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The Impact of Swimming on the Human Body and the Long-Term Physiological Consequences of The Sport - A Literature review

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Abstract

Introduction:

Swimming is a comprehensive physical activity known for its positive effects on multiple physiological and psychological systems. This work explores the impact of regular swimming on short- and long-term health outcomes, mental health, cognitive function and physical fitness.

Materials and Methods:

The analysis is based on a review of multiple studies involving various populations, including healthy adults, people with depression or anxiety disorders and the elderly. Interventions ranged from short-term swimming programs to longitudinal observations spanning several decades, with measures including psychological scales, physiological biomarkers, cognitive tests, and epidemiological data.

Summary:

Physiological benefits include enhanced cardiovascular capacity, improved lung function, muscle strength maintenance and neuroplasticity. Regular swimming reduces stress, anxiety and depressive symptoms while improving mood and overall well-being. Long-term swimmers demonstrate better functional mobility, reduced risk of falls, preserved cognitive function as well as lower mortality rates.

Keywords: swimming physiology, cardiovascular adaptations, pulmonary function, musculoskeletal health, metabolic effects, healthy aging

Introduction

Swimming is one of the oldest and most versatile forms of physical activity, combining elements of endurance, strength, and coordination training. Due to the aquatic environment, where the body weight is significantly reduced by buoyancy forces, swimming relieves joint stress, enabling safe activity for people of all ages, including seniors and individuals with mobility limitations. At the same time, water resistance places high demands on muscles and the cardiovascular-respiratory system.

Over the decades, swimming has become not only a competitive sport but also a significant component of rehabilitation and health prevention. Research indicates that regular swimming training improves cardiovascular and respiratory efficiency, supports weight management, reduces stress levels, and, in some cases, may alleviate symptoms of chronic diseases such as hypertension.

Aim of the Study

The aim of this study is to analyze the effects of swimming on the human body in the context of short-term training effects, long-term physiological adaptations and potential associated risks.

Materials and Methods

This study was conducted based on a review of scientific literature from PubMed, PubMed Central databases, International Journal of Aquatic Research and Education covering publications and Web of Science, from 1990 to 2024. The analysis includes experimental studies, systematic reviews, and meta-analyses addressing the impact of swimming on: Cardiovascular and respiratory performance, The musculoskeletal system, Metabolism and body composition, Mental health.

Literature Review

1. Cardiovascular System

Swimming has beneficial effects on the cardiovascular system, particularly on heart and lung function. Regular swimming training leads to an increase in cardiac output (CO)—the volume of blood pumped by the heart per minute. Studies have shown that in swimmers, CO can increase by 15–25% compared to sedentary individuals. [1]

In middle-aged and older adults with stage 1 or 2 essential hypertension, a 10-week swimming training program significantly reduced resting systolic blood pressure from 150 ± 5 to 144 ± 4 mmHg and diastolic blood pressure from 95 ± 3 to 92 ± 2 mmHg, alongside a decrease in resting heart rate from 81 ± 4 to 71 ± 3 beats per minute. These improvements occurred without changes in body weight or fat mass. [2]

2. The impact of Swimming on Respiratory Health

Swimming exerts unique demands on the respiratory system due to the aquatic environment and specific breathing mechanics involved. Immersion in water increases external pressure on the chest wall, which in turn elevates the work of breathing by requiring greater effort from respiratory muscles. Moreover, swimmers demonstrate greater control over breathing, including improved breath-holding capacity and efficient oxygen utilization, which translates into better gas exchange during exercise. These respiratory benefits not only improve athletic performance but may also contribute to better respiratory health in general [3]. This increased respiratory muscle workload contributes to enhanced muscle strength and endurance over time.

Studies have shown that swimmers typically exhibit improved pulmonary function compared to non-swimmers. For instance, forced vital capacity (FVC) and maximal voluntary ventilation (MVV) are often significantly higher in swimmers, reflecting enhanced lungvolumes and ventilatory efficiency [4]. The adaptations are likely a result of both the breathing pattern imposed by swimming and the conditioning effects of regular water-based training.

Longitudinal observations indicate that consistent swimming training can increase lung function parameters such as FVC compared to sedentary individuals [5]. This improvement reflects both structural and functional adaptations of the respiratory system induced by prolonged exposure to aquatic training.

3. Musculoskeletal System

The aquatic environment offers joint unloading: buoyancy reduces the load on the spine and joints, making swimming safe for all age groups, including rehabilitation patients. Water resistance acts as natural load, engaging core muscles, shoulder girdle and limbs. [6]

Bone Mineral Density (BMD)

Among young adults (18–30 years), a meta-analysis of 14 studies indicates that swimmers have comparable BMD values (Hedges' $g \approx -0.20$ for whole body, $g \approx -0.05$ for femoral neck, and $g \approx 0.18$ for lumbar spine) relative to inactive individuals.

