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The Beneficial Effects of Aerobic Exercise on Human Systems and Organs: A Literature Review

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ABSTRACT:

Introduction: Engaging in regular aerobic exercise can have a tremendous impact on one's physical and mental well-being. Despite the known benefits, a significant number of adults worldwide continue to lead sedentary lifestyles. Aerobic exercise, in particular, has been shown to improve lipid profiles, reducing the risk of cardiovascular diseases and mortality rates. Additionally, it promotes healthy metabolism, hormonal balance, and mental well-being, all of which contribute to overall health and quality of life. This is especially crucial for cancer patients undergoing treatment.

Aim of the Study: The primary objective of this study is to conduct a comprehensive analysis of the physiological and psychological benefits of aerobic exercise on the human body.

Description of the State of Knowledge: Moderate and regular aerobic exercise has been shown to have a beneficial effect on both physical and mental health. The importance of improving physical performance, overall body fitness, endurance, strength, balance, and mobility cannot be overstated, as it has a proven therapeutic and preventive effect against various diseases.

Materials and methods: An unsystematic scientific literature review was conducted using specific keywords such as earobic exercise, lipid profile, cardiovascular system, cardiovascular disease, diabetes. The review was carried out on PubMed, analyzing a total of 70 sources published until 2023.

Conclusions: Exercise has beneficial effects on all organ systems and is a non-pharmacological form of treatment for cardiovascular, musculoskeletal, metabolic and nervous system diseases. They have the benefits of reducing stress, lowering blood pressure, stimulating osteogenesis, and having a beneficial effect on body shape and self-perception. Exercise can be considered an effective treatment for established diseases or the alleviation of their symptoms.

KEY WORDS: aerobic exercise, lipid profile, cardiovascular system, cardiovascular disease, diabetes

INTRODUCTION

Moderate and regular aerobic exercise has a beneficial effect on physical and mental health. Currently, it is estimated that ¼ of the adult population around the world is insufficiently physically active and leads a sedentary lifestyle. Improving physical performance, overall body fitness, endurance, strength, balance and mobility have a positive effect on health and have a proven therapeutic and preventive effect on various diseases [1].

Aerobic exercise improves the lipid profile, which is associated with a reduced risk of occurrence and progression of cardiovascular diseases. It has been proven that moderate physical activity improves the treatment outcomes of patients suffering from various CVD diseases, and also has a positive effect on life expectancy and reduces mortality [2]. Aerobic exercise has a positive effect on the body's metabolism, insulin sensitivity, resting heart rate, blood pressure, vascular perfusion, cardiac output, as well as the lipid metabolism of orgasm by increasing the level of HDL cholesterol [3]. Low or no physical activity is associated with a significant risk of cardiovascular diseases, which are currently the leading cause of death in many countries. Aerobic exercise also affects a person's hormonal balance depending on age and health status [4].

Apart from the somatic aspects, physical exercises have proven beneficial effects on the human psyche. It has been proven that people who do not exercise have a higher rate of illness and spend more on health care [5]. Studies have shown that regular exercise significantly affects the perception of one's own body and self-awareness. In this article, we will also discuss the links between aerobic exercise and depression and anxiety, as well as its impact on sleep and overall quality of life [5].

Aerobic exercise also correlates with the well-being of cancer patients. In addition to the physical effects of cancer, patients often experience side effects of radio- and chemotherapy treatment, and are more likely to suffer from depression and have reduced quality of life and sleep [6]. Physical exercise has an important impact on the well-being of oncology patients, it improves overall well-being, and also affects the quality of treatment, the severity of side effects and the patients' fitness [7]. The type and intensity of exercises depend strictly on the patient's clinical and mental condition. There is also a proven relationship between physical activity and a reduced risk of cancer [8].

Aerobic exercises are an important part of many rehabilitation programs for various groups of patients. Staff and patient education has a beneficial, long-term impact on many aspects of medicine.

