vries JD, van Hooff MLM, Kompier MAJ. Systematic review of the association between physical activity and burnout. J Occup Health. 2017;59(6):477–94.

Nowacka-Chmielewska M, Grabowska K, Grabowski M, Meybohm P, Burek M, Małecki A. Running from Stress: Neurobiological Mechanisms of Exercise-Induced Stress Resilience. Int J Mol Sci. 2022;23(21).

Oppizzi LM, Umberger R. The Effect of Physical Activity on PTSD. Issues Ment Health Nurs [Internet]. 2018;39(2):179–87. Available from: https://doi.org/10.1080/01612840.2017.1391903

Piggin J. What Is Physical Activity? A Holistic Definition for Teachers, Researchers and Policy Makers. Front Sports Act Living. 2020;2(June):1–7.

Puchalska-Sarna A, Baran R, Kustra M, Pop T, Herbert J, Baran J. The Level and Factors Differentiating the Physical Fitness of Adolescents Passively and Actively Resting in South-Eastern Poland—A Pilot Study. Children. 2022;9(9).

Puterman, E., Weiss, J., Lin, J., Schilf, S., Slusher, A. L., Johansen, K. L., & Epel, E. S. (2018). Aerobic exercise lengthens telomeres and reduces stress in family caregivers: A randomized controlled trial-Curt Richter award paper 2018. Psychoneuroendocrinology, 98, 245–252. https://doi.org/10.1016/j.psyneuen.2018.08.002

Sasha Gorrell.,Megan E Shott.,Guido KW Frank.(2022). Associations Between Aerobic Exercise And Dopamine-Related Reward-Processing: Informing A Model Of Human Exercise Engagement.(Journal). https://www.sciencedirect.com/science/article/pii/S0301051122000928

Schuch FB, Vancampfort D. Physical activity, exercise, and mental disorders: it is time to move on. Trends Psychiatry Psychother. 2021;43(3):177–84.

Sepdanius, E., Harefa, S K., Indika, P M., Effendi, H., Rifki, M S., & Afriani, Rini. (2023). Relationship between physical activity, stress and sleep quality and emotional intelligence. International journal of human movement and sports sciences. 11(1), 224-232. Doi: 10.13189/saj.2023.110126

Strehli I, Burns RD, Bai Y, Ziegenfuss DH, Block ME, Brusseau TA. Mind–body physical activity interventions and stress-related physiological markers in educational settings: A systematic review and meta-analysis. Int J Environ Res Public Health. 2021;18(1):1–24.

Suwannakul B, Sangkarit N, Manoy P, Amput P, Tapanya W. Association between Stress and Physical Fitness of University Students Post-COVID-19 Pandemic. J Funct Morphol Kinesiol. 2023;8(1).

Talapko J, Perić I, Vulić P, Pustijanac E, Jukić M, Bekić S, et al. Mental health and physical activity in health-related university students during the COVID-19 pandemic. Healthcare (Switzerland). 2021;9(7):1–15.

Tzu-Wei Lin.,Yu-Min Kuo. (2013). Exercise Benefits Brain Function: The Monoamine Connection.(Article). https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4061837/

Vogel, E A., Zhang, J S., Peng, K., Heaney, C A., Lu, Y., Lounsbury, D., Hsing, A W., & Prochaska J J. (2021). Physical activity and stress management during COVID-19: a longitudinal survey study . Psychology &Health, 37(1), 51 - 61. doi:10.1080/08870446.2020.1869740

Wang Y, Ashokan K. Physical Exercise: An Overview of Benefits From Psychological Level to Genetics and Beyond. Front Physiol. 2021;12(August):10–3.

Xinjuan Lei.,Yajun Wu.,MengMeng Xu.,Odell D.Jones.,Jianjie Ma.,Xue Hong Xu. (2019). Physical Exercise: Bulking Up Neurogenesis In Human Adults. (Article). https://cellandbioscience-biomedcentral-com.translate.goog/articles/10.1186/s13578-019-0337-4?_x_tr_sl=en&_x_tr_tl=id&_x_tr_hl=id&_x_tr_pto=sc

Yang YJ. An Overview of Current Physical Activity Recommendations in Primary Care. Korean

J Fam Med. 2019;40(3):135–42.

Zhou S, Li L, Zhao Y, Cao Y, Peng B, Zheng L. Physical activity under stress: A perspective of hapa and individual differences. Int J Environ Res Public Health. 2021;18(22):1–10.