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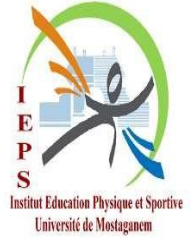
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**A DESCRIPTIVE AND ANALYTICAL STUDY ON
THE EFFECTS OF INTENSIVE PHYSICAL
TRAINING ON CARDIORESPIRATORY
INDICATORS IN YOUNG ATHLETES**

**Using a Descriptive Analytical Approach:
A Study Conducted on a Sample of Male
Athletes Aged 14 to 18 Years**

**PRESENTED BY:
HOUIDEF MOHAMED.
HIBER MOHAMED ABDEL BARI**

**FRAMED BY:
PR. SAID AISSA
KHELIFA**

University year: 2025-2024

Dedicate

HOUIDEF

"Be a scholar. If you cannot, then be a learner. If you cannot, then love the scholars. And if you cannot, then at least do not hate them. "Allah Almighty says: "And whoever is grateful, it is only for the benefit his own self. "And the Messenger of Allah (peace and blessings be upon him) said: "Whoever does not thank people, does not thank Allah. "We praise Allah Almighty who granted us success in completing this scientific research, and inspired us with health, wellness, and determination. We extend our sincere thanks and deep appreciation to Pr. SAID AISSA Khaliah for all the guidance, instructions, and valuable information the provided, which contributed to enriching the subject of my study in all its aspects.

Hiber Mohamed

First and foremost, we thank Allah, the Almighty, who continues to surround us with His care and protection. Thank You, Lord, for granting us the patience and Perseverance needed to complete this dissertation. I would like to take this opportunity To express my deep gratitude and appreciation to my late mother — may Allah Have? Mercy on her soul and grant her the highest place in Paradise. Her love and prayers Continue to guide me, even in her absence. I also dedicate this work to my dear father , may Allah reward him abundantly, and to my brothers and sisters, who have always Been a pillar of support with their unconditional love and valuable advice throughout our academic journey. We also extend our sincere thanks to Said Alissa Khelifa, our supervisor, for his kindness and generosity. It was truly a pleasure to work under your guidance. Finally, we would like to thank everyone who, directly or indirectly, contributed to the success of our academic journey and the development of this dissertation.

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Abstract:

High-intensity exercise training is one of the primary parameters responsible for improvement in cardiorespiratory efficacy in young athletes. The aim of the current study is to provide a descriptive and analytical overview of the physiological effect of such training on a series of cardiorespiratory indicators, e.g., heart rate, respiratory rate, oxygen consumption (VO_2), and tidal volume.

The study follows a descriptive analytical approach by analyzing and commenting on a set of previous scientific studies that have been debating the relationship between intense physical exercise and the functioning efficiency of the cardiorespiratory system among young athletes. By comparing study approaches, findings, and conclusions, the study identifies the dominant theoretical trends and recurring outcomes in the area.

Recurrent positive physiological adaptations to structured high-intensity training programs were identified in the analysis, including reduced resting heart rate, improved lung function, and increased oxygen consumption during exercise.

Research concludes by pointing toward the necessity to adopt well-structured intensive training programs for improvement in athletic performance and promotion of long-term cardiovascular and respiratory health among youth athletes. It also argues that more research is needed to fill the gaps and inconsistencies seen in the reviewed literature.

ملخص بالعربية

لملخص:

يُعتبر التدريب البدني عالي الشدة من أهم العوامل المسؤولة عن تحسين كفاءة الجهاز القلبي التنفسي لدى الرياضيين الشباب. وتهدف هذه الدراسة إلى تقديم نظرة وصفية تحليلية حول التأثيرات الفسيولوجية لمثل هذا النوع من التدريب على مجموعة من المؤشرات القلبية التنفسية، مثل معدل ضربات القلب، معدل التنفس، استهلاك الأوكسجين (VO_2)، وحجم التهوية الرئوية (حجم التيار الهوائي). تعتمد الدراسة على منهج وصفي تحليلي من خلال تحليل ومناقشة مجموعة من الدراسات العلمية السابقة التي تناولت العلاقة بين التدريب البدني المكثف وكفاءة عمل الجهاز القلبي التنفسي لدى الرياضيين الشباب. ومن خلال مقارنة مناهج تلك الدراسات ونتائجها واستنتاجاتها، تحدد الدراسة الاتجاهات النظرية السائدة والنتائج المتكررة في هذا المجال. كشفت نتائج التحليل عن وجود تكيفات فسيولوجية إيجابية متكررة للبرامج التدريبية المنظمة عالية الشدة، من بينها انخفاض معدل ضربات القلب أثناء الراحة، وتحسن وظائف الرئة، وزيادة استهلاك الأوكسجين أثناء التمرين. وتختتم الدراسة بالتأكيد على ضرورة تبني برامج تدريبية مكثفة ومنظمة لتحسين الأداء الرياضي وتعزيز الصحة القلبية التنفسية طويلة المدى لدى الرياضيين الشباب. كما تؤكد على الحاجة إلى المزيد من البحوث لسد الثغرات ومعالجة التباينات التي لوحظت في الأدبيات العلمية المستعرضة.

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Study introduction

Introduction

Physiological capacities, especially those related to the efficiency of the cardiorespiratory system, are considered fundamental to athletic performance. The importance of this topic increases particularly in competitive sports, where high physical ability and endurance are required, especially on the cardiovascular and respiratory levels.

However, despite the increasing reliance on this type of training in the sports field, many questions remain regarding its effects on young athletes, particularly during sensitive developmental stages in which the cardiorespiratory system has not yet fully matured. While a significant number of studies have examined high-intensity training and its positive effects on physiological indicators, most of them have focused on professional athletes (Bechet & Larsen, 2013), neglecting the youth category, which constitutes the future foundation of competitive sports.

On the other hand, some research has indicated that overtraining of this kind may lead to negative effects, such as cardiac stress or irregular heart rate patterns (Neelan et al., 2006). This highlights the need to investigate the phenomenon carefully and understand the boundaries of the positive effects of intensive training in comparison to the potential harms it may cause if not applied under scientific and controlled standard

Based on this, the current study aims to analyze and review the most relevant previous studies that explored the relationship between intensive physical training and cardiorespiratory indicators in young athletes. This will be carried out by adopting a descriptive analytical approach, in order to extract general theoretical results and identify points of agreement and disagreement among researchers. Furthermore, the study seeks to highlight both the benefits and risks of this training method from a scientific perspective that promotes safer and more effective practices in the development of young athletes.

This research relies on theoretical analytical investigation, that is, based on analyzing and comparing findings from previous literature, in order to present a clear scientific vision that can contribute to improving training methods in a more balanced and informed manner.

Research Problem

While rigorous physical training has been considered to be among the most significant ways of physical abilities development in young sportsmen, its effect on cardiorespiratory indicators remains a subject of scientific debate in accordance with the multiple and opposing results of available studies. Some research has established remarkable improvements in indicators such as maximal oxygen uptake (VO₂max), resting heart rate, waist circumference, and body fat percentage, while others have indicated no clear or consistent effects on these indicators. This discrepancy requires a descriptive analytical research to examine the findings of previous studies with an eye towards improved and more accurately understanding this relationship

Question

To what extent does strenuous physical training affect cardiorespiratory indicators in young athletes, as supported by findings of previous studies?

Hypothesis

We expect that strenuous physical training enhances cardiorespiratory indicators in young athletes, such as increased VO₂max, increased resting heart rate, and decreased waist circumference and percentage body fat, as supported by most previous studies.

Significance of the Study

The importance of the research relies on emphasizing the effects of intense physical training on the cardiorespiratory indicators of young athletes, by studying previous scientific studies using a descriptive analytical approach. This leads to the best and safest training models to be chosen by coaches for this age group to build physical performance and cardiorespiratory function without resulting in uncalculated health risks on young athletes. The study contributes to scientific know-how in the field of exercise physiology of adolescents and helps to improve the quality of training programs applied in practice.

The importance of the study

This study is important because it sheds light on the effects of intensive physical training on cardiorespiratory indicators in young athletes by analyzing the results of previous studies. It helps coaches choose appropriate and safe training methods and supports young athletes in improving their performance without harming their health. Additionally, the study contributes to expanding scientific knowledge in the field of exercise physiology for the youth category.

Objectives of the Study

Main Objective:

To critically assess earlier scientific research in a bid to explain the effects of intense physical training on cardiorespiratory parameters of young athletes.

Secondary Objectives:

In order to identify physiological modifications that occur in the respiratory and cardiovascular systems after intense training, e.g., VO₂max, resting heart

rate, functional lung capacity, waistline circumference, and body fat percentage.

In order to obtain scientific evidence from findings of current research with the aim of maximizing training techniques among young players in a way that minimizes health risks and *enhances sporting performance*.

Key words

Cardiorespiratory Indicators

"Measurements that show how efficiently the heart and lungs function during physical effort, such as heart rate, vital lung capacity, and maximal oxygen uptake (VO₂ max). These indicators are recorded before and after training to assess improvement."

Source: *Fundamentals of Sports Physiology* (Dr. Ali Abdelrahman, 2023, p. 89).

Intensive Training

"Exercise programs that exceed 75% of an athlete's maximum effort, applied over specific periods (such as 8 weeks) to improve physical performance. These programs raise heart rate to 150–180 beats per minute."

Source: *Coaches' Guide – Saudi Sports Federation* (2024).

Young Athletes

"Adolescents aged 12–18 years who regularly engage in organized sports activities under the supervision of a certified coach, such as club players or students in specialized sports schools."

Source: *World Health Organization – Adolescent Health Guide* (2022).

Similar studies:

Study 1

. principal Investigator

Gas haw Teesta (Lead Author) from Mekelle University and Bahir Dar University, Ethiopia, in collaboration with a research team

Study Title

"Effects of One-Week Endurance Training at Different Intensities on Cardiorespiratory and Cardio metabolic Markers in Junior Athletes"

Research Problem

Unclear impact of endurance training intensities (60-70% vs. 70-80% of maximum heart rate) on physiological markers after short-term exposure (1 week) in moderately trained athletes

Objectives

Compare effects of both intensity levels on:

Cardiorespiratory markers: VO₂ max, blood pressure, heart rate.

Cardio metabolic markers: LDH enzyme, cardiac troponin (catnip) , creating kinase (CK-MB)

Hypotheses

Higher intensity (70-80% HR_{max}) would cause greater elevation in cardio metabolic markers.

Both intensities would induce changes in cardiorespiratory markers

Methodology

Design: Randomized two-group trial

Sample: 30 male athletes (19.4 ± 1.3 years)

Intervention:

Group 1: 45 min/session at 60-70% HR_{max}

Group 2: 30 min/session at 70-80% HR_{max}

(3 sessions/week for 1 week)

Measurements: Blood samples pre-training and 4hr post-final session [citation: user].

Key Findings

Cardiorespiratory Markers:

No significant changes in VO₂ max, blood pressure, or heart rate within or between groups.

Cardio metabolic Markers:

Significant elevation in LDH, catnip, and CK-MB within both groups (*p*=0.001).

No inter-group differences in marker elevation

Core Conclusion

Both training intensities (60-70% and 70-80% HR_{max}) induced similar acute elevations in cardio metabolic markers without affecting cardiorespiratory parameters or showing intensity-dependent differences. This indicates that the acute physiological response to short-term exercise is identical regardless of moderate or relatively high intensity [citation: user].

Study 2

Study Title

Effects of Endurance Training Intensity on Pulmonary Diffusing Capacity at Rest and after Maximal Aerobic Exercise in Young Athletes (2021)

Research Problem

In this study, the researchers aimed to understand how endurance training intensity (high or moderate) affects lung efficiency in young athletes, both at rest and after maximal exercise. The problem was the lack of clear information about whether training intensity in young athletes can improve the lung's ability to transfer oxygen and carbon dioxide from the lungs to the blood, and how this contributes to athletic performance development.

Objectives

To compare the effects of high-intensity endurance training (IET) and moderate-intensity endurance training (MET) on lung efficiency indicators in young athletes.

To find out how gas transfer capacity (TLCO, TLNO), lung capillary blood volume (V_{ic}), and alveolar-capillary membrane capacity (DM) change after 8 weeks of training.

To assess how training intensity affects lung function at rest and after maximal exercise.

Hypotheses

High-intensity endurance training would have a greater effect than moderate-intensity training in improving lung efficiency indicators.

The improvements in lung function would be linked to increased vascularization of the lungs and enhanced alveolar-capillary membrane capacity, which would help improve athletic performance.

Methodology

The researchers used a comparative experimental method. The athletes were divided into two groups (high-intensity training and moderate-intensity training) and followed an 8-week training program.

Study Sample

The sample consisted of 16 young athletes (aged 16–18 years), all middle-distance runners, divided into:

High-intensity training group (IET): 8 athletes

Moderate-intensity training group (MET): 8 athletes

Main Results

High-intensity training improved VO₂max by about 5%, while moderate training had little effect.

The high-intensity group showed significant increases in TLCO, TLNO, DM, and Vic both at rest and after exercise.

High-intensity endurance training had about three times the effect of moderate-intensity training in improving lung capacity.

Study 3

Author: Mohsen Sheykhloovand (M. Sheykhloovand)

Title of the Study:

Low-volume high-intensity interval vs. continuous endurance training: Effects on hematological and cardiorespiratory system adaptations in professional canoe polo athletes (Sheykhloovand et al., 2018)

Study Objective:

The current study aimed to examine and contrast the impact of two forms of high-intensity interval training that were based on variable intensity (VIHIIT) and variable volume (VVIIT) with continuous endurance training (CET) on hematological and cardiorespiratory adaptation in elite canoe polo athletes within a short span of three weeks.

Methodology:

The research utilized a systematic planned experimental approach to provide systematic comparison among different training schedules. The sample consisted of 21 competitive canoe polo athletes (24 ± 3 years), randomly distributed in three equal groups (7 participants/group). These groups completed different training programs: VIHIIT, VVIIT, or CET. The training protocols were conducted under the same conditions to ensure objectivity, maintaining strict control over cardiorespiratory and hematological markers both before and after the intervention.

Results

Cardiorespiratory

Endurance: Improvements in $\dot{V}O_{2peak}$ were significant in both VIHIIT (7.6%) and VVIIT (6.7%) groups, but not in the CET group. Peak ventilation increased in both interval groups, although VVIIT was more effective in enhancing ventilator threshold and corresponding respiratory markers.

Hematological Markers: There was a significant decrease in RDW in the VVIIT group. MPV was raised in both VIHIIT and VVIIT, but to a greater extent in VIHIIT. MCHC was raised only in CET.

Immunological Markers: There was a decrease in lymphocytes in CET, but not in either of the HIIT groups.

Conclusion

Outcomes confirmed both forms of high-intensity interval training to be effective in enhancing aerobic capacity and respiratory function within a short time. VVIIT appeared more effective at enhancing ventilator threshold and respiratory indices. HIIT is a valuable alternative for canoe polo players who want to enhance performance during short preparation times without compromising immune function.

Practical Applications

Low-volume high-intensity interval training offers a time-efficient process of improving hematological and respiratory markers among athletes. It is particularly best suited for application under rigorous competition schedules with little time but a requirement for performance enhancement.

Study 4

others

Delgado-Flood, P., Latorre-Román, P., Jerez-Mayorga, D., Caamaño-Navarrete, F., & García-Pinillos, F.