IMPACT ON CARDIOVASCULAR SYSTEM

Regular aerobic training exerts a profound influence on both structural and functional aspects of cardiovascular system, leading to a cascade of beneficial adaptations. The gold standard measure for aerobic capacity is peak oxygen consumption (VO2), which can be assessed using graded exercise ergometry or treadmill protocols with an oxygen consumption analyzer, or through mathematical formulas. The significance of peak VO2 was illustrated in a study by Vaitkevicius et al. [39], where VO2max, among other parameters, was calculated. Their findings concluded that a higher level of physical conditioning was directly associated with decreased arterial stiffness.

Aerobic training primarily influences cardiac function, potentially through the modulation of certain mediators. For instance, it may enhance cardiac vagal tone post-exercise through factors like nitric oxide, promoting parasympathetic activity. Conversely, substances like angiotensin II might inhibit cardiac vagal function. Overall, aerobic exercise seems to drive adaptations in the autonomic nervous system, favoring a shift towards parasympathetic dominance [17, 18].

Heart rate variability refers to the rhythmic fluctuations in the time intervals between successive myocardial contractions, also known as systoles [26]. Heart rate (HR) is mediated by the direct activity of the autonomic nervous system (ANS), specifically through the sympathetic and parasympathetic branches activities over the sinus node automaticity, with superiority of the vagal activity (parasympathetic) at rest, that is inhibited since the beginning of the workout [9]. Studies suggest that well-trained or physically well-fit (aerobically) individuals present a lower resting-HR although these studies did not consider the extent of aerobic performance and the vagal function of sportsmen before training [10-14]; also there is an important genetic impact on heart rate HR fluctuations. Exercise-connected bradycardia can also be a result of internal sinus node adaptation [15]. A lower resting-HR can also be an outcome of other factors such as the increase of venous return and systolic volume. The increase of systolic volume leads to increased heart contractility and lower heart rate to keep constant resting cardiac output [16]. Despite employing varied methodologies and durations of effective training ranging from six weeks to 12 months, the findings remained consistent. They consistently demonstrated an increase in vagal activity or a reduction in resting sympathetic activity resulting from exercise programs, both contributing to hemodynamic improvements [30, 31]. Observations indicated that individuals exhibiting superior cardiac vagal tone showed more favorable responses to aerobic training, experiencing greater increases in maximum oxygen uptake and additional reductions in resting heart rate [32].

In the first seconds of the aerobic training, HR increases due to inhibition of vagal activity, which not only increases atria contractility, but also conduction velocity of the ventricle depolarization wave from AV node. After this initial stage, as one goes on exercising, HR increases again, due to adrenergic overstimulation on sinus node, or due to increase of serum norepinephrine, or atrial mechanics distention and therefore, sinus node distention due to a higher venous return, and the increase in body's temperature and blood's acidity [27]. Aerobic training-induced enhancement in maximal oxygen uptake can mitigate the age-related decline in baroreflex sensitivity [28, 29]. Another crucial aspect highlighted in recent literature is the examination of heart rate recovery (HRR) following both maximal and submaximal exercise bouts. The way heart rate behaves during the immediate recovery period after exercise serves as an additional marker for assessing the integrity of the vagus nerve [9]. Towards the conclusion of exercise, particular emphasis should be placed on observing heart rate (HR) patterns. If the decrease in HR is less than 12 beats per minute (bpm) during active recovery or 18 bpm during passive recovery in the supine position within the first minute after completing a maximal exercise test, it signifies an adverse prognosis for the relative risk of cardiovascular mortality in both asymptomatic individuals and those with heart conditions. In essence, for both the initial and final phases of recovery, a smaller variation in HR indicates a higher relative risk [9, 19, 20]. The duration required for heart rate (HR) to return to resting levels is influenced by the interplay of autonomic functions, individual fitness levels [21], and the intensity of the exercise. Recovery duration may span one hour following light or moderate exercise [22], extend to four hours after prolonged aerobic activity [23], and potentially persist for up to 24 hours following intense or maximal exertion [24]. Even five minutes after a moderate to intense exercise session, serum norepinephrine levels remain elevated compared to resting levels, indicating continued heightened sympathetic activity during this period. The reduction in post-exercise norepinephrine concentration coincides with the decrease in heart rate (HR), suggesting a correlated response. However, there are indications that during the initial stages of recovery, vagal modulation primarily drives the decline in HR [25].