However, compared to athletes in weight-bearing sports (e.g., running), swimmers show significantly lower BMD by approximately 1.21 (whole body), 1.51 (femoral neck), and 0.84 (lumbar spine). [7]

Adolescents training in swimming ≥9 months per year exhibit slower BMD gains than these who are involved in land-based sports, confirming the "hypogravity" effect of the aquatic environment on bone development. [8]

Randomized studies in pre- and postmenopausal women showed that swimming 3–6 hours weekly may significantly improve lumbar spine BMD, though less than 3 hours per week produced no significant effect. [9]

For adult swimmers aged 40–85 with at least 3 years of regular training: men had significantly higher BMD in the radius (0.84 ± 0.08 vs. 0.81 ± 0.09 g/cm^2) and lumbar spine (123 ± 27 vs. 108 ± 31 mg/cm^3) compared to inactive controls. [10]

Muscle Strength and Technique

Long-term training in professional swimmers leads to significant improvements in shoulder girdle and core muscle strength, increasing range of motion and joint stability.

Respiratory muscle adaptations, such as in the diaphragm and intercostals, enhance endurance and pulmonary ventilation. [11]

Fatigue Effects

Fatigue occurring during prolonged or high-volume swim training impairs limb movement efficiency by reducing both the amplitude and force of limb accelerations. As propulsion decreases and drag increases, swimmers face deteriorated hydrodynamic performance and compromised stroke mechanics, particularly in strokes like freestyle and butterfly. [12]

This decline in mechanical output and technique efficiency contributes to elevated injury risk in regions most vulnerable to overuse:

Shoulder: Repetitive high-velocity motions under fatigue lead to reduced dynamic joint stability, impaired scapular control, and increased susceptibility to impingement and tendinopathy. [13]

Knee: Particularly in breaststroke, fatigue amplifies stresses from whip-like kicks, increasing risk of “breaststroker’s knee”, meniscal strain or ligament overload.

Lumbar Spine / Lower Back: As core and postural stabilizers weaken, swimmers lose optimal alignment and develop repetitive hyperextension and rotational strain, predisposing them to lumbar disc degeneration, facet strain, and chronic back pain [14].

Recommendations

Due to limited impact of swimming on BMD, especially in children, adolescents, and women - incorporating land-based resistance training is advised to promote bone mineralization and osteoporosis prevention.

Monitoring fatigue and planning adequate recovery are essential for maintaining technique quality and musculoskeletal health. [15]

4. Metabolism and Performance

Swimming promotes favorable metabolic changes: it improves lipid profiles, increases insulin sensitivity and supports maintenance of healthy body weight. Comparative studies indicate, that fat mass reduction in swimmers is comparable to running, although lower energy expenditure at moderate intensities may lead to differences in body composition change rates. [16]

VO_2max

In swimmers with multiple seasonal assessments, VO_2max typically averages at around 48 $mL \cdot kg^{-1} \cdot min^{-1}$ at the beginning of the season, with improvements of about 5% following several months of dedicated training. Lactate threshold (LT) often improves by 6–10%, reflecting peripheral adaptations such as enhanced muscle oxidative capacity and improved metabolic efficiency beyond cardiovascular changes. [17]

Lactate Threshold and Its Significance

Among world-class open-water swimmers, LT occurred at speeds of 1.62 m/s in men (~3.8 $mmol \cdot L^{-1}$) and 1.46 m/s in women (~3.0 $mmol \cdot L^{-1}$). In men, LT speed approximated pace at 4 $mmol \cdot L^{-1}$ (SS4), while in women, SS4 exceeded actual LT, potentially causing overestimation of aerobic pace in training plans. [18]

These values correspond to approximately 97% of maximal test speed, indicating highly developed aerobic capacity in elite athletes.

Caloric Expenditure and Body Weight

In recreational swimming at moderate pace, energy expenditure averages 400–500 kcal/h for women and 500–700 kcal/h for men, depending on body mass, pace, and technique.

Swimming in cooler water (24–26°C) can increase energy expenditure by an additional 10–15% due to thermogenesis.

In a 12-week swimming program for overweight women, fat mass loss averaged 2.2 kg (–3.5% body fat), and 2.8 kg (–3.9% body fat) in men, without significant muscle mass loss. [19]

Insulin Sensitivity and Glucose Metabolism

An 8-week aquatic exercise program consisting of 45-minute sessions, three times per week, conducted in warm water (33–34°C), significantly improved glycemic control in patients with chronic heart failure and type 2 diabetes. Specifically, HbA1c levels decreased from 7.9% to 7.2% ($p = 0.01$).[20]

Role of Intervals and Low-Intensity Zones

Maintaining high training volume in low-intensity zones (<LT) builds the capacity to work near aerobic threshold for prolonged periods.