Title of study

(2019). Feasibility of incorporating high-intensity interval training into physical education programs to improve body composition and cardiorespiratory capacity of overweight and obese children

Publication Date:

The study was published in 2019

Study Objective:

This systematic review aimed to analyze the feasibility of incorporating high-intensity interval training (HIIT) programs into physical education classes to improve body composition and cardiorespiratory capacity in overweight and obese children and adolescents.

Study Methodology:

Systematic review conducted according to PRISMA recommendations.

Search conducted in the databases Web of Science, Scopus, MEDLINE, SPORT Discus, and PUBMED.

Included studies published between January 2012 and January 2017.

The review included 6 studies (3 conducted on children under 12 years old and 3 on adolescents between 12 and 18 years old).

Training Protocols:

Number of sessions: 2–3 per week.

Effort duration: 15–30 seconds; rest duration (active or passive): 15–30 seconds.

Program duration: between 6 and 24 weeks.

Main Results:

Improvements in body composition: Reduction in body mass index (BMI), body fat percentage (BF%), waist circumference (WC), sum of skinfolds, and increase in lean mass (LM).

Improvements in cardiorespiratory fitness: Increase in VO₂max, performance in the Yo-Yo test, maximal aerobic speed (MAS), and aerobic capacity.

HIIT was more effective or equivalent to continuous low-intensity training despite its shorter duration.

Conclusions:

The study demonstrated that HIIT programs are feasible for inclusion in school physical education classes and are an effective tool for combating obesity in children and adolescents. The study recommends 2–3 HIIT sessions per week with effort and rest periods between 15–30 seconds each, which can be combined with traditional activities within the same class or during specific periods of the school day.

Comment on previous and similar studies

Commentary on the Previous Studies

It is already known that strenuous physical training, both moderate and high intensity, has positive influences on cardiorespiratory and hematological indices in young athletes. The above studies demonstrated that high-intensity interval training (HIIT) is a highly effective means of increasing aerobic capacity and the efficiency of the heart and lungs, even within a limited time period. We also noted that some of the research had been targeted at school age groups or school programs, showing the importance of this type of training for not only sports individuals but also for general health.

This gives our research even more relevance since it supports these findings and contrasts them with our own.

Part One: Theoretical Framework

chapter 1:

Physical training

Introduction

Physical training and sports preparation are considered elementary factors contributing to the shaping of functional and physical qualities of the human body, especially in childhood and adolescence, as the body undergoes various stages of development and growth, with a direct effect on its motor and sports performance. From this perspective, this chapter addresses a sequence of theoretical concepts that form the scientific background of the research, starting with the general principles of physical training and its most relevant principles, passing through the physiology of physical exercise, and ending at the body morphology and cardiorespiratory system and their performance criteria. This chapter is intended to present a correct scientific background in order to understand the effect of intensive training on cardiorespiratory markers among young athletes.

1.1 "General Concepts of Physical Training"

1.1.1 Overload Principle

Definition:

The overload principle is a foundational concept in physical training that states that in order to stimulate physiological adaptations and improvements in performance, the body must be subjected to stresses that exceed its current capacities. This is achieved by progressively increasing the training load through variables such as intensity (weight or speed), duration (time spent exercising), or volume (number of repetitions or sets) (American College of Sports Medicine [ACSM], 2024).

Application:

for example, in resistance training, an individual might increase the load lifted by 5–10% per week. In endurance sports, the distance or duration might be gradually extended. The overload should be applied systematically to avoid injuries and overtraining while promoting continuous improvement in muscle strength, cardiovascular endurance, and other fitness components (American College of Sports Medicine [ACSM], 2024).

Scientific Basis:

The body's response to overload involves physiological processes such as muscle fiber hypertrophy, increased mitochondrial density, and enhanced neural efficiency, which together lead to performance gains.

American College of Sports Medicine (ACSM). (2024). Guidelines for Exercise Testing and Prescription (11th ed.). Lippincott Williams & Wilkins.

Definition:

The principle of specificity dictates that the body adapts in a manner that is specific to the demands imposed on it. In other words, the physiological systems (muscular, cardiovascular, neural) will improve according to the type of stress they are subjected to during training. For example, strength training will primarily enhance muscular power, while endurance training will target aerobic capacity (Hassan, 2023; American College of Sports Medicine [ACSM], 2024).

Example:

Plyometric drills such as bounding and jumping exercises are highly specific for athletes like long jumpers because they replicate the explosive actions required during the actual sport. Similarly, distance runners benefit from long-duration aerobic runs that mirror race conditions (Powers & Howley, 2020).

Application:

Training programs must be designed with the sport or activity goal in mind, ensuring that exercises closely match the movements, energy systems, and muscle groups predominantly used in the sport (Kenney, Wilmore, & Costill, 2020).

1.1.3 /Recovery

Definition:

Recovery refers to the period during which the body repairs and strengthens itself after exercise. It encompasses both immediate rest between sets or sessions and long-term strategies such as sleep and nutrition. Recovery is crucial for muscle tissue repair, glycogen replenishment, and the reduction of accumulated fatigue (Powers & Howley, 2017).

Duration:

The appropriate recovery period depends on the intensity and type of exercise:

After high-intensity strength training: 48–72 hours.

After moderate endurance training: 24–48 hours.

Between sets: 30 seconds (light load) to 3 minutes (heavy load) (Powers & Howley, 2017).

Warning:

Insufficient recovery can lead to overtraining syndrome, which manifests through chronic fatigue, decreased performance, mood disturbances, and increased injury risk. To protect the athlete's physical and mental health, rest must be considered an essential part of any training program—not a luxury but a physiological necessity (Powers & Howley, 2017).

1.1.4 Individualization

Definition:

Individualization emphasizes that training programs should be tailored to the unique characteristics of each person. Factors influencing training responses include:

Age: Young athletes require careful progression to avoid injury to growing tissues.

Gender: Hormonal differences can influence strength and endurance development.

Fitness level: Beginners need a lower initial load and slower progression compared to experienced athletes (Kenney, Wilmore, & Costilla, 2019).

Application:

For example, teenagers should not be subjected to the same weight training intensities as adults due to the ongoing development of their musculoskeletal system. Similarly, female athletes might have different nutritional and recovery requirements compared to males. Respecting individual differences is not just a scientific requirement, but also an ethical and human-centered approach to training (Kenney, Wilmore, & Costilla, 2019).

1.1.5 Variation

Definition:

Variation (or periodization) involves regularly changing training variables—such as intensity, volume, exercise selection, and rest periods—to stimulate continuous adaptation and prevent plateaus or overuse injuries (Bump & Buzzichelli, 2018).

Example:

An athlete may alternate between running and swimming in successive weeks to engage different muscle groups, improve overall fitness, and prevent monotony. Similarly, in strength training, cycles of hypertrophy (high volume, low intensity) and strength phases (low volume, high intensity) are alternated (Bompa & Buzzichelli, 2018).

Benefits:

Prevents psychological burnout and boredom.

Reduces risk of overuse injuries by distributing stress across different body parts.

Promotes comprehensive development of different physical capacities (strength, endurance, flexibility) (Bompa & Buzzichelli, 2018).

1.2 High-Intensity Training (HIT):

Definition:

A training system characterized by short-duration sessions (typically 20–30 minutes) with high intensity reaching 80–95% of maximum heart rate, and limited or no rest periods between exercises (Abdelwahab, 2021, p. 178).

Basic Components:

High intensity: 80–95% of maximum heart rate

Short duration: 15–30 minutes per session

Rest periods: 30–90 seconds between sets (Abdelwahab, 2021)

.1.21 /Main Benefits:

Rapid improvement of cardiorespiratory fitness

Increased calorie burning rate

Improved insulin sensitivity

Reduced workout time with effective results Common

.1.22/Types:HIIT:

High-Intensity Interval Training Tabata: 20 seconds effort + 10 seconds rest Circuit

Training: Consecutive exercises without rest Precautions: Warm-up for 10

Avoid for patients with minutes is necessary Gradual increase in intensity

unstable heart conditions Consult a doctor before starting if over 40 years old

1.3/Human biological development

Human biological development is a complex and continuous process that occurs throughout an individual's life, beginning from the very first moment of fertilization inside the mother's womb and extending through various stages of physical and physiological growth and changes. This development includes the growth of organs and tissues, increases in size and muscle mass, changes in the structure and function of vital systems such as the cardiovascular and nervous systems, as well as hormonal changes that affect growth and puberty. Biological development also involves adaptation to environmental and genetic factors that influence the rate and extent of bodily growth, allowing the individual to progress from childhood to adolescence, then to adulthood and aging.

Understanding this process helps in assessing normal growth and identifying any disorders or delays in development. (Smith, 2020)

1.4/Growth in Children and Adolescents

Growth refers to the sequential changes an individual undergoes in physical, mental, emotional, and social aspects, starting from childhood and continuing through adolescence. This process involves increases in body size and functional complexity of organs, as well as the development of various abilities and skills.

Key growth stages include early childhood (0-5 years), characterized by rapid development of motor and language skills; middle childhood (6-11 years), where academic and social skills advance; and adolescence (12-18 years), marked by significant physical and psychological changes such as puberty and the formation of self-identity.

Several factors influence growth, including genetic factors that determine certain individual traits, environmental factors such as nutrition and family care, as well as cultural and social factors that shape an individual's personality and behavior

: Bark, L. E. (2018). *Development Through the Lifespan* (7th ed.). Pearson.)

Papilla, D. E., & Feldman, R. D. (2021). *Human Development* (14th ed.). McGraw-Hill

1.5 Physical Activity

Physical activity refers to any bodily movement produced by skeletal muscles that requires energy expenditure. This includes activities such as walking, running, cycling, and sports activities (World Health Organization, 2024).

1.5.1 Physical Fitness

Physical fitness is the ability of the body to perform daily tasks effectively and efficiently, while maintaining low levels of fatigue. Its components include strength, flexibility, endurance, agility, and speed (American College of Sports Medicine, 2024).

1.5.2 Physical Preparation

Physical preparation is the process of developing fundamental physical qualities such as strength, speed, endurance, flexibility, and agility to enhance athletic performance. It involves specialized training programs tailored to the specific demands of the sport and development (Bompa & Buzzichelli, 2018).

1.5.3 Physical Training

Physical training encompasses a set of exercises and activities designed to improve physical performance and enhance strength, flexibility, endurance, and speed. It includes aerobic exercises, strength training, and sport-specific drills (Powers & Howley, 2020).

1.5.4 Nutrition and Rest

Proper nutrition and adequate rest are essential for improving physical performance. Nutrition involves consuming balanced meals that provide proteins, carbohydrates, and healthy fats.

Rest includes sufficient sleep and recovery periods between training sessions (American College of Sports Medicine, 2024).

1.5.5 Mental Health and Physical Performance

Regular physical activity positively impacts mental health by reducing anxiety and depression, enhancing self-confidence, and improving overall mood. It also contributes to better stress management and cognitive function (World Health Organization, 2021).

1.5.6 Training Principles

Training programs are based on scientific principles to ensure effectiveness. These include:

Individual Differences: Considering variations in abilities among individuals.

Progression: Gradually increasing training intensity.

Overload: Increasing training load to stimulate improvement.

Specificity: Targeting specific physical qualities required for the sport (Kenney, Wilmore, & Costill, 2020)

1.6 /Concepts of Sports Physiology<<

.1.61 /A / General Concept and Origins of the Field Definition:

Sports physiology is "the study of acute and chronic functional changes in body systems due to physical activity", aiming to explain adaptation mechanisms and enhance athletic performance. It focuses on interactions between muscular, nervous, and cardiorespiratory systems during exercise .

B/Historical Origins:

Emerged as a branch of human physiology in the 19th century, with the first specialized book "Physiology of Exercise" by Fernand Lagrange (1889), discussing muscle function and fatigue mechanisms .

Advanced through research by Archibald Hill (Nobel Prize 1922) on maximal oxygen uptake (VO_2)

1.6.2/.Mechanisms of Physiological

Immediate changes during exercise, such as:

50-100% increase in heart rate, 200-300% rise in pulmonary ventilation .

Lactic acid accumulation in muscles when exercise intensity exceeds 85% of max

1.6.3. /capacity.

These changes subside minutes after activity cessation . Chronic **1.7.2.3Adaptations:**

Permanent structural/functional shifts after regular training:

Cardiovascular System: 10-20% enlargement of left ventricle, resting heart rate below 60 bpm in athletes

Muscular System: 40-50% increase in mitochondrial density, enhancing aerobic energy efficiency.

Nervous System: Improved neuromuscular coordination and motor unit recruitment.

1.6.3 / Specialized Concepts

1.6.3.1 / Energy Systems

1.6.3.1.1 / Anaerobic System:

Produces energy without oxygen via glycogen breakdown; supports short efforts (≤ 90 sec) like sprinting.
McArdle, W. D., Katch, F. I., & Katch, V. L. (2015). Exercise physiology: Nutrition, energy, and human performance (8th ed.). Wolters Kluwer Health.

1.6.3.1.2 / Aerobic System:

Uses oxygen to metabolize fats/carbs; essential for endurance sports (e.g., marathons).
Powers, S. K., & Hawley, E. T. (2017). Exercise physiology: Theory and application to fitness and performance (10th ed.). McGraw-Hill Education.

1.6.3.2 / Components of Physiological Fitness

Flexibility: Joint range of motion.

Body Composition: Fat-to-muscle ratio.

Aerobic Capacity: Oxygen efficiency.

Anaerobic Capacity: Energy production without oxygen, measured via lactate threshold.

Metabolic Health: Blood pressure, glucose tolerance.

Kenney, W. L., Wilmore, J. H., & Costilla, D. L. (2019). Physiology of sport and exercise (7th Ed.). Human Kinetics.

1.6.3.3 / Adaptation Principle

Defined as "functional or structural modifications in response to repeated training stressors." Example: Increased bone density after 6 months of resistance training.

Powers, S. K., & Hawley, E. T. (2017). Exercise physiology: Theory and application to fitness and performance (10th ed.). McGraw-Hill Education.

1.6.3.4 / Environmental Chambers

Used for acclimatization to heat/cold.

Kenney, W. L., Wilmore, J. H., & Costilla, D. L. (2019). Physiology of sport and exercise (7th ed.). Human Kinetics.

1.6.4 / Practical Applications

1.6.4.1 / Training Load Management

Using physiological markers (e.g., heart rate) to regulate intensity. Endurance training should not exceed 80-90% of max heart rate. VO_2 max testing to design personalized training programs.

Joyner, M. J., & Coyle, E. F. (2008). Endurance exercise performance: The physiology of champions. Journal of Physiology, 586(1), 35-44. <https://doi.org/10.1113/jphysiol.2007.143834>

1.6.4.2 / Athlete Selection

Analyzing physiological traits (e.g., respiratory efficiency) to match athletes with suitable sports.

Example: Endurance sports (e.g., running) require high VO_2 max (≥ 60 ml/kg/min).

Powers, S. K., & Hawley, E. T. (2017). Exercise physiology: Theory and application to fitness and performance (10th ed.). McGraw-Hill Education.

1.6.4.3 / Injury Prevention

Periodic tests (e.g., lung vital capacity) detect early dysfunction.

World Health Organization. (2020). Guidelines on physical activity and sedentary behavior.

1.6.4.4 / Training in Extreme Environments

Altitude Simulation: Boosts red blood cell production for oxygen transport. Environmental Chambers: Acclimatization to heat/cold.

Kenney, W. L., Wilmore, J. H., & Costilla, D. L. (2019). Physiology of sport and exercise (7th ed.). Human Kinetics.