Growing evidence suggests that blood pressure variability (BPV), which refers to fluctuations in blood pressure over time, serves as a robust and independent indicator of cardiovascular risk. Routine aerobic exercise lowers blood pressure and is advocated in current hypertension guidelines as a fundamental lifestyle adjustment. Pagonas et al. observed that the exercise regimen led to a significant reduction in both systolic and diastolic daytime ambulatory blood pressure by 6.2±10.2 mm Hg (P<0.01) and 3.0±6.3 mm Hg (P=0.04), respectively. Additionally, it decreased blood pressure during physical exertion and enhanced physical performance (P<0.05 for both). However, the exercise did not influence the variability of daytime (10.2±2.7 vs. 9.8±2.6%, P=0.30) and night-time systolic (8.9±3.2 vs. 10.5±4.1%, P=0.10) and diastolic ambulatory blood pressure (daytime 11.5±3.3 vs. 11.5±3.1%, night-time 12.0±4.3 vs. 13.8±5.2%; P>0.05 for all). While regular aerobic exercise proves beneficial in managing hypertension by controlling blood pressure, it does not impact the 24-hour blood pressure variability, which serves as an independent predictor of cardiovascular risk [40]. Among the primary physiological advantages of physical training for hypertensive patients are decreases in both heart rate (HR) and peripheral vascular resistance [41], which are associated with reductions in systolic and diastolic blood pressure [42]. The substantial drop in blood pressure (BP) during the recovery period following training sessions could be linked to enhancements in aerobic performance. Numerous studies have indicated that improvements in aerobic capacity and subsequent increased muscle vasodilation result in notable BP reductions post-exercise, potentially amplifying the hypotensive effects following physical activity [44].

Several recent studies have suggested a potential positive relationship between biochemical signal markers, such as endothelin-I (ET-1), and aerobic exercise. ET-1, produced by vascular endothelial cells, acts as a vasoconstrictor [43] and promotes atherosclerosis [37]. Maeda et al. observed a statistically significant positive linear correlation between increasing age and elevated levels of ET-1. Additionally, they demonstrated a noticeable decrease in ET-1 levels following a three-month aerobic exercise regimen [38]. Changes elicited by regular exercise training in the vascular system include increasing vasodilation due to an elevation of bioavailable nitric oxide [41]. Among endothelial cells, eNOS predominates as the primary enzyme responsible for producing nitric oxide (NO), which in turn governs vasodilation, resulting in reduced peripheral resistance and enhanced perfusion [43]. Moreover, vascular endothelial growth factor receptor-2 (VEGFR2) has the capability to bind with VE-cadherin, ß-catenin, and phosphatidylinositol 3 kinase, leading to the phosphorylation of Akt and subsequently inducing AKT-mediated eNOS phosphorylation, thereby elevating nitric oxide (NO) production [47]. Disruption of eNOS was detected in several pathologies including atherosclerosis, hypertension, and HF [48, 49, 50].

Epidemiological studies in large cohorts support the notion that physical fitness is associated with reduced cardiovascular mortality and hospitalization due to cardiovascular disease [41]. It has been estimated that decreasing physical inactivity by 10% or 25% could lead to approximately 500,000 or 1.3 million fewer deaths globally, respectively [42].

Drawing from epidemiological observations, it's reasonable to infer that maintaining an active lifestyle correlates with a decreased risk of developing cardiovascular disease. The health advantages linked to exercise become apparent only when physical activity is sustained across one's lifetime. Furthermore, the positive impacts of exercise training extend to secondary prevention in individuals with cardiovascular conditions, independent of age and the severity of the disease [41].