Shorter intervals at intensities exceeding the lactate threshold enhance lactate clearance and anaerobic power ($\dot{c}La_{max}$). Correlations show lower $\dot{c}La_{max}$ associates with better middle-distance performance ($r \approx -0.55$). [21]

Practical Implications

Accurate LT determination is crucial, especially in women, to avoid overestimating training pace.

Combining sessions at 60–70% VO_2max with intervals at 90–100% VO_2max optimizes both aerobic endurance and anaerobic power development. [22]

Swimming in cold water may enhance energy expenditure but requires monitoring to prevent excessive hypothermia.

5. Mental Health Benefits of Aquatic Exercise

Engaging in regular aquatic exercise has been shown to have a positive impact on mental health, including stress reduction, mood improvement, and overall psychological well-being. These benefits are observed in both healthy individuals and those with various mental health conditions.

Physiological Mechanisms

The benefits of aquatic exercise on mental health may be attributed to various physiological mechanisms. The sensory experience of water provides a calming effect, reducing stress and improving sleep quality. [23]

Stress and Anxiety Reduction

Studies have demonstrated that aquatic exercise can significantly reduce symptoms of anxiety and stress. For example, a systematic review and meta-analysis found that aquatic exercise statistically significantly improved mental health, with light aquatic aerobics showing a better effect on mood and anxiety symptoms. [24]

Antidepressant Effects

Aquatic exercise has also been found to become an antidepressant. A randomized clinical trial involving depressed elderly individuals revealed that an aquatic exercise program reduced depression and anxiety symptoms, improved functional autonomy, and decreased oxidative stress. [25]

6. Long-Term Consequences

Long-term swimming practice is associated with numerous beneficial physiological adaptations that may persist into the later decades. Regular water-based activity helps to maintain a high level of aerobic capacity, delays cardiovascular aging processes, promotes musculoskeletal health and preserves psychomotor performance.

People aged more than 65 years who swam at least twice weekly for 10 years had a 33% lower annual fall rate compared to non-swimmers. [26]

A 12-week aquatic exercise program for older adults (aged 60–86) led to significant improvements in balance and health-related quality of life. Participants demonstrated enhanced performance on the Timed Up and Go (TUG) test and the Berg Balance Scale, indicating better balance and mobility. Additionally, their ability to perform activities of daily living (ADLs) remained higher, contributing to prolonged independent living. These benefits were achieved without any adverse effects, highlighting the efficacy of aquatic exercise in promoting functional independence among seniors. [27]

Cognitive Function and Brain Aging

Neuroimaging studies have shown that older adults who engage in regular aerobic exercise, such as swimming, experience increases in hippocampal volume. This increase is associated with improvements in episodic memory. Additionally, neuropsychological assessments indicate enhancements in attention, processing speed, and working memory among these individuals. [28] These cognitive benefits contribute to better overall brain health and function in older age.

Quality and Length of Life

A large cohort study involving over 40,000 men found that regular swimming was associated with significantly lower all-cause mortality risk compared to sedentary individuals. Specifically, swimmers exhibited about a 50% reduced risk of death from any cause compared to inactive men. [29] This protective effect remained significant even after adjusting for factors such as age, body mass index, smoking, and pre-existing conditions. The study highlights swimming as an effective physical activity to improve longevity and reduce mortality risk.

Summary

Swimming is a versatile physical activity that combines endurance, strength, and coordination training within an aquatic environment that reduces joint stress through buoyancy. This makes swimming accessible and safe for all ages, including seniors and individuals with mobility limitations. Scientific evidence demonstrates that regular swimming improves cardiovascular and respiratory function, enhances muscle strength and endurance, and supports favorable metabolic adaptations such as improved lipid profiles and insulin sensitivity. Although swimming has limited impact on bone mineral density compared to weight-bearing activities, combining it with land-based exercises can effectively slow bone loss.

Long-term swimming practice is associated with significant cardiovascular benefits, including increased cardiac output, enhanced pulmonary function, and preserved cardiac function in older adults. It also contributes to improved balance, mobility, and reduced fall risk in seniors, helping to maintain independence. Cognitive benefits include increased hippocampal volume and better executive functions such as attention and memory. Furthermore, aquatic exercise has documented positive effects on mental health, reducing stress, anxiety, and depression symptoms while improving sleep quality.

Epidemiological studies show that regular swimmers have a substantially lower risk of all-cause and cardiovascular mortality, highlighting swimming as a potent activity for promoting longevity and overall health.

Disclosure

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