1.7 / Body Adaptation to Physical Effort

1.7.1 / Definition of Physiological Adaptation

It refers to a set of physiological changes that occur in the body as a result of regular and continuous physical activity, with the goal of enhancing physical performance and reducing fatigue.

📖 Fox, E. L. (1998). Fox's Physiological Basis for Exercise and Sport (6th ed., pp. 216–220).

1.7.2 / Types of Physiological Adaptations

1.7.2.1 / Cardiovascular System

Enlargement of the heart, particularly the left ventricle.

Increase in cardiac output (amount of blood pumped by the heart per minute).

Decrease in resting heart rate.

📖 Fox, E. L. (1998). Fox's Physiological Basis for Exercise and Sport (6th ed., pp. 216–220).

1.7.2.2 / Respiratory System

Improved respiratory efficiency and increased pulmonary ventilation.

Enhanced capacity for gas exchange (O₂ and CO₂).

📖 Wilmore, J. H., & Costilla, D. L. (2004). Physiology of Sport and Exercise (4th ed., pp. 120–125).

1.7.2.3 / Muscular System

Increase in muscle mass and contraction strength.

Increase in both the number and size of mitochondria within muscle cells.

Improved oxygen utilization in the muscles.

📖 Powers, S. K., & Hawley, E. T. (2017). Exercise Physiology: Theory and Application to Fitness and Performance (9th ed., pp. 239–245).

1.7.2.4 / Nervous System

Improved motor coordination.

Faster neural response times.

More efficient activation of motor units.

📖 McArdle, W. D., Ketch, F. I., & Ketch, V. L. (2010). Exercise Physiology: Nutrition, Energy, and Human Performance (7th ed., pp. 172–175).

1.7.3 / Types of Adaptation Based on Exercise Type

Exercise Type	Main Adaptation
Endurance exercises (e.g., running, swimming)	<i>Improved cardiovascular and respiratory efficiency</i>
Strength training (e.g., weightlifting)	<i>Increased strength and muscle mass</i>
Aerobic exercises	<i>Enhanced ability to use fat as an energy</i>

	<i>source</i>
Anaerobic exercises	<i>Improved tolerance to lactic acid buildup</i>

1.7.4/Factors Influencing Adaptation

Intensity, duration, and consistency of training
 .Age and gender.
 Nutrition and overall health.
 Genetic predisposition.

1.7.5./importance of Physical Adaptation:

Reduces the risk of chronic diseases.
 Enhances endurance and physical performance.
 Improves mental health and sleep quality.
 Boosts metabolic efficiency.

1.8 / Concepts of Sports Morphology

1.8.1 / Definition of Sports Morphology

Sports morphology is a branch of sports science concerned with studying body structure and the composition of its parts in relation to physical performance. It involves analyzing physical dimensions (such as height, weight, proportions, diameters, girths, and fat percentage) and their impact on athletic and physical abilities.

📖 *Ahmed Nasser. (2010). Morphology of Athletes – Concepts and Applications (2nd ed.). Dar Al-Fikr Al-Arabi, Cairo, p. 1.*

1.8.2 / Key Elements of Sports Morphology

1.8.2.1 / Body Composition

Includes fat percentage, muscle mass, bone mass, and body water. Used to determine an athlete's suitability for specific performance requirements.

📖 *Wilmore, J. H., & Costill, D. L. (2004). Physiology of Sport and Exercise (4th ed., p. 200).*

1.8.2.2 / Anthropometry

Includes height, weight, body girths, and segmental lengths. Used to determine somatotype (Ectomorph, Mesomorph, Endomorph).

📖 *Carter, J. E. L., & Heath, B. H. (1990). Somatotyping: Development and Applications. Cambridge University Press, pp. 12–30.*

1.8.2.3 / Functional Morphological Analysis

Studies the relationship between body structure and neuromuscular function during athletic performance. Example: High jumpers often have long lower limbs and low body mass.

📖 *Powers, S. K., & Howley, E. T. (Arabic edition). Exercise Physiology, p. 311.*

1.8.3 / Importance of Morphology in Sports

Helps determine the most suitable sport for each individual.
 Improves physical training programs.
 Supports sports talent identification and selection in youth.
 Reduces risk of injuries caused by anatomical mismatch.

Hussein Magdy. (2012). *Anthropometric Measurements and Applications in Sports*. Dar Al-Wafaa, Alexandria, pp. 88–91.

1.8.4 / Somatotypes Theory According to Sheldon

Sheldon classified human body types into three main categories based on physique and body composition:

Ectomorph: slim build, long limbs.

Mesomorph: muscular build, broad shoulders.

Endomorph: higher fat percentage, rounded shape.

Somatotype	Characteristics	Suitable Sports
Ectomorph	Slim body, low fat, long limbs	Long-distance running
Mesomorph	High muscle mass, strong and athletic build	Wrestling, Weightlifting
Endomorph	Rounded physique, higher fat percentage, broad waist/hips	Archery, Shot Put

References:

Carter, J.E.L. & Heath, B.H. (1990). *Somatotyping: Development and Applications*. Cambridge University Press, pp. 44–50.

Zatsiorsky, V.M. & Kraemer, W.J. (2006). *Science and Practice of Strength Training*. Human Kinetics, pp. 23–27.

1.8.5/Practical Applications of Sports Morphology

Athlete Selection:

Assessing morphological traits helps in selecting the right sport for each athlete based on body type.

Training Program Design:

Exercises are tailored to match the athlete's body composition (muscle mass, fat percentage, structure).

Monitoring Development:

Morphology is used to track changes in body composition over time, particularly under regular training programs.

Chapter Summary

The chapter reviewed the theoretical foundations of physical training and its physiological and morphological effects on young athletes, with a focus on training principles, high-intensity training, biological growth, physiological adaptations, and sports morphology, all serving to understand the relationship between training and cardiorespiratory fitness level.

Chapter2: Bibliography analysis

Introduction chapter

This chapter will provide the physiological systems' (cardiorespiratory, circulatory, and respiratory systems) theoretical background and their functional integration during physical exertion. It will also determine the biological markers (i.e., VO_2 max and lactate threshold) and anthropometric criteria that are used in the measurement of motor performance, according to the most recent scientific literature, in preparation for the subsequent applied analysis.

2 / Reminder of Cardiovascular Physiology

2.1 /Cardiorespiratory System

The cardiorespiratory system refers to the interaction and integration between the cardiovascular system (heart and blood vessels) and the respiratory system (lungs and airways) in performing essential body functions. This system plays a central role in maintaining homeostasis, primarily by:

Supplying body tissues with **oxygen (O_2)** necessary for **cellular energy production** (ATP synthesis),
Removing **carbon dioxide (CO_2)**, a metabolic waste product generated during respiration.
Through this coordinated function, the cardiorespiratory system supports the body during both rest and physical effort, ensuring efficient **gas exchange** and **nutrient transport**, which are critical for sustaining life.

📖 Reference:

Jerald, & Zahra. (2021–2022). *Physiology of the Cardiorespiratory System*. University of Mostaganem.

2.1.1/ Components of the Cardiorespiratory System

2.1.1.1 / The Heart

The heart is a hollow muscular organ that acts as the main pump circulating blood throughout the body.

It performs two integrated circuits:

A **pulmonary circuit** to enable gas exchange in the lungs.

A **systemic circuit** to distribute oxygenated blood throughout the body.

📖 Marieb, E. N. (2005). *Human Anatomy & Physiology* (6th ed.).

2.1.1.2 / The Lungs

The lungs are the primary organs of the respiratory system, located in the thoracic cavity. Their main functions include:

Gas exchange (O_2 and CO_2) between air and blood.

Filtering incoming air through the nose and mouth.

Humidifying and warming inhaled air.

📖 Samira. (2015–2016). *Lecture notes on human physiology*.

2.1.1.3 / Respiratory Passages

The respiratory passages include:

Nose

Pharynx

Larynx

Trachea

Bronchi

Bronchioles

This structure directs air into the lungs and purifies it from dust and microbes via mucus and cilia.

📖 Wilmore, J. H., Costill, D. L., & Kenney, W. L. (2009). *Physiology of Sport and Exercise* (4th ed., p. 136).

2.1.2/Physiological Functions of the Cardiorespiratory System

2.1.2.1/Gas Exchange

Takes place in the alveoli of the lungs, where:

Oxygen diffuses from the air into the blood.

Carbon dioxide diffuses from the blood into the air to be exhaled.

(Marieb, 2005, p. 739)

2.1.2.2/Oxygen Delivery to Tissues

After oxygen is loaded into the blood in the lungs, it is pumped by the heart to the tissues, allowing cells to use oxygen in **cellular respiration** to produce energy (ATP). (Samira, 2015–2016)

2.1.2.3/Regulation of pH

The respiratory system helps maintain acid-base balance by adjusting the levels of carbon dioxide in the blood through the process of ventilation.

(Wilmore, Costill & Kenney, 2009, p. 145)

2.1.4/Heart-Lung Interaction During Physical Activity

During physical exertion, oxygen demand increases, leading to:

Increased respiratory rate

Increased heart rate

Increased cardiac output

This interaction improves aerobic efficiency and enhances the body's endurance

Capacity

(Jeraal & Zahra, 2021–2022)

2.1.5 / Indicators of Cardiorespiratory Efficiency

The efficiency of this system is measured using several indicators, the most important of which are:

Pulmonary ventilation

VO₂ Max: Maximal oxygen consumption

Resting heart rate (RHR)

Recovery time after exertion

■ Wilmore, J. H., Costilla, D. L., & Kenney, W. L. (2009). *Physiology of Sport and Exercise* (4th ed., p. 167).

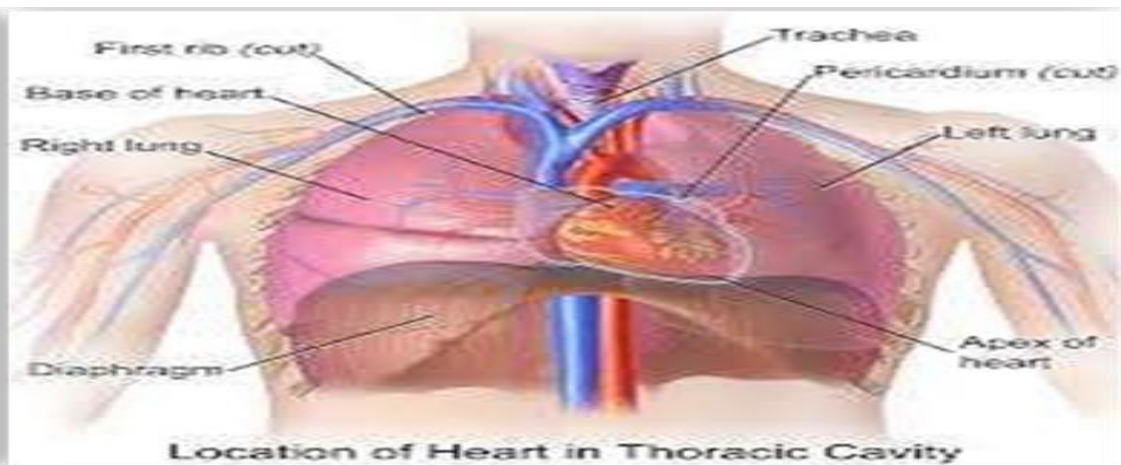


Figure1 The location of the heart within the thoracic cag

2.2 / Cardiovascular System

The cardiovascular system is a vast network of organs and blood vessels responsible for the circulation of blood, nutrients, hormones, oxygen, and other gases to and from the cells.

Jeraal & Zahra. (2021/2022). Lecture notes on cardiovascular physiology.

The human cardiovascular system operates as a closed loop in which blood circulates through all body tissues. Blood circulation requires the action of a muscular pump—the heart—which generates the pressure necessary to propel blood throughout the body. Blood flows from the heart through the arteries and returns via the veins within the systemic circulation.

Dr. Samira. (2015–2016). Lecture notes on human physiology.

2.2.1 / Components of the Cardiovascular System

2.2.1.1 / The Heart

The heart is considered the most important organ of the circulatory system, and it works as a pump that brings blood to it from all parts of the body in order to push it through the blood vessels again, by contracting and relaxing alternately, depending on the body's need and the intensity of the effort expended.

The heart weighs about 300 grams in a man and about 250 grams in women. It is covered by a thin membrane called the pericardium, and there is fluid between this membrane and the heart that facilitates movement.

Jeraal & Zahra. (2021/2022). Lecture notes.

2.2.1.2 / The Heart and Its Anatomical Location

The heart is located within the lower mediastinum—the central compartment of the thoracic cavity—bordered laterally by the lungs.

More precisely, the human heart lies medially between the lungs, in an area known as the mediastinum, within the thoracic cavity. The heart is enclosed in a tough, double-walled membrane known as the pericardium or pericardial sac, and it rests in its own compartment called the pericardial cavity.

Marieb, E. N. (2005). *Human Anatomy & Physiology* (6th ed.).

2.2.1.3 / The Layers (Envelopes) of the Heart

2.2.1.3.1 / Pericardium

The pericardium is the outer protective sac that surrounds the heart and holds it in place within the thoracic cavity. It helps reduce friction during heartbeats and movement.

Marieb, E. N. (2005). *Human Anatomy & Physiology* (6th ed.). p. 704.

2.2.1.3.2 / The Myocardium

The myocardium is the muscular tissue of the heart. Its thickness varies based on the workload each chamber must perform. The left ventricle has the thickest myocardium because it is responsible for generating enough pressure to pump blood throughout the entire systemic circulatory system. When the body is in an upright position (sitting or standing), the left ventricle also has to overcome the gravitational pull that draws blood downward to the lower extremities. Therefore, it has the most powerful muscle wall among all heart chambers.

Wilmore, J. H., Costilla, D. L., & Kenney, W. L. (2009). *Physiology of Sport and Exercise* (4th ed., pp. 124–125).

2.2.1.3.3 / Endocardium

The endocardium is the thin, smooth inner lining of the heart chambers. It ensures that blood flows easily inside the heart and helps protect the heart tissues.

Marieb, E. N. (2005). *Human Anatomy & Physiology* (6th ed.). p. 704.

2.2.1.4 / The Chambers of the Heart

The heart contains four chambers: two atria (or auricles) and two ventricles.

Each chamber is lined with the endocardium, a smooth inner lining that facilitates the flow of blood through the heart.

The atria (upper chambers) serve primarily as entrance chambers that receive blood from the veins at low pressure and direct it to the ventricles. They contribute little to the actual pumping action.

The ventricles (lower chambers) have thicker muscular walls and act as the main pumps of the heart. When they contract, they propel blood out of the heart into the arteries.

The right ventricle forms most of the anterior surface of the heart, while the left ventricle forms the apex.

The septum is the wall that separates the right and left sides of the heart:

The interatrial septum separates the atria.

The interventricular septum separates the ventricles.

Marieb, 2005

2.2.1.5 / The Heart Valves

Blood flows through the heart in one direction: from the atria to the ventricles, then out to the arteries.

This unidirectional flow is maintained by four valves that open and close in response to pressure changes:

A / The Atrioventricular Valves

A1 / Tricuspid Valve: Located between the right atrium and right ventricle. It consists of three cusps (flaps) of endocardium reinforced with connective tissue. It prevents backflow of blood into the right atrium when the right ventricle contracts.