IMPACT ON METABOLIC

In recent years, a significant health issue has emerged: the metabolic risk factors syndrome, which can lead to the development of atherosclerosis, type 2 diabetes, and vascular complications. It is speculated that insulin resistance and excess fat tissue in the abdominal cavity are the main factors leading to the metabolic syndrome. Genetic predispositions are also considered possible causes. Lifestyle factors such as a high-calorie, pro-inflammatory diet and lack of physical activity also significantly influence the components of the so-called metabolic syndrome [51]. Aerobic exercise in individuals with risk factors for the metabolic syndrome or its developed consequences acts in multiple ways. Primarily, regular aerobic exercise, especially at a moderate pace for an extended period, leads to increased fat burning as the primary source of energy. This can aid in weight loss and fat tissue reduction. Physical activity also affects the regulation of adiponectin and leptin hormone levels by reducing abdominal obesity. Additionally, mechanisms have been shown whereby cellular insulin sensitivity improves. Insulin resistance, described as the inability of exogenous or endogenous insulin to uptake and utilize glucose circulating in the blood by cells, is a key mechanism. Increased cellular insulin sensitivity leads to better glucose utilization by cells and may help regulate blood sugar levels. The correlation between insulin sensitivity and insulin resistance is crucial in the development of diabetes [52]. Physical activity combined with dietary restrictions also lowers triglyceride and low-density lipoprotein (LDL) levels while increasing high-density lipoprotein (HDL) levels, thereby reducing the risk of insulin resistance-associated arterial atherosclerosis. Exercise, besides inducing quantitative changes in serum lipids, has a beneficial effect on the maturation, composition, and functionality of HDL particles [53]. Aerobic training also influences the reduction of arterial wall stiffness, although its effect may vary among obese individuals. In this group, attention should be paid to the intensity of the training. Running or brisk walking may cause an undesirable increase in blood pressure and act as an additional stressor for vascular endothelium. However, cycling may have a beneficial effect, causing less activation of the sympathetic nervous system and a smaller increase in blood pressure. Therefore, it can be hypothesized that low-intensity relief exercises may be more beneficial at the beginning of weight loss [54]. Reduction in inflammatory markers, reduction of free radicals, and increased antioxidant processes are also observed in physically active individuals, all playing a significant role in the pathogenesis of diabetes. Adipose tissue participates in TNF-alpha production, resulting in elevated levels of soluble TNF-alpha receptors, i.e., IL-6, IL-1 receptor antagonists, and C-reactive protein. During exercise, IL-6 is produced via a different pathway independent of TNF-alpha. IL-6 secreted by muscle fibers stimulates the appearance of other anti-inflammatory cytokines in circulation and participates in the feedback inhibition of pro-inflammatory TNF-alpha production. Additionally, IL-6 is involved in regulating lipid metabolism by activating lipolysis and fat oxidation mechanisms. Regular exercise contributes to TNF-alpha suppression, reducing inflammation, and also provides protection against insulin resistance [55]. Physical exertion may also affect the level of the stress hormone cortisol. During exercise, cortisol levels increase, regulating the hypothalamic-pituitary-adrenal axis. Depending on the intensity of physical activity, cortisol reactivity to psychosocial stress is mitigated, which in the long term may lead to depressive and anxiety disorders [56].

BENEFITS OF AEROBIC EXERCISE ON THE SKELETAL SYSTEM

As a result of an aging population, the incidence of osteoporosis and osteopenia is increasing. Both disease entities are associated with a decrease in bone mineral density, leading to increased fragility and thus an increased risk of fractures, most commonly in the elderly [57]. Global data show that regular exercise leads to a reduction in cardiovascular disease and diabetes, as mentioned in another paragraph. They also lead to improved weight control, skeletal function and increased bone resistance [58]. Physical training is therefore recommended as a safe and cost-free form of disease progression intervention. It provides a non-pharmacological method of maintaining musculoskeletal health [59]. The mechanism linking physical activity to the osteogenic effect is stimulation of the hypothalamic-pituitary-adrenal axis manifested by increased secretion of growth hormone (GH) and insulin-like growth factor 1 (IGF-1). These hormones can cause differentiation of osteoblasts from mesenchymal stem cells [60]. Such differentiated cells increase the synthesis of osteogenic markers responsible for bone repair: osteoprotegerin (OPG), RUNX2, alkaline phosphatase (ALP), osteocalcin (OCL) and receptor activator of nuclear factor κB ligand (RANKL) [61].

From the available data, it is known that mechanical force and load induced by exercise, increases muscle mass, causing stress in the skeleton and increasing osteoblast activity. Thus, it increases mineral density as well as bone strength, which explains why weight-bearing exercise can improve bone structure [62]. Because not all types of exercise exert an equal osteogenic effect, training that exceeds the load that occurs during daily activities is preferred [63]. It has been shown that the best osteogenic effects are achieved after moderate- to high-intensity workouts, as well as after load training. They have a beneficial effect on bone mineral density, especially of the spine and hip bones in older patients [62].