A2 / Mitral Valve (Bicuspid Valve): Located between the left atrium and left ventricle. It consists of two cusps. It prevents backflow of blood into the left atrium during contraction of the left ventricle.

Marieb, 2005, p. 705

B / The Semilunar Valves

B1 / Pulmonary Valve: Located at the opening of the pulmonary trunk. It prevents blood from flowing back into the right ventricle after contraction.

B2 / Aortic Valve: Located at the opening of the aorta. It prevents blood from flowing back into the left ventricle.

Both semilunar valves consist of three crescent-shaped cusps that open when ventricular pressure exceeds arterial pressure and close to prevent backflow as the ventricles relax.

Marieb, 2005, p. 705

✓ Summary:

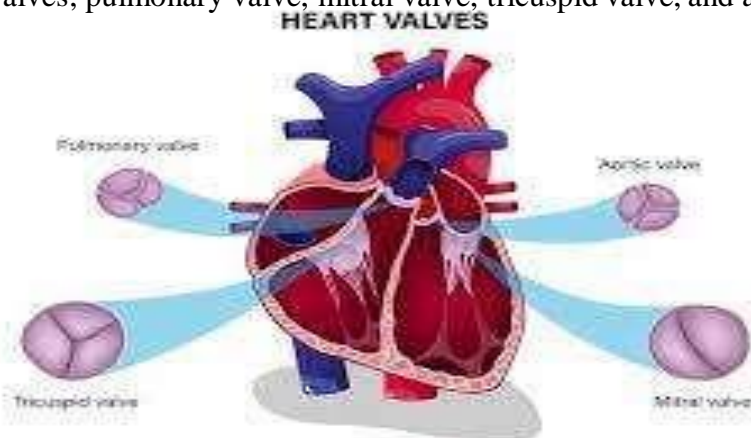
The heart has four valves:

- 1 Tricuspid valve
- 2 Mitral (bicuspid) valve
- 3 Pulmonary valve
- 4 Aortic valve

These valves ensure unidirectional blood flow and efficient heart function.

Figure 2

The heart has 4 valves; pulmonary valve, mitral valve, tricuspid valve, and aortic valve



2.2.3 / Blood Vessels

Blood vessels are a fundamental component of the cardiovascular system. They form a closed network of tubes through which blood circulates from the heart to various parts of the body and back again. Their primary role is to transport oxygen, nutrients, and hormones to the cells while removing carbon dioxide and metabolic waste. Blood vessels also play a central role in maintaining homeostasis and regulating blood pressure.

▣ Hall, J. E., & Guyton, A. C. (2020). *Guyton and Hall Textbook of Medical Physiology* (14th ed.). Elsevier.

2.2.3.1 / Arteries

Arteries are the blood vessels that carry blood away from the heart to the tissues. They typically transport oxygenated blood, except for the pulmonary artery, which carries deoxygenated blood to the lungs. The walls of arteries consist of three layers: a smooth inner lining that facilitates blood flow, a middle layer rich in smooth muscle and elastic fibers, and an outer layer that provides structural support. This structure allows arteries to withstand the high pressure generated by the heart's contractions and to regulate blood flow effectively.

▣ Silverthorn, D. U. (2019). *Human Physiology: An Integrated Approach* (8th ed.). Pearson.

2.2.3.2 / Capillaries

Capillaries are tiny blood vessels with thin walls. Oxygen and nutrients from the blood can move through the walls into organs and tissues, while waste products move from tissues into the blood. Capillaries are where oxygen and nutrients are exchanged for carbon dioxide and waste.

▣ Clinic. (2021).

2.2.3.3 / Venues

Venues are the smallest veins and serve as the starting point of the venous system. They collect blood from capillaries and gradually merge into larger veins as they approach the heart.

▣ Clinic. (2021).

2.1.3.4 / Veins

Veins carry blood under low pressure, typically deoxygenated, back to the heart. Their walls are thin and less elastic because they do not handle high pressure, but they are adapted to transport large volumes of blood. Most veins contain valves that open and close to maintain unidirectional blood flow and prevent backflow.

Clinic. (2021).

2.2.4 / Blood

Blood is a fluid connective tissue that constitutes about 7–8% of total body weight. It serves as the primary medium for transporting vital substances such as oxygen, nutrients, hormones, and waste products. In addition to its transport role, blood regulates body temperature and pH, supports immune functions, and enables blood clotting.

▣ Hall, J. E., & Guyton, A. C. (2020). *Guyton and Hall Textbook of Medical Physiology* (14th ed.). Elsevier.

2.2.4.1 / Main Components of Blood

Blood consists of two primary components:

Plasma

Plasma is the liquid portion of blood, accounting for about 55% of total blood volume. It consists of about 90% water, 7% proteins (e.g., albumin, globulins, fibrinogen), and 3% other substances (electrolytes, hormones, glucose, metabolic waste).

Functions of plasma:

Transports nutrients, gases, and waste products

Maintains osmotic pressure

Regulates acid-base balance

Supports immune responses and coagulation

▣ Marieb, E. N., & Hoehn, K. (2018). *Human Anatomy & Physiology* (11th ed.). Pearson.

Formed Elements

These make up about 45% of blood volume:

Red Blood Cells (RBCs): Biconcave, disc-shaped cells without a nucleus that transport oxygen via hemoglobin and help carry carbon dioxide to the lungs.

▣ Torture, G. J., & Derrickson, B. (2021). *Principles of Anatomy and Physiology* (16th ed.). Wiley.

White Blood Cells (WBCs): Specialized immune cells that fight pathogens. Divided into granulocytes (neutrophils, eosinophils, basophils) and a granulocytes (lymphocytes, monocytes).

▣ Silverthorne, D. U. (2019). *Human Physiology: An Integrated Approach* (8th ed.). Pearson.

Platelets: Small cytoplasmic fragments involved in blood clotting and vascular repair.

▣ Wimpier, E. P., Raff, H., & Strang, K. T. (2019). *Vander's Human Physiology: The Mechanisms of Body Function* (15th ed.). McGraw-Hill Education.

2.1.4.2 / Physiological Functions of Blood

Transport of oxygen, carbon dioxide, nutrients, hormones, and waste products

Regulation of body temperature, pH, and fluid balance

Protection through clotting and immune responses

▣ Hall, J. E., & Guyton, A. C. (2020). *Guyton and Hall Textbook of Medical Physiology* (14th ed.). Elsevier

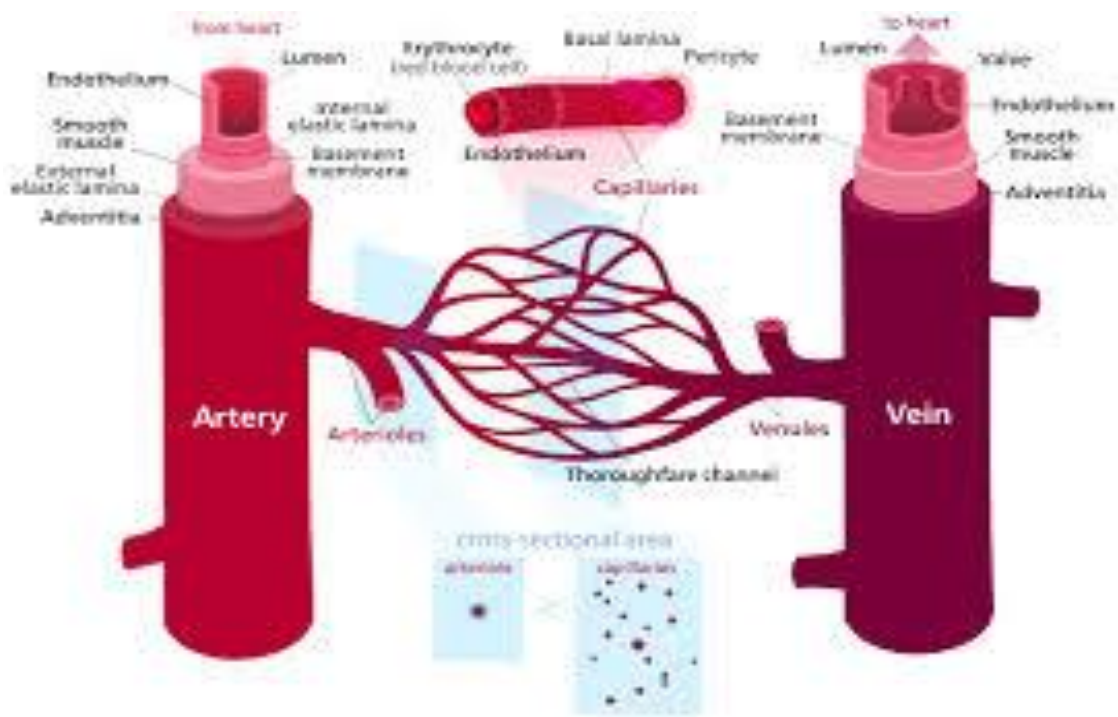


Figure3 Blood Vessels of the Body

2.3 / Concepts of the Respiratory System

2.3.1 / Definition of the Respiratory System

The respiratory system is a group of organs and tissues that work together to exchange gases between the body and the external environment. It supplies the body with oxygen essential for life and eliminates carbon dioxide produced by metabolic processes.

Hall, J. E., & Guyton, A. C. (2020). *Guyton and Hall Textbook of Medical Physiology* (14th ed.). Elsevier

2.3.2 / Components of the Respiratory System

The respiratory system is divided into two main parts:

✓ 2.2.2.1 / Upper Respiratory Tract

Nose

Paranasal sinuses

Pharynx (nasopharynx and oropharynx)

Larynx

✓2.3.2.2 / Lower Respiratory Tract

Trachea

Bronchi

Bronchioles

Lungs and alveoli

Torture, G. J., & Derrickson, B. (2021). *Principles of Anatomy and Physiology* (16th ed.). Wiley

2.3.3 / Functions of the Respiratory System

◆ Primary Function:

Gas exchange:

Intake of oxygen (O₂) into the blood

Removal of carbon dioxide (CO₂) from the body

◆ Additional Functions:

Regulation of blood pH through control of CO₂ levels

Olfaction (smell) via receptors in the nasal cavity

Filtering, humidifying, and warming inhaled air

Silverthorn, D. U. (2019). *Human Physiology: An Integrated Approach* (8th ed.). Pearson

2.3.4 / Respiration

Respiration occurs in three sequential phases:

✓2.3.4.1 / Pulmonary Ventilation

Movement of air in and out of the lungs (inhalation and exhalation)

✓2.3.4.2 / External Respiration

Exchange of gases (O₂ and CO₂) between alveoli and pulmonary blood

✓2.3.4.3 / Internal Respiration

Exchange of gases between systemic blood and body cells

Widmaier, E. P., Raff, H., & Strang, K. T. (2019). *Vander's Human Physiology* (15th ed.). McGraw-Hill

Education

2.3.5 / Mechanics of Breathing

Breathing involves changes in thoracic cavity volume caused by muscle action:

Inhalation:

Active process involving contraction of the diaphragm and intercostal muscles

Exhalation:

Passive at rest, occurring when respiratory muscles relax

Marieb, E. N., & Hoehn, K. (2018). *Human Anatomy & Physiology* (11th ed.). Pearson

2.3.6 / Alveoli

Alveoli are the functional units of the lungs.

Gas exchange between alveolar air and pulmonary capillaries occurs via simple diffusion through thin alveolar walls.

Torture, G. J., & Derrickson, B. (2021). *Principles of Anatomy and Physiology* (16th ed.). Wiley

2.3.7 / Control of Breathing

Breathing is regulated by the respiratory centers in the brainstem:

Medulla oblongata

Pons

These centers respond to blood concentrations of:

Carbon dioxide (CO₂)

pH (hydrogen ion concentration)

Oxygen (O₂)

Hall, J. E., & Guyton, A. C. (2020). *Guyton and Hall Textbook of Medical Physiology* (14th ed.).

Elsevier

2.4 / Pulmonary Function Tests (PFTs)

Pulmonary function tests are clinical tools used to assess the efficiency of the respiratory system and to diagnose certain diseases such as:

Asthma

Chronic Obstructive Pulmonary Disease (COPD)

Pulmonary fibrosis

▣ Hall, J. E., & Guyton, A. C. (2020). *Guyton and Hall Textbook of Medical Physiology* (14th ed.). Elsevier.

2.4.1 / Spirometry

This test measures air volume and flow during inhalation and exhalation.

Key indicators:

Forced Vital Capacity (FVC)

Forced Expiratory Volume in 1 second (FEV1)

FEV1/FVC ratio: helps identify obstructive lung disorders

▣ Marieb, E. N., & Hoehn, K. (2018). *Human Anatomy & Physiology* (11th ed.). Pearson.

2.4.2 / Lung Volume Measurement (Plethysmography)

This assesses:

Total Lung Capacity (TLC)

Residual Volume (RV)

It helps detect restrictive disorders or air trapping.

▣ Hall, J. E., & Guyton, A. C. (2020). *Guyton and Hall Textbook of Medical Physiology* (14th ed.). Elsevier.

2.4.3 / Diffusing Capacity Test (DLCO)

This test evaluates the lung's ability to transfer gases (e.g., O₂, CO) from the alveoli to the blood.

It is essential for diagnosing interstitial lung disease and pulmonary vascular conditions.

▣ West, J. B. (2012). *Respiratory Physiology: The Essentials* (9th ed.). Lippincott Williams & Wilkins.

2.4.4 / Bronchial Challenge Tests

These are used to diagnose asthma and airway hyperreactivity.

They involve inhaling methacholine or performing supervised exercise.

▣ Levitzky, M. G. (2013). *Pulmonary Physiology* (8th ed.). McGraw-Hill Education.

2.4.5 / Uses of Pulmonary Function Tests

Accurate diagnosis of obstructive, restrictive, or mixed lung diseases

Evaluation of treatment efficacy

Preoperative risk assessment

Monitoring of disease progression

▣ Weinberger, S. E., Cockrill, B. A., & Mandel, J. (2021). *Principles of Pulmonary Medicine* (7th ed.).

Elsevier.

2.5 Physical Activity in Cardiovascular Diseases

2.5.1 Importance of Physical Activity

Regular physical activity:

Improves blood circulation

Enhances cardiac efficiency

Reduces risk of cardiovascular complications

Helps control risk factors (e.g., hypertension, diabetes, dyslipidemia)

▣ Thompson, P. D., et al. (2013). *ACSM's Guidelines for Exercise Testing and Prescription* (9th ed., pp. 243–245).

2.5.2 Indications for Exercise in Cardiac Patients

1 Stable Ischemic Heart Disease

Moderate activity (e.g., brisk walking) is encouraged regularly.

█ Fletcher, G. F., et al. (2013). *Circulation*, 128(8), 873–934.

2 Post-Myocardial Infarction Rehabilitation

Exercise improves functional capacity and reduces mortality.

█ Pescatello, L. S. (2014). *ACSM's Guidelines* (9th ed., p. 247).

3 Stable Heart Failure (NYHA Class I–II)

Aerobic activity is safe and effective under medical supervision.

█ McKelvie, R. S., et al. (2002). *Journal of the American College of Cardiology*, 39(12), 1995–2002.

2.4.3 / Contraindications for Exercise in Cardiac Patients

Physical activity should be avoided until clinical stabilization in the following conditions:

Unstable Angina

Thompson et al. (2013). *ACSM's Guidelines* (p. 251).

Acute or Decompensated Heart Failure

Marie, E. N., & Hoehn, K. (2018). *Human Anatomy & Physiology* (11th ed., p. 822). Pearson.

Severe Aortic Stenosis █ Braun Wald, E., et al. (2019). *Braun Wald's Heart Disease* (11th ed., Vol. 1, p. 1064).

Uncontrolled Arrhythmias

Zips, D. P., & Joliffe, J. (2013). *Cardiac Electrophysiology* (6th ed., p. 1123).

2.4.4 █ Pre-Exercise Evaluation Guidelines

Before starting a cardiac exercise program:

Conduct full clinical evaluation (e.g., ECG, stress test, BP monitoring)

Determine physical capacity (VO₂ max or METs)

Begin under medical supervision

Monitor vital signs during and after sessions

Arena, R., Myers, J., et al. (2007). *Progress in Cardiovascular Diseases*, 49(6), 420–429.

2.5.5 /Practical Summary

Exercise is a therapeutic tool for cardiovascular patients. However:

It must be individualized

Supervision is essential

Cardiac rehabilitation programs provide the safest, most effective approach

Franklin, B. A., et al. (2000). *American Journal of Cardiology*, 85(5), 16–22

2.6 /Sports Performance Indicators for Physical Fitness

Sports performance indicators are quantitative and qualitative tools used to assess the functional capacities of the body during physical activity. These indicators help identify strengths and weaknesses in order to improve athletic performance or promote general health.

2.6.1 /Scientific Definition

Sports performance indicators refer to a set of measurable data that reflect:

The efficiency of physiological systems (cardiovascular, respiratory, muscular, metabolic)

The body's capacity for energy production and adaptation to physical stress

Neuromuscular responses to motor demands

Reference: Arena, R., Myers, J., et al. (2007). Assessment of functional capacity in clinical and research settings. *Progress in Cardiovascular Diseases*, 49(6), 420–429.

2.6.2/ Top Global Indicators

VO₂ max (Maximal Oxygen Consumption)

An indicator of cardiorespiratory efficiency, representing the maximum oxygen uptake during intense physical activity.

Formula: $VO_2 \text{ max} = \text{Peak oxygen consumption (ml/min)} \div \text{Body weight (kg)}$

Interpretation: 30–40 ml/kg/min = Average level / ≥ 60 ml/kg/min = Elite athlete

Reference: Powers, S. K., & Howley, E. T. (2017). *Exercise Physiology: Theory and Application to Fitness and Performance* (10th ed.). McGraw-Hill Education. p. 245.

Lactate Threshold (LT)

Represents the point where blood lactate starts to accumulate significantly (>4 mol/L), and reflects anaerobic capacity.

Approximate Formula: $LT \approx 0.8 \times VO_2 \text{ max}$

Reference: Brooks, G. A., Fahey, T. D., & Baldwin, K. M. (2005). *Exercise Physiology: Human Bioenergetics and Its Applications* (4th ed.). McGraw-Hill. p. 123.

Heart Rate Recovery (HRR)

Indicates the heart's ability to recover post-exercise and is a strong predictor of autonomic function and cardiovascular health.

Formula: $HRR = \text{Peak heart rate} - \text{Heart rate after 1 minute of rest}$

Interpretation: $HRR < 12$ bpm \rightarrow Higher cardiovascular risk

Reference: Cole, C. R., Blackstone, E. H., Packo, F. J., Sander, C. E., & Lauer, M. S. (1999). *Heart-rate recovery immediately after exercise as a predictor of mortality. New England Journal of Medicine, 341(18), 1351–1357.*

Relative Strength

A measure of muscular power relative to body mass.

Formula: $\text{Relative Strength} = \text{Max weight lifted (kg)} \div \text{Body weight (kg)}$

Example: Lifting 100 kg at a body weight of 70 kg \rightarrow Relative Strength = 1.42

Reference: Baechle, T. R., & Earle, R. W. (2008). *Essentials of Strength Training and Conditioning* (3rd ed.). Human Kinetics. p. 245.

Endurance Index

Used to measure fatigue resistance during exercise.

Formula: $\text{Endurance Index} = \text{Performance duration (seconds)} \div \text{Average heart rate}$

Reference: McArdle, W. D., Ketch, F. I., & Ketch, V. L. (2015). *Exercise Physiology: Nutrition, Energy, and Human Performance* (8th ed.). Lippincott Williams & Wilkins. p. 623.

2.6.3/ Practical Applications

Athlete Selection:

Endurance athletes typically have $VO_2 \text{ max} > 60$ ml/kg/min and high LT values.

Strength athletes require Relative Strength > 1.5 .

Reference: Reilly, T., Bangs, J., & Franks, A. (2000). *Anthropometric and physiological predispositions for elite soccer. Journal of Sports Sciences, 18(9), 669–683.*

Training Program Design:

Indicators like HRR and LT help regulate intensity and prevent overtraining.

2.6.4 /Measurement Protocols

Standardized Conditions

4-hour fasting before measurement

Measurement in the morning after bladder emptying

Use of calibrated instruments (non-stretchable measuring tape, precision electronic scales)

Reference: International Society for the Advancement of Ki anthropometry (2011). *International Standards for Anthropometric Assessment.*

Instrument Accuracy

DEXA (Dual-energy X-ray Absorptiometry): $\pm 1.5\%$ error (Gold standard)

Skinfold Calipers: $\pm 3\text{--}5\%$ error, depending on the examiner's skill

Reference: Lohman, T. G., et al. (1988). *Advances in Body Composition Assessment*. Human Kinetics.

2.6.5/ Sports Applications

Athlete Selection (e.g., swimmers: Arm span / Height > 0.4 ; runners: Leg length / Torso length > 1.1)

Performance Monitoring (e.g., a 5% increase in muscle mass with stable fat percentage indicates improved performance)

References: Auckland, T. R., et al. (2012). *Morphological characteristics of elite athletes*. *British Journal of Sports Medicine*, 46(9), 613.

Huff, G. G., & Triplett, N. T. (2016). *Essentials of Strength Training and Conditioning*. Human Kinetics, p. 215.

2.6.6/ Physiological Standards

Maximal Oxygen Uptake (VO_2 max)

Maximum volume of oxygen the body can consume during maximal effort (ml/kg/min)

Normal Range: 35–40 ml/kg/min; >60 for elite athletes

Reference: Bassett, D. R., & Hawley, E. T. (2000). *Limiting factors for maximum oxygen uptake*. *Exercise and Sport Sciences Reviews*, 28(1), 25.

Lactate Threshold

The point during exercise at which blood lactate exceeds 4 mmol/L, reflecting endurance capacity

Reference: Jones, A. M., & Carter, H. (2000). *Effect of endurance training on lactate threshold*. *Sports Medicine*, 29(6), 418.

Maximal Strength (1RM)

The maximum weight an athlete can lift once in a specific movement (e.g., bench press)

Reference: Haff, G. G., & Triplett, N. T. (2016). *Essentials of Strength Training and Conditioning*. Human Kinetics, p. 381.

Reaction Time

Time from the presentation of a stimulus (like sound) to the initiation of a movement response (measured in milliseconds)

Reference: Schmidt, R. A., & Lee, T. D. (2011). *Motor Control and Learning* (5th ed.). Human Kinetics, p. 93.

2.6.7/ Functional Indicators

Quantitative indicators measuring the vital physiological systems (cardiovascular, respiratory, metabolic) to evaluate health, physical performance, and stress responses.

Reference: Kenney, W. L., Wilmore, J., & Costilla, D. (2015). *Physiology of Sport and Exercise* (7th ed.). Human Kinetics, p. 10.

2.6.8/ Metabolic Indicators

Basal Metabolic Rate (BMR)

The amount of energy expended at rest to maintain essential body functions (e.g., breathing, heartbeat).

BMR formula for men: $\text{BMR} = 66 + (13.7 \times \text{weight in kg}) + (5 \times \text{height in cm}) - (6.8 \times \text{age})$

Reference: Harris, J. A., & Benedict, F. G. (1918). *A biometric study of basal metabolism*. *Proceedings of the National Academy of Sciences*, 4(12), 370.

Exercise Economy

The amount of oxygen consumed to perform a specific task (e.g., running a fixed distance)

Reference: Saunders, P. U., et al. (2004). *Factors affecting running economy*. *Sports Medicine*, 34(7), 465.

2.6.9 /Practical Applications of Metabolic Standards

Clinical Medicine

Heart Failure Diagnosis: Cardiac output < 4 L/min with increased pulmonary artery pressure

Reference: Ponikowski, P., et al. (2016). *ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. European Heart Journal*, 37(27), 2129.

Sports Science

Training Intensity Optimization: Training at 85–90% of lactate threshold improves endurance

Reference: Seiler, S., & Tenenbaum, E. (2009). *Intervals, thresholds, and long slow distance: the role of intensity and duration in endurance training. Sports Science*, 23(4), 6.

2.6.10 /Advanced Measurement Protocols

Cardiopulmonary Exercise Testing (CPET)

Conducted on a treadmill or cycle ergometer with gas exchange analysis

Measures VO_2 max, ventilator threshold, and heart electrical activity (ECG)

Reference: American Thoracic Society. (2003). *ATS/ACCP Statement on Cardiopulmonary Exercise Testing. American Journal of Respiratory and Critical Care Medicine*, 167(2), 211.

1RM Strength Test

Involves progressive loading until the participant reaches maximal effort

Should be conducted under expert supervision

Reference: American College of Sports Medicine (ACSM). (2021). *Guidelines for Exercise Testing and Prescription* (11th ed.). Lippincott, p. 154

2.7 Anthropometric Standards

2.7.1 Definition of Anthropometric Standards

Anthropometric standards are a set of quantitative measurements of the human body aimed at describing the dimensions and morphological characteristics of the individual. These standards include height, weight, body circumferences, relative lengths of limbs, and skinfold thickness. These measurements are used to assess growth, body composition, general health, and physical abilities.

Ross, W. D., & Marvell-Jones, M. J. (1991). *Ki anthropometry. In J. D. MacDougall, H. A. Wenger, & H. J. Green (Eds.), Physiological testing of the high-performance athlete (2nd ed., pp. 223-308). Human Kinetics.*

2.7.2 /Components of Anthropometric Standards

Anthropometric standards include:

Longitudinal dimensions: such as total body height, limb length, trunk length.

Weight: total body mass.

Circumferences: such as arm circumference, chest circumference, waist circumference, thigh circumference.

Skinfolds: measuring the thickness of the subcutaneous fat layer.

Diameters and widths: such as shoulder width, pelvic width.

International Society for the Advancement of Ki anthropometry (ISAK). (2011). International standards for anthropometric assessment (2011 ed.).

2.7.3/ Types of Anthropometric Standards

Anthropometric standards can be classified into:

Longitudinal standards: measurement of various body lengths.

Transverse standards: measurement of body diameters, such as shoulder or pelvic width.

Circumference standards: measurement of various body circumferences.

Skinfold thickness standards: estimation of body fat percentage.

Derived equations: such as fat-free mass or body fat percentage calculations.

Lohman, T. G., Roche, A. F., & Marmoreal, R. (1988). Anthropometric standardization reference manual. Human Kinetics.

2.7.4/ Importance of Anthropometric Standards

Health assessment: helps identify cases of obesity, thinness, or malnutrition.

Sports guidance: determines the body specifications suitable for various sports activities.

Estimation of fat and muscle mass: useful for designing training and nutrition programs.

Monitoring growth in children and adolescents.

Studying physiological adaptations resulting from physical training.

Norton, K., & Olds, T. (1996). Anthropometrical: A textbook of body measurement for sports and health courses. UNSW Press.

2.7.5/ Functions of Anthropometric Standards in Sports

Athlete selection: to determine the suitability of body characteristics for the targeted sport.

Designing individual training programs: based on the athlete's characteristics.

Periodic evaluation of performance and physical development.

Scientific research: to understand the relationship between body composition and physical performance.

Carter, J. E. L. (1996). The Heath-Carter anthropometric somatotype: Instruction manual. San Diego State.

2.7.6/ Standard Measurement Protocols

To ensure measurement accuracy, standard scientific protocols must be followed:

Measurement in the morning after bladder emptying.

Fasting for at least 4 hours before measurement.

Use of calibrated tools, such as a non-stretchable tape measure and precision electronic scale.

Device accuracy:

DEXA: $\pm 1.5\%$ (gold standard)

Skinfold caliper: $\pm 3-5\%$

BIA: $\pm 3-8\%$

International Society for the Advancement of Ki anthropometry (ISAK, 2011).

2.7.7 /Scientific and Practical Importance

Anthropometric standards have wide scientific and practical significance:

Clinical medicine: for diagnosing malnutrition and assessing disease risks (e.g., diabetes, cardiovascular diseases).

Sports: for selecting athletes suitable for specific sports and designing training programs.

Anthropology: for studying physical variations between populations and races.

Nutrition: for monitoring body composition changes during diets or supplementation.

Reilly, T., Bangs, J., & Franks, A. (2000). Anthropometric and physiological predispositions for elite soccer. Journal of Sports Sciences, 18(9), 669–683.

2.7.8 /Challenges and Limitations

Despite their importance, anthropometric standards face several challenges:

Population variability: European standards may not apply to Asian or African populations.

Dynamism: measurements change with age, training, and hormonal status.

Incompleteness: they do not measure functional indicators such as strength or endurance, making it necessary to combine them with other assessments for a comprehensive evaluation.

Carter, J. E. L. (1996). *The Heath-Carter anthropometric somatotype*.

2.8 /Physiological Standards

.28.1 /Definition of Physiological Standards

Physiological standards are a set of quantitative and qualitative indicators that reflect the efficiency and functioning of the body's vital systems, such as the cardiovascular, respiratory, muscular, and nervous systems. These standards aim to assess physical capacities, overall health, and the body's response to various physical stresses. They are used to determine the level of physical fitness and to monitor the effects of physical training.

Kenney, W. L., Wilmore, J., & Costilla, D. (2015). Physiology of Sport and Exercise (7th ed.). Human Kinetics.

2.8.2/ Components of Physiological Standards

Physiological standards include:

Cardiorespiratory indicators: e.g., maximal oxygen consumption (VO₂ max), heart rate during exertion and recovery, aerobic capacity.

Neuromuscular indicators: e.g., maximal strength (1RM), motor reaction time, muscular power.

Metabolic indicators: e.g., basal metabolic rate (BMR), lactate threshold, exercise economy.

Powers, S. K., & Hawley, E. T. (2017). Exercise Physiology: Theory and Application to Fitness and Performance (10th ed.). McGraw-Hill Education.

2.8.3 /Types of Physiological Standards

Physiological standards can be classified as:

Aerobic standards: e.g., VO₂ max, ventilator threshold.

Anaerobic standards: e.g., lactate threshold, maximal anaerobic power.

Strength and power standards: e.g., one-repetition maximum (1RM), muscular power.

Metabolic standards: e.g., BMR, exercise economy.

McArdle, W. D., Ketch, F. I., & Ketch, V. L. (2015). Exercise Physiology: Nutrition, Energy, and Human Performance (8th ed.). Lippincott Williams & Wilkins.

2.8.4 /Importance of Physiological Standards

Health evaluation: To assess the efficiency of vital systems and detect early dysfunction.

Sports guidance: For designing training programs based on individual physiological capacities.

Performance monitoring: To track progress during sports seasons.

Scientific research: To study the relationship between physiological functions and athletic or pathological performance.

American College of Sports Medicine (ACSM). (2021). Guidelines for Exercise Testing and Prescription (11th ed.). Lippincott.