Based on the available information, aerobic and weight-bearing workouts, in combination with other interventions (e.g., pharmacological) and lifestyle changes, are a beneficial way to prevent bone disease. They lead to improvements in muscle and bone mass, and the effects have been confirmed in postmenopausal women and the adults [64, 65].

BENEFITS OF AREBOBIC EXERCISE ON MENTAL HEALTH

Aerobic exercise, a cornerstone of preventive medicine, has been increasingly recognized for its mental health benefits. Recent studies consistently demonstrate that regular aerobic exercise can ameliorate symptoms of depression, anxiety, and enhance overall mental well-being[66][67].

A systematic review by Sharma et al. (2024) found that scheduled aerobic exercises significantly improve sleep quality, depression levels, and quality of life in postmenopausal women. The study underscores the importance of regular physical activity in managing mental health issues, particularly those linked with hormonal changes[66]. Furthermore, the research conducted by Marais (2024) on South African mental health care providers suggests that aerobic exercise is frequently recommended as a therapeutic intervention, highlighting its acceptability and perceived effectiveness in clinical settings[67].

Aerobic exercise's influence on psychological health is attributed to several biological mechanisms. It enhances endorphin release, which provides a natural euphoria, often referred to as the 'runner's high.' It also improves neuroplasticity by increasing the production of brain-derived neurotrophic factor (BDNF), which supports brain health and cognitive functions[68].

Moreover, engaging in regular aerobic activity can lead to long-term reductions in stress hormones like cortisol, thus stabilizing mood and reducing anxiety[69]. Research further suggests that exercise not only helps in acute stress relief but also in developing resilience against future stressors, enhancing an individual's capacity to manage stress more effectively[70].

Additionally, aerobic exercise is linked to improved self-esteem and self-image, which are crucial aspects of mental health. Regular physical activity can significantly improve one's perception of their physical self, which correlates with higher self-esteem and better mental health outcomes. This improvement in self-perception is particularly impactful for individuals suffering from body image issues or low self-esteem[69].

Aerobic exercise represents a non-pharmacological therapy that can significantly benefit mental health. It reduces symptoms of mood disorders, improves sleep, and enhances life quality, making it a vital component of mental health management. The evidence strongly supports incorporating regular physical activity into daily routines as a means to promote mental well-being and resilience.

CONCLUSION

In our literature review, we focused on the effects of sports on the cardiovascular, nervous, and musculoskeletal systems. We showed that physical exercise is often the first non-pharmacological form of improving patients' quality of life. It has been confirmed that exercise at higher training intensities can improve the quality of mental health. They improve the quality of sleep, reduce the risk of depression, and cause a decrease in cortisol levels, influencing the alleviation and reduction of stress levels. Physical exercises allow patients to cope with stressful situations, so they become more resilient to external factors affecting their mental health. In patients with skeletal diseases, exercise has been proven to lead to increased bone strength and density. They stimulate osteogenesis and increase the synthesis of markers responsible for bone repair processes. They also have a beneficial effect on the regulation of adiponectin and leptin levels, reducing obesity. However, they have the greatest effect on the cardiovascular system, affecting the contraction of the heart muscle, showing beneficial effects in the treatment of, among other things, hypertension - thereby reducing cardiovascular risk.

In conclusion, aerobic exercise and all physical activity have multidirectional effects on health. The positive effects apply to the majority of patients choosing to support treatment with physical activity and have real health benefits and improve the quality of life of patients affected by the aforementioned diseases.

DISCLOSURE

Author's contribution

Anna Maria Koman: Conceptualization, writing rough preparation,

Katarzyna Chamera-Cyrek: Writing rough preparation, formal analysis,

Marzena Pliszka: supervision, resources

Izabela Janik: visualization, data curation

Katarzyna Gadżała: Methodology, software,

Klaudia Brygida Kułak: check

Izabela Sztybór: investigation,

Karolina Alicja Pałacz: writing and editing,

Project administration: Karolina Alicja Pałacz

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

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The authors deny any conflict of interest

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