.28.5 Functions of Physiological Standards in Sports

To accurately determine the level of physical fitness.

To select athletes according to the requirements of specific sports (e.g., aerobic threshold for runners).

To design individualized training programs and control exercise intensity.

To predict performance and identify risks of fatigue or injury.

Seiler, S., & Tenenbaum, E. (2009). Intervals, thresholds, and long slow distance: The role of intensity and duration in endurance training. Sports Science, 23(4), 6.

2.8.6 Standardized Measurement Protocols

Physiological standards require precise procedures for reliable measurement:

Tests should be conducted under standardized conditions (e.g., in the morning, after a 4-hour fast, in a thermoneutral environment).

Use of accurately calibrated instruments, such as respiratory gas analyzers, ECG devices, and lactate analyzers.

Examples of tools:

CPET (Cardiopulmonary Exercise Testing): The gold standard for VO_2 max and ventilator threshold.

1RM strength test: To assess maximal muscular strength.

American Thoracic Society (2003). ATS/ACCP Statement on Cardiopulmonary Exercise Testing. American Journal of Respiratory and Critical Care Medicine, 167(2), 211.

.28.7 Scientific and Practical Importance

Clinical medicine: Supports the diagnosis of heart and lung diseases and the assessment of disease severity.

Sports science: Determines athletes' ability to perform high-intensity efforts and guides training to achieve specific goals.

Research: Studies the physiological adaptations resulting from training, injury, or illness.

Ponikowski, P., et al. (2016). ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure. European Heart Journal, 37(27), 2129.

2.8.8 Challenges and Limitations

Influence of individual variables: Such as age, gender, and hormonal status.

Environmental effects: Temperature and humidity can affect results.

Measurement complexity: Some tests require advanced equipment and specialized expertise.

Bassett, D. R., & Hawley, E. T. (2000). Limiting factors for maximum oxygen uptake. Exercise and Sport Sciences Reviews, 28(1), 25.

Chapter Summary:

The chapter reviewed the theoretical foundations of physical training and its physiological and morphological effects on young athletes. It focused on training principles, high-intensity training, biological development, physiological adaptations, and sports morphology, in a way that contributes to understanding the relationship between training and cardiorespiratory fitness levels.

Part two: Field Study

Chapter 1: Research Methodology and Field Procedures

introduction:

Now having discussed the theoretical framework of the research in the previous chapters, where we talked about the key ideas pertaining to intensive physical training, cardiorespiratory markers, and the characteristics of young athletes' biological development, we can see that the theoretical part alone is not sufficient for a comprehensive image of the research subject as well as for the realization of the research goals, which are to learn the effect of intensive training on young athletes' cardiorespiratory markers.

To test empirically the hypothesis that has been advanced and to conduct an exact scientific inquiry of practical significance, we undertook this applied section. It is dedicated to determining the population and sample of the investigation, the approach pursued, and the measuring instruments used, as well as to presenting and discussing the outcomes of the study with the aim of drawing scientific conclusions that advance knowledge regarding the impact of intensive training on the efficiency of the cardiorespiratory system in the current population.

/ Methods and mean

Introduction

After addressing the theoretical part of the study in the previous chapters, where we covered the basic concepts related to intensive physical training, cardiorespiratory components, and the importance of these indicators in improving athletic performance in young athletes, it is clear that the theoretical part alone is not sufficient to fully understand the nature of the relationship between intensive training and these indicators. This is because previous studies in this field have provided mixed results; some showed a clear positive impact of intensive training on cardiorespiratory indicators such as VO₂max, heart rate, and vital lung capacity, while others found no significant differences.

Therefore, we have dedicated this chapter to the applied part of the research, in which we will analyze the results of real previous studies using the descriptive analytical method, focusing on cardiorespiratory indicators in young athletes. In doing so, we as researchers aimed to compare and interpret these results in order to draw scientific conclusions that may help coaches and researchers better understand the effects of intensive physical training and develop practical recommendations.

Study Methodology:

In this study, we relied on the descriptive analytical approach because it is the most suitable for the nature of our topic. Through this method, we collected and analyzed a set of previous studies that examined the effect of intensive physical training on cardiorespiratory indicators in young athletes. This approach allowed us to gain a better understanding of the different results reported in these studies and to discuss them in a way that helps us reach conclusions that are closer to reality. We compared the results related to VO₂max, heart rate, and lung capacity across the selected studies, in order to identify points of similarity and difference, and to clarify the impact of intensive physical training on these key indicators.

Study Population and Sample:

The population of study consists of adolescent athletes aged between 14 to 18 years who receive intensive physical training in sports clubs, schools, or organized training schemes. The research was taken from an analysis of previous studies' results based on actual samples in the same age range, namely:

Study 1: This study used a review of the results of 12 previous studies conducted among participants of aerobic gymnastics. The samples were overweight or obese teenagers within the ages of 14 to 18 years to varying degrees.

Study 2: The study utilized a cohort of young athletes who were subjected to endurance training of different intensities. The participants were between the age of 14 and 18 years, and changes in lung volume and oxygen consumption at rest and after maximal effort were determined.

Study 3: The subjects were 20 professional canoe polo athletes who went through training regimens consisting of high-intensity interval training and low-intensity continuous training. Cardiorespiratory and hematological effect on the athletes was the measure used in this study.

Study 4: It was a systematic review with 6 studies involving adolescents aged 14 to 18 years with obesity. The impact of having high-intensity interval training in school physical education classes was studied.

All the researches mentioned above had stringent criteria in selecting samples, i.e., stable weight in the past several months, absence of chronic disease or medical contraindication for exercise, and informed consent of volunteers or parents when required.

Sources of Data

We grounded our research in this research on the results of four recent scientific papers that explored the influence of intensive physical exercise on cardiorespiratory indicators in young sportsmen, aged from 14 to 18 years. We selected these papers because they represent the core of our subject and deal with variables directly related to our research parameters, such as heart rate, VO₂max, and lung capacity.

The data was collected from reliable and open-access academic sources such as Google Scholar, one of the most prominent search engines in the scientific world; Frontiers, an outlet for publishing peer-reviewed scientific articles in health and sports sciences; and Wiley Library, which provides professional scientific content in life and health sciences.

These tools and sources were chosen due to the competence of the research published, pertinence of the sources to the theme of the research in terms of methodology, group under study, and type of the cardiorespiratory indicators analyzed.

Title of the study:

Effects of one week different intensity endurance exercise on cardiorespiratory and cardio metabolic markers in junior young athletes

Objective of the study:

The objective of the current study was to establish the effect of one week of endurance training of varying intensity on certain cardiorespiratory and cardio metabolic indexes in young athletes.

Study methodology

The study relied on a review of the literature, utilizing already conducted studies that had explored the impact of endurance training on cardiorespiratory parameters among young sport practitioners.

Study population:

Population was young athletes aged between 14 and 18 years old who were endurance training practitioners at sports clubs or centers specializing in sports.

Data collection tools:

The data were collected from 12 earlier scientific studies that examined the influence of endurance training with different intensities in young athletes. The studies were retrieved from reliable academic sources such as Google Scholar, Springer Link, and Garuda.

The researchers analyzed the data in four major steps:

- 1 Searching and retrieving studies on the impact of endurance training on cardiorespiratory measures.
- 2 Categorizing and organizing information according to the topics covered in the studies.
- 3 Comparing and analyzing the findings to identify important information related to the cardiorespiratory markers.
- 4 Drawing concise scientific conclusions that help in understanding the effect of endurance training on these markers.

Table 1 General characteristics of participants

Parameters	Moderate intensity training group	High intensity training group	ANOVA
	M±SD	M±SD	P value
Age	19.27±1.28	19.47±1.30	0.67
Height	1.67±0.06	1.67±0.07	0.84
Body mass	53.87±4.76	53.96±5.67	0.964
BMI	19.39±1.49	19.31±1.41	0.881

ANOVA, analysis of variance; BMI, body mass index; M±SD, mean and standard deviation; P, probability.

Table 2 A comparison of cardiorespiratory and cardio metabolic responses between and within the groups

Moderate intensity group Variables	High intensity group M±SD		between groups I					
Cardiorespiratory markers								
Systolic BP	120.5±8.3	119.4±10.3	0.762	113.5±5.5	114.5±6.5	0.644	7.449	0.01
Diastolic BP	74.1±8.5	77.5±9.80	0.242	73.5±8.7	74.1±6.9	0.828	0.29	0.866
MAP	89.5±7.1	91.6±9.7	0.454	86.8±6.5	87.3±4.8	0.759	2.275	0.143
RHR	75.9±8.3	71.7±0.6	0.250	71.2±8.8	71.7±7.0	0.872	2.235	0.146
VO2max	60.7±4.5	62.2±4.7	0.345	60.4±4.5	60.8±4.2	0.082	0.46	0.831
Cardio metabolic markers								
LDH	136±38.4	245.8±102.1	0.002	178.9±52	297.5±10	0.001	1.961	0.172
catnip	0.10±0.11	0.44±0.22	0.0001	0.12±0.12	0.59±0.32	0.0001	2.482	0.126
CK-MB	1.12±0.97	3.39±10	0.0002	1.71±1.4	4.1±1.6	0.00001	1.764	0.195

ANOVA, analysis of variance; BP, blood pressure; CK-MB, creatine kinase myocardial band; catnip, cardiac troponin I; LDH, lactate dehydrogenase; MAP, mean arterial pressure; M±SD, mean and standard deviation; RHR, resting heart rate; VO2max, maximum oxygen consumption

Study2

Effects of Endurance Training Intensity on Pulmonary Diffusing Capacity at Rest and after Maximal Aerobic Exercise in Young Athletes

Objective:

To determine the effect of variable intensity endurance training on changes in essential lung capacity and oxygen consumption rate at rest and after maximal exercise.

Methodology:

Experimental study design.

The subjects were subjected to sessions of varying intensity endurance training, followed by measurement of pulmonary function at rest and after maximal aerobic exercise.

✓Study population and sample:

The sample consisted of a group of young athletes, both genders, 14 to 18 years of age, who participated in systematic training programs in sport clubs or schools and conducted endurance training

at different intensities. The sample was selected on the basis of stable body weight in the past few months and the absence of chronic disease or medical contraindications to physical exertion. A

Collection Instruments

The researcher in this study relied on a set of instruments and data collection methods that are appropriate to the descriptive analytical method adopted, to achieve the research goals specifically and objectively. These instruments were as follows:

High-Intensity Interval Training (HIIT) Program:

The researchers implemented a training program intensively for three months, with the aim of building up the cardiorespiratory parameters of the research sample. The program was designed on scientific basis and consisted of the following phases:

Warm-up phase: Lasted between 5 to 10 minutes, with the aim of preparing the muscles and both the cardiovascular and respiratory systems for the upcoming high-intensity effort.

Loading phase: Characterized by high-intensity exercises lasting 30 to 60 seconds, performed at the participants' maximum load capacity.

Recovery phase: Each loading phase was followed by an active recovery phase lasting two to three times the duration of the previous exercise, with exercise intensity at a moderate level. The recovery phase was dictated by the principle of "sufficient rest," concluded when the participant was physically ready for the next loading phase.

Total session duration: Each session attempted to complete as many intervals as possible, and the total duration ranged from 15 to 40 minutes depending on the capacity and physical response of the participants.

Pre- and post-tests:

Body Mass Index (BMI) and simple physical function in both the control group and the experimental group were recorded before and after the program, using the In Body 770 machine to assess body composition (muscle mass, fat mass, body water, etc.).

Statistical analysis:

Data were processed and analyzed using the SPSS statistical program, where the researcher employed appropriate statistical treatments from which research hypotheses could be tested and accurate scientific conclusions could be reached regarding the effect of intensive training on the cardiorespiratory parameters of the study sample.

Key Rest

		Mean ± SD	<i>p</i> (Paired <i>t</i> Test)	ICC	ICC: CI 95%	CV (%)
VI (L)						
Rest	1st trial	5.18 ± 0.18	0.48	0.92	0.78–0.97	1.73
	2nd trial	5.17 ± 0.15				
Exercise	1st trial	5.45 ± 0.24	0.07	0.89	0.68–0.96	2.65
	2nd trial	5.38 ± 0.22				
VA (L)						
Rest	1st trial	7.48 ± 0.33	0.14	0.89	0.69–0.96	2.63
	2nd trial	7.40 ± 0.29				
Exercise	1st trial	7.56 ± 0.35	0.69	0.96	0.89–0.99	1.76
	2nd trial	7.54 ± 0.34				

DLNO (ml/kman ⁻¹ ·mmHg ⁻¹)						
Rest	1st trial	196.78 ± 1.32	0.13	0.80	0.41-0.93	1.62
	2nd trial	196.29 ± 1.63				
Exercise	1st trial	256.46 ± 5.97	0.08	0.91	0.75-0.97	1.34
	2nd trial	254.28 ± 6.07				
DLCO (ml/kman ⁻¹ ·mmHg ⁻¹)						
Rest	1st trial	47.84 ± 0.79	0.71	0.84	0.54-0.94	1.23
	2nd trial	47.46 ± 0.58				
Exercise	1st trial	53.92 ± 2.41	0.92	0.94	0.83-0.98	2.07
	2nd trial	53.89 ± 2.32				
DM (ml/kman ⁻¹ ·mmHg ⁻¹)						
Rest	1st trial	97.43 ± 2.84	0.56	0.96	0.86-0.98	1.24
	2nd trial	97.25 ± 3.05				
Exercise	1st trial	131.35 ± 2.57	0.11	0.96	0.89-0.99	0.81
	2nd trial	130.89 ± 2.96				

Condition	Trial	VC (mL) ± SD	p (Paired t Test)	ICC (95% CI)	CV (%)
Rest	1st trial	130.79 ± 6.68	0.38	0.94	2.38
	2nd trial	131.50 ± 6.92		(0.84-0.98)	
Exercise	1st trial	159.36 ± 1.24	0.87	0.82	0.86
				(0.48-0.94)	
	2nd trial	159.41 ± 2.14			

Table 3. Intra-class correlation coefficients (ICCs) for relative reliability and coefficients of variation for absolute reliability. Data are mean ± standard deviation (SD) of VI: inspiratory volume; VA: alveolar volume; TL_{NO}: pulmonary diffusing capacity for nitric oxide; DL_{CO}: pulmonary diffusing capacity for carbon monoxide; DM: membrane component of alveolar- capillary transfer of gases; VC: capillary blood volume. IET group: intense endurance training group; MET: moderate endurance training group.

Parameter	IET Group (Mean ± SD)			MET Group (Mean ± SD)			Variance Analysis/Effects					
	Pre	Post	ES	Pre	Post	ES	Group		Time		Group × Time	
							p	ES	p	ES	p	ES
VI (L)	5.17 ± 0.22	5.43 ± 0.32	0.94	5.26 ± 0.27	5.22 ± 0.08	0.2	0.526	0.015	0.214	0.055	0.091	0.099
DM (ml/min/mm Hg)	96.06 ± 3.90	108.85 ± 3.69	3.36	99.69 ± 2.87	101.84 ± 4.11	0.61	0.203	0.057	0.000	0.541	0.000	0.374
(ml/min/mm Hg)	189.21 ± 3.63	213.16 ± 8.98	2.72	197.08 ± 1.83	200.24 ± 2.62	1.4	0.003	0.279	0.000	0.567	0.000	0.388
(ml/min/mm Hg)	46.88 ± 1.46	53.43 ± 3.18	2.36	47.89 ± 3.93	47.84 ± 1.23	0.02	0.000	0.411	0.000	0.407	0.000	0.404
Vc (mL)	131.68 ± 10.17	150.05 ± 3.39	2.42	130.96 ± 7.75	130.51 ± 14.51	0.08	0.009	0.221	0.016	0.190	0.009	0.222
VA (L)	7.40 ± 0.04	7.52 ± 0.15	1.09	7.46 ± 0.37	7.42 ± 0.45	0.1	0.857	0.001	0.724	0.005	0.449	0.021
Resting HR (bpm)	63.5 ± 1.7	62 ± 1.8	0.84	64.5 ± 2.3	63.8 ± 0.9	0.35	0.03	0.16	0.09	0.10	0.48	0.09

Table 4. Pulmonary parameters measured at rest: alveolar volume (VA), nitric oxide lung transfer (TL_{NO}), carbon monoxide lung transfer (TL_{CO}), membrane factor for CO (Dam_{CO}), lung capillary blood volume (V_c), inspiratory volume (VI), residual volume (VR) and resting heart rate (Herr) before and after training program in experimental and control groups. Values for interaction effects and effect sizes (ESS) are also shown. Data are mean ± standard deviation (SD) of alveolar volume (VA), nitric oxide lung transfer (TL_{NO}), carbon monoxide lung transfer (TL_{CO}), membrane factor for CO (Dam_{CO}), lung capillary blood volume (V_c), inspiratory volume (VI), residual volume (VR) and resting heart rate (Resting HR), intense endurance training (IET) and moderate endurance training (MET).

Parameter	IET Group (Mean ± SD)			MET Group (Mean ± SD)			Variance Analysis/Effects					
	Pre	Post	ES	Pre	Post	ES	Group		Time		Group × Time	
							p	ES	p	ES	p	ES
VI (L)	5.41 ± 0.43	5.49 ± 0.22	0.23	5.36 ± 0.29	5.41 ± 0.2	0.2	0.537	0.014	0.553	0.013	0.889	0.001
DM (mL/min/mmHg)	131.3 ± 3.21	140.09 ± 1.00	3.69	131.4 ± 1.96	132.56 ± 6.63	0.24	0.011	0.211	0.001	0.324	0.009	0.220
TL _{NO} (mL/min/mmHg)	256.39 ± 8.59	276.91 ± 6.59	2.68	256.54 ± 1.59	261.04 ± 7.79	8	0.003	0.281	0.000	0.498	0.002	0.289
TL _{CO} (mL/min/mmHg)	53.71 ± 0.85	59.03 ± 0.80	6.45	54.14 ± 3.41	54 ± 5.21	0.03	0.049	0.131	0.028	0.160	0.022	0.174
V _c (mL)	159.09 ± 0.63	179.31 ± 7.23	3.94	159.15 ± 0.58	160.48 ± 8.81	0.21	0.000	0.435	0.000	0.504	0.000	0.439
VA (L)	7.49 ± 0.38	7.96 ± 0.30	1.37	7.50 ± 0.27	7.53 ± 0.47	0.05	0.125	0.082	0.068	0.114	0.104	0.091
HR _{max} (bpm)	196.7 ± 2.1	189.7 ± 1.2	3.1	195.7 ± 1.7	196.1 ± 2.3	0.19	0.000	0.36	0.000	0.46	0.000	0.52
VO ₂ max (mL/kg/min)	47.2 ± 1.39	49.7 ± 0.66	2.22	47.5 ± 1.23	47.7 ± 0.91	0.12	0.03	0.15	0.003	0.28	0.006	0.24

Table 5. Comparison between the intense endurance training group (IET) and moderate endurance training group (MET) before and after 8-week period. Values for interaction effects and effect sizes (ESS) are also shown. Data are mean ± standard deviation (SD) of alveolar volume (VA), nitric oxide lung transfer (TL_{NO}), carbon monoxide lung transfer (TL_{CO}), membrane factor for CO (Dam_{CO}), lung capillary blood volume (V_c), inspiratory volume (VI), residual volume (VR), maximal heart rate (Humax), maximal oxygen uptake (VO₂max), intense endurance training (IET) and moderate endurance training (MET).

Study 3

Study Title

Title:

Effects of Low-Volume High-Intensity Interval Training Versus Continuous Endurance Training on Hematological and Cardiorespiratory Adaptations in Professional Canoe Polo Athletes.

Objective:

This study aimed to compare the effects of low-volume high-intensity interval training (HIIT) in two forms (variable intensity and variable volume) with continuous endurance training (CET) on hematological, immunological, and cardiorespiratory adaptations in professional canoe polo athletes over a short period.

Method:

Experimental comparative design.

Population and Sample:

The study sample consisted of 21 professional canoe polo athletes (mean age 24 ± 3 years), all elite players including members of the Iranian national team. Participants were randomly divided into three groups:

Variable intensity HIIT group (7 athletes)

Variable volume HIIT group (7 athletes)

Continuous endurance training (CET) group (7 athletes)

Data Collection Tools:

Training Program:

The training program was 3 weeks with 3 weekly sessions (9 sessions in total). The interventions during the training were as follows:

Variable intensity HIIT: 6 repetitions × 60 seconds per session, with intensity that progressively increased up to 130% of $v\text{VO}_2$ peak, and a work-to-rest ratio of 1:3.

Variable volume HIIT: 6 to 9 repetitions × 60 seconds per session at 100% $v\text{VO}_2$ peak, with a work-to-rest ratio of 1:3.

CET: Prolonged paddling for 60 minutes at 75% $v\text{VO}_2$ peak.

Physiological Measurements:

VO_2 peak, ventilator threshold (VT), ventilation during peak and VT (VE), tidal volume (VT), respiratory frequency (R f), oxygen pulse (VO_2/HR), and ventilator equivalent per oxygen pulse (VE/HR) were measured using gas analyzer (Costed K4B2).

Hematological and Immunological Measurements

Blood was sampled for the measurement of mean platelet volume (MPV), mean corpuscular hemoglobin concentration (MCHC), red cell distribution width (RDW), lymphocyte, monocyte, and eosinophil counts on an automated hematology analyzer (Diatom Abacus C).

Statistical analyses were carried out using the implementation of IBM SPSS 21. Two-way ANOVA was used to test between-groups and within-groups differences and then followed by Tukey's post hoc test in the event of significant differences. The significance level was ($\alpha = 0.05$).

Data Collection Tools:

Training Program:

The training program was 3 weeks with 3 weekly sessions (9 sessions in total). The interventions during the training were as follows:

Variable intensity HIIT: 6 repetitions × 60 seconds per session, with intensity that progressively increased up to 130% of $v\text{VO}_2$ peak, and a work-to-rest ratio of 1:3.

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CET: Prolonged paddling for 60 minutes at 75% $v\text{VO}_2$ peak.

Physiological Measurements:

VO_2 peak, ventilator threshold (VT), ventilation during peak and VT (VE), tidal volume (VT), respiratory frequency (Fry), oxygen pulse (VO_2/HR), and ventilator equivalent per oxygen pulse (VE/HR) were measured using gas analyzer (Costed K4B2).

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Statistical analyses were carried out using the implementation of IBM SPSS 21. Two-way ANOVA was used to test between-groups and within-groups differences and then followed by Tukey's post hoc test in the event of significant differences. The significance level was ($\alpha = 0.05$).

TABLE 1. Pretraining vs. post-training values for \dot{V}_{O_2} peak, peak ventilation at \dot{V}_{O_2} peak ($\dot{V}_E@V_{O_2}$ peak), tidal volume at \dot{V}_{O_2} peak ($V_T@V_{O_2}$ peak), respiratory frequency at \dot{V}_{O_2} peak ($R@V_{O_2}$ peak), ventilatory equivalent for oxygen at \dot{V}_{O_2} peak ($\dot{V}_E@V_{O_2}$ peak), oxygen pulse at \dot{V}_{O_2} peak ($\dot{V}_{O_2}/HR@V_{O_2}$ peak), ventilatory equivalent for oxygen pulse at \dot{V}_{O_2} peak ($\dot{V}_E/HR@V_{O_2}$ peak).*

	VIHIIT		VHIIT		CET	
	Pre	Post	Pre	Post	Pre	Post
\dot{V}_{O_2} peak (mlskg ^{2.1} smin ^{2.1})	37.8 6 4.6	†40.7 6 3.4	39.2 6 4.1	†41.8 6 4.6	37.1 6 5.7	37.9 6 5.9
%Δ		+7.6		+6.7		+2.1
\dot{V}_{O_2} peak (lsmin ^{2.1})	3.04 6 0.53	†3.30 6 0.46	3.27 6 0.37	†3.56 6 0.53	3.14 6 0.37	3.21 6 0.35
%Δ		+8.5		+8.8		+2.2
$V_T@V_{O_2}$ peak (lsb ^{2.1})	112.1 6 14.4	†125.1 6 20.9	121.9 6 16.9	†140.5 6 13.4	121.5 6 23.5	125.2 6 11.5
%Δ		+11.5		+15.2		+3.0
$V_E@V_{O_2}$ peak (lsb ^{2.1})	2.10 6 0.48	2.07 6 0.27	2.27 6 0.29	2.23 6 0.25	2.16 6 0.46	2.21 6 0.37
%Δ		21.4		21.7		+2.3
$R@V_{O_2}$ peak (bsmin ^{2.1})	54.5 6 7.6	59.8 6 8.2	53.0 6 6.8	†64.2 6 6.2	56.7 6 8.8	57.5 6 8.8
%Δ		+9.7		+21.1		+1.7
$\dot{V}_E/V_{O_2}@V_{O_2}$ peak	40.8 6 3.8	42.1 6 5.0	37.7 6 5.0	39.8 6 3.1	38.7 6 7.5	41.0 6 5.6
%Δ		+3.1		+5.5		+5.9
$\dot{V}_{O_2}/HR@V_{O_2}$ peak (mlsbsmin ^{2.1})	18.9 6 4.7	19.4 6 3.1	19.1 6 3.0	19.7 6 2.5	19.1 6 1.5	19.1 6 2.1
%Δ		+2.6		+3.1		0.00
$\dot{V}_E/HR@V_{O_2}$ peak (lsbsmin ^{2.1})	0.61 6 0.12	0.65 6 0.13	0.71 6 0.11	0.79 6 0.07	0.70 6 0.09	0.72 6 0.05
%Δ		+6.5		+11.2		+2.8

*VIHIIT = HIIT with variable intensity; VHIIT = HIIT with variable volume; CET = continuous endurance training; lsb^{2.1} = litersbreath^{2.1}; bsmin^{2.1} = breathsmin^{2.1}; mlsbsmin^{2.1} = millilitersbeatsmin^{2.1}; lsbsmin^{2.1} = litersbeatsmin^{2.1}.

†Significantly greater than pretraining value ($p \neq 0.05$).

TABLE 2. Pretraining vs. post-training values for ventilatory threshold (VT) expressed as \dot{V}_{O_2} at VT ($\dot{V}_{O_2}@VT$), ventilation at VT ($\dot{V}_E@VT$), tidal volume at VT ($V_T@VT$), respiratory frequency at VT ($R@VT$), ventilatory equivalent for oxygen at VT ($\dot{V}_E/V_{O_2}@VT$), oxygen pulse at VT ($\dot{V}_{O_2}/HR@VT$), ventilatory equivalent for oxygen pulse at VT ($\dot{V}_E/HR@VT$).*

	VIHIIT		VHIIT		CET	
	Pre	Post	Pre	Post	Pre	Post
$\dot{V}_{O_2}@VT$ (mlskg ^{2.1} smin ^{2.1})	28.5 6 5.31	†31.5 6 4.31	26.3 6 4.61	†32.9 6 4.50	27.3 6 1.83	28.31 6 2.09
%Δ		+10.5		+25.1		+3.6
$\dot{V}_E@VT$ (lsmin ^{2.1})	59.6 6 9.4	†67.0 6 9.0	63.4 6 16.4	†85.0 6 11.1	64.7 6 22.5	67.9 6 12.2
%Δ		+12.4		+34.0		+4.9
$V_T@VT$ (lsb ^{2.1})	1.45 6 0.18	†1.62 6 0.16	1.57 6 0.29	†2.09 6 0.23	1.68 6 0.45	1.71 6 0.30
%Δ		+11.7		+33.3		+1.7
$R@VT$ (bsmin ^{2.1})	32.7 6 7.7	†35.9 6 5.4	35.2 6 5.8	38.1 6 5.5	37.5 6 4.7	40.3 6 7.0
%Δ		+9.7		+8.2		+7.4
$\dot{V}_E/V_{O_2}@VT$	29.0 6 2.3	29.2 6 2.2	28.1 6 3.0	†31.8 6 3.3	29.9 6 2.2	30.0 6 2.2
%Δ		+0.06		+13.1		+0.03
$\dot{V}_{O_2}/HR@VT$ (mlsbsmin ^{2.1})	14.7 6 3.1	†16.6 6 3.7	15.12 6 2.0	†18.37 6 2.2	15.5 6 2.9	16.8 6 1.8
%Δ		+12.9		+21.4		+8.3
$\dot{V}_E/HR@VT$ (lsbsmin ^{2.1})	0.38 6 0.08	†0.41 6 0.07	0.44 6 0.08	†0.56 6 0.07	0.46 6 0.09	0.49 6 0.04
%Δ		+7.8		+27.2		+6.5

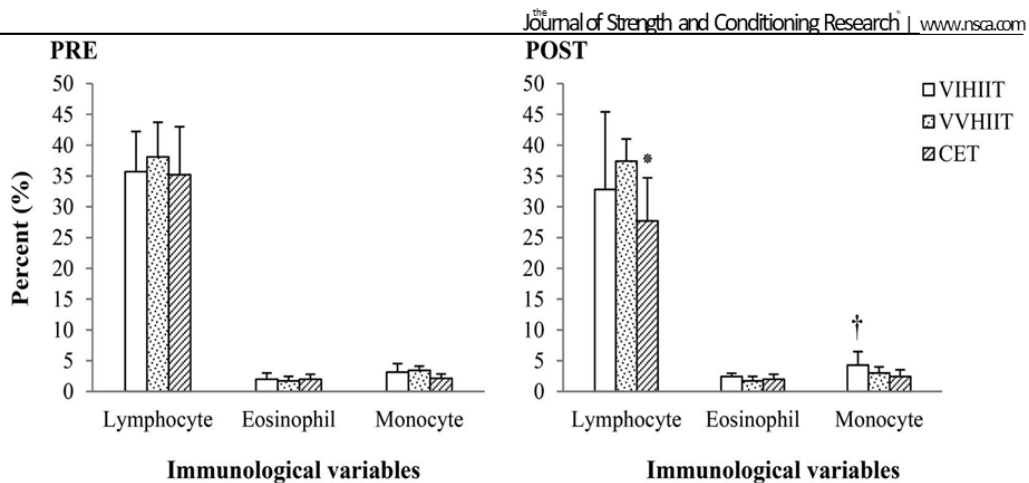
*VIHIIT = HIIT with variable intensity; VHIIT = HIIT with variable volume; CET = continuous endurance training; lsb^{2.1} = litersbreath^{2.1}; bsmin^{2.1} = Breathsmin^{2.1}; mlsbsmin^{2.1} = millilitersbeatsmin^{2.1}; lsbsmin^{2.1} = litersbeatsmin^{2.1}.

†Significantly greater than pretraining value ($p \neq 0.05$).

TABLE 3. Pretraining vs. post-training resting values for red blood cell distribution width (RDW), mean corpuscular volume (MCV), mean corpuscular hemoglobin concentration (MCHC), mean platelet volume (MPV), and white blood cell (WBC).*

	VIHIIT		VWHIIT		CET	
	Pre	Post	Pre	Post	Pre	Post
RDW (%)	11.9 6 0.85	12.0 6 0.91	12.1 6 0.44	†11.6 6 0.31	11.6 6 0.6	11.7 6 0.4
%Δ		+0.08		24.3		+0.08
MCV (fL)	82.6 6 7.6	83.8 6 8.8	84.7 6 2.7	†86.2 6 2.9	86.1 6 3.7	*84.2 6 3.0
%Δ		+1.4		+1.7		22.2
MCHC (%)	33.1 6 1.5	33.1 6 1.5	0.72 6 32.9	0.91 6 32.8	33.3 6 0.49	*34.4 6 0.34
%Δ		0.00		20.03		+3.3
Platelet (31,000\$mm ²³)	249.0 6 38.4	227.7 6 47.3	254.1 6 30.8	246.4 6 36.7	256.0 6 44.4	269.7 6 28.9
%Δ		29.3		23.1		+5.3
MPV (fL)	9.45 6 0.59	†9.71 6 0.61	8.58 6 0.57	†8.75 6 0.54	8.75 6 0.78	8.75 6 0.95
%Δ		+2.7		+1.9		0.00
WBC (31,000\$mm ²³)	6.41 6 1.27	6.22 6 1.41	5.17 6 1.2	5.10 6 0.84	5.72 6 1.3	5.82 6 1.1
%Δ		+3.7		21.3		+1.7

*VIHIIT = HIIT with variable intensity; VWHIIT = HIIT with variable volume; CET = continuous endurance training.
 †Significantly greater than pretraining value ($p \neq 0.05$).



Study 4

Title:

The Effect of High-Intensity Interval Training on Body Composition, Cardiorespiratory Fitness, Mental Health, and Executive Function in Young Obese and Overweight Women

Objective:

To evaluate the effect of a short-term high-intensity interval training (HIIT) program on selected health indicators in young overweight and obese women.

Methodology:

Experimental.

Population and Sample:

The study sample consisted of 48 university women aged between 18 and 25 years, who did not suffer from any health issues that could prevent them from performing physical activity. All participants were overweight or obese and were randomly divided into two groups: an experimental group subjected to the training program and a control group.

Data Collection Tools:

Training program:

A HIIT program was employed 3 times a week for 4 weeks with a 48-hour rest interval between them so that there was no physical and mental fatigue. The sessions were supervised by one graduate in physical education together with an aerobic exercise instructor to ensure the training intensity was equivalent to the effort that was needed.

Each session included:

8 movements × 4 repetitions of aerobic exercises.

Short resting times between exercises (passive recovery).

5-minute warm-up and 5-minute cool-down.

A mixture of dance movements and strength training exercises (skip, front kick, jumps).

The participants also wore Polar H7 heart rate monitors connected to the Team Polar iPad application with real-time heart rate feedback. The goal was $\geq 85\%$ H_{max} ($220 - \text{age}$) to achieve sufficient training intensity.

Anthropometric and body composition measurement:

Height and weight using electronic scale and audiometer (accuracy 0.1 cm and 0.1 kg).

$BMI = \text{weight (kg)} \div \text{height (m}^2\text{)}$.

Percentage body fat (BF%) by bioelectrical impedance analysis (DBA210).

Waist circumference (WC) using a soft metric tape at the level midway between the iliac crest and the lower border of the 12th rib, during the end of expiration, to 0.1 cm nearest.

The measurement taken was the average of two measurements with a deviation not more than 1 cm.

Studies	Subject description	Study design	Training program	Outcomes	Result
Lau et al. (2014)	n ¼ 15 Age: 11.0 ± 0.6 years BM: 51.1 ± 6.6 kg Size: 146.7 ± 5.2 cm	Randomized clinical trial. HIIE, LIIE and CON	HIIE ¼ 12 sets x 15-s at 120% MAS followed by a 15- second passive recovery. Duration: 6 weeks, three times a week.	BMI (kg/m ²) Skinfold thickness (mm) Sum of skinfolds (mm) YYIET (level one)	Y Sum of skinfolds (mm) [YYIET distance covered (m)
Racil et al. (2016)	n ¼ 17 Age: 14.2 ± 1.2 years. BM: 87.3 ± 4.5 kg Size: 164.0 ± 5.0 cm	Randomized clinical trial. HIIT, MIIT and CON	HIIT ¼ 3 sessions x 4e8 min (15 s/15 s)15-s at 100% MAS follow by 15 s recovery at 50% MAS. 3-min of inter-session passive recovery period. Duration: 12 weeks, three times a week.	BM (kg) BMIeZ-score BF (%) WC (cm) VO _{2max} (L\$min ⁻¹)	Y BM (kg) Y BMI Z-score Y WC (cm) Y BF (%) [VO _{2max} (ml/kg/min)
Hay et al. (2015)	n ¼ 38 Age: 15.3 ± 1.7 years BM:89.1 ± 15.7 kg Size: not reported	Randomized clinical trial. HIIT, moderate-intensity and CON	HIIT ¼ 70e85% HRres Duration: 6- month, three times a week.	BM (kg) BMI (kg•m ²) WC (cm). BF% trunk fa% VO _{2max} (ml/kg/min)	[VO _{2max} (ml/kg/min)
Racil et al. (2015)	n ¼ 23 Age: 16.6 ± 0.9 years BM: 83.9 ± 4.5 kg Size: 163 ± 5.0 cm	Randomized clinical trial HIIT, P+HIIT and CON	HIIT ¼ 6 e8 blocks per session of 30-s runs at 100%MAS, with 30-s active recovery between bouts at 50%. Duration: 12 weeks, three times a week.	BMI Z-score WC (cm) BF (%) LM (kg) VO _{2max} (ml/kg/min).	Y BM (kg) Y BMI Z-score Y WC (cm) Y BF (%) [VO _{2max} (ml/kg/min)
McNarry et al. (2015)	n ¼ 15 Age: 9.3 ± 0.9 years BM: 49.1 ± 10.8 Kg Size: 143.3 ± 9.2 cm	Randomized clinical trial EX and CON	EX ¼ 6-min high- intensity exercise followed by 2 min of recovery (6 games per session) and a 4-min circuit. Duration: 6 weeks, two times a week	BM (kg) BMI (kg•m ²) VO _{2max} (ml/kg/min).	[VO _{2max} (ml/kg/min)
Lambrick et al. (2015)	n ¼ 28 Age: 9.3 ± 0.9 years BM 48.9 ± 11.0 kg Size: 143.3 ± 9.0 cm	Randomized clinical trial EX and CON	EX ¼ 6-min high- intensity exercise followed by 2 min of recovery (6 games per session) and a 4-min circuit. Duration: 6 weeks, two times a week.	BM (kg) BMI (kg•m ²) WC(cm) BF(%) LM (kg) VO _{2max} (ml/kg/min).	Y WC (cm) [LM (kg) [VO _{2max} (ml/kg/min).

BM ¼ body mass; BMI ¼ body mass index; WC ¼ waist circumference; BF ¼ body fat; LM ¼ lean mass; FFM ¼ free fat mass; LIIE ¼ low intensity intermittent exercise; HIIE ¼ high intensity intermittent exercise; HIIT ¼ high intensity interval training; MIIT ¼ moderate-intensity interval training; CON ¼ control group; AT ¼ aerobic training; P ¼ plyometric training; P+HIIT ¼ plyometric exercise combined with HIIT; EX ¼ exercise; YYIET¼ Yo-Yo intermittent endurance test; MAS ¼ maximal aerobic speed; HRres ¼ reserve heart rate; VO_{2max}¼ maximal oxygen uptake; [¼ Significant increase; Y ¼ Significant reduction.

Table 2
Physiotherapy evidence database scale (PEDro).

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	Total Score
Lau et al. (2015)	1	1	0	1	0	0	0	1	1	1	1	7
Racilet al.(2016)	1	1	0	1	0	0	0	1	1	1	1	7
Hay et al. (2016)	1	1	0	1	0	0	0	1	1	1	1	7
Racilet al. (2015)	1	1	0	1	0	0	0	1	1	1	1	7
McNarry et al. (2015)	1	1	0	1	0	0	0	1	1	1	1	7
Lambrick et al. (2015)	1	1	0	1	0	0	0	1	1	1	1	7

Chapter Two: Results Presentation and Discussion

Commentary on the Previous Studies

objective:

We observe that all the reviewed studies had the aim of probing the effect of prolonged or rigorous physical training on health, particularly on cardiorespiratory indicators in young athletes. Most of the studies, such as the first, second, and third, were interested in particular indicators such as maximal oxygen uptake (VO₂max), resting heart rate, functional lung capacity, and waist circumference. The fourth study, however, was more holistic in its aim; it did not limit itself to studying the effect of intensive training on body composition alone but also investigated general health parameters like cardiac health, mental well-being, and the feasibility of introducing such programs in school. This testifies to the fact that physical training has a generalized positive effect on health and is not only about weight loss

methodology:

Most of the research was experimental in nature, where the training programs were actually conducted and followed up post the training interventions for changes among the participants. This allowed for the collection of accurate and tangible results. Contrarily, the fourth study utilized a descriptive analytical method through a systematic review of published research, which gave it scientific worth through providing an overall summary of published research, making worthwhile recommendations, and indicating gaps to be addressed by future research.

In terms of population and sample:

We notice that the initial study focused on young athletes, either teenagers or young adults at the beginning of their sports life, with general good health and without chronic diseases. The fourth study, on the contrary, specifically focused on overweight or obese children and adolescents in schools and thus had a different structure since it targeted a risky group from the point of view of health. The samples were at times gender diverse, but the overarching unifying condition was either involvement in or necessity of physical activity to promote health.

With regards to data collection instruments:

All the research employed proper, standardized scientific measuring tools. They utilized modern equipment such as VO₂max measuring devices, heart rate monitors, body fat percentages, and waistline measurement, as well as physical exertion tests such as the Yo-Yo test and maximum aerobic capacity tests. The fourth study, being a systematic review, utilized credible scientific databases such as PubMed and Scopus to gather data, and hence its credibility.

discussion of the Results

First Study:

The results of the present study revealed that the application of an aerobic exercise program led to a significant weight reduction as the mean weight decreased from 66.86 kg in the pre-test to 66.12 kg in the post-test, down by 0.74 kg. Furthermore, percentage body fat decreased from 40.45% to 37.18%, indicating an improvement in body composition because of aerobic exercises. The (t) test results showed that the calculated value was greater than the tabulated value, confirming that the research hypothesis must be accepted. These results can be interpreted as evidence that aerobic training significantly contributed to enhancing the health of the participants in a gentle and natural manner without side effects, which is an indication of validity and appropriateness of the applied program to the study population.

Second Study:

The findings of this research indicated that a six-month program of weight loss (WL) alone or in combination with aerobic exercise (AEX) had an equivalent effect on body weight, visceral fat, and muscle fat in obese women. However, the addition of aerobic

exercise to WL resulted in improved glucose uptake and insulin sensitivity. These findings suggest that the coordination of exercise with diet plans is more effective in improving metabolic markers. Additionally, the changes observed in this study were described as healthy and normal, which further contributes to the scientific validity and significance of the findings.

Third Study:

The research showed that the applied HIIT regimen led to positive results regarding weight, body mass index, and body fat percentage. However, the weight loss was fairly rapid, which is unhealthy and unsustainable, and this may have been because there was a rigorous diet regimen that was not clearly outlined in the research. Yet the study did verify that HIIT exercises have a positive effect on weight, body fat percentage, and body mass index but also must regulate concomitant dietary factors to render the results safe and healthy.

Fourth Study:

The results of this study showed a significant improvement in all parameters measured after just 4 weeks of HIIT intervention. Substantial changes were observed from the second week in body composition assessments, VO₂max, and measures of cognitive function such as SDS and SCWT, and the improvements continued through to program completion.

Also, the loss of weight along with the decline in fat was moderate as well as healthy, which would mean that the study was conducted according to precise as well as standard criteria, and such findings are scientifically significant as well as practically valuable within the field of training interventions for adolescents.

results

The results of this study confirmed that high-intensity interval training (HIIT) was a productive way to improve most of the indicators being examined. It significantly contributed to weight reduction, reduction in body mass index (BMI), reduction in body fat percentage, and reduction in waist circumference. This shift appeared increasingly and continuously throughout the intervention process, and changes remained within normal and healthy levels, which enhances the validity of the applied program.

The results of data analysis indicated that HIIT interventions led to enhanced cardiorespiratory fitness, as indicated by the notable increase in VO₂max, as well as in aerobic capacity test performance such as that of the Yo-Yo test and maximal aerobic speed (MAS). The results indicate that HIIT not only constitutes an effective intervention to enhance cardiorespiratory fitness but also a viable option in programs for adolescents.

We also learned that there was a positive effect on fat percentage and weight loss as a consequence of performing aerobic exercises. The subjects showed a natural, moderate decrease in weight, waist circumference, and subcutaneous fat percentage. This shows the crucial role of the exercises in regulating weight for the target age group.

Besides, the research results showed that daily habits of healthy exercise helped contribute to glucose utilization and insulin sensitivity, still demonstrating that exercise has an advantageous effect beyond body composition and aerobic power to include factors of a metabolic nature, thereby maximizing overall well-being in adolescents.

Through descriptive analysis of results, we observe that the increase in various indicators (e.g., weight, BMI, waistline, fat percentage, VO₂max) was within scientifically acceptable and normal rates, and there were no cases of sudden or unhealthy decline except for one study involving rapid weight loss, potentially due to unspecified dietary habits. This renders it even more important to design training

programs carefully and incorporate the supportive nutrition as well.

Finally, the above conclusions assure that both HIIT training protocols and traditional aerobic training are valid options for improving physical as well as cardiorespiratory health indicators in youth and adolescents, provided that the scientific standards of the training program are maintained and variables are strictly and regularly controlled to achieve the intended results safely and healthily.

Final recommendations

1 Encourage the incorporation of High-Intensity Interval Training (HIIT) programs in school sports and curriculums, given their proven effectiveness at improving adolescents' cardiorespiratory fitness and body composition, highlighting the need for specialist supervision to foster safety and effectiveness.

2 HIIT programs must be created with individual variability in mind among young people in terms of age, fitness level, and health status to avoid complications and achieve the maximum health benefits naturally and safely.

3 Promote youth and family awareness of the necessity of combining regular physical activity and a balanced diet in order to attain sustainable and healthy results in obesity reduction and cardiovascular and respiratory health.

4 Call for more long-term field trials to examine the sustained impact of HIIT training on the general and mental health of adolescents, as well as the optimal formats and timing for the delivery of such programs in school and sporting environments.

Conclusion

This study has been able to prove that high-intensity interval training (HIIT) is a consistent method to improve cardiorespiratory fitness and lower weight and body fat percentage in adolescents in a health-friendly and safe way. The study also revealed that HIIT was a suitable technique for adolescents due to its short duration and positive effects and thus is a practical tool.

For obesity prevention and heart wellness and respiratory comfort, it is an indispensable tool. We hope that the results of this study will promote the introduction of such programs under professional guidance, as they have a beneficial effect on the health of the younger generation.

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