Morphological, Physiological and Biochemical Variables in Athletes and Non-Athletes

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To the memory of my beloved parents,
whose silent sacrifices built the foundation of everything I am.
And to my family,
whose unwavering presence continues to give my life meaning.

Në kujtim të prindërve të mi të dashur,
sakrificat e tyre të heshtura ndërtuan themelet e gjithçkaje që unë jam sot.
Dhe për familjen time,
praninë e të cilës e ndjej si kuptimin më të thellë të jetës sime.

‘Behind every data point lies a young life in motion, a moment of breath, effort and transformation.’
— The Author

“Pas çdo pikë të dhënash fshihet një jetë e re në lëvizje, një çast frymëmarrjeje, përpjekjeje dhe ndryshimi.”
— Autori

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EDITORIAL PREFACE TO THE REVISED EDITION (2025)

This volume presents a revised edition of a doctoral dissertation originally defended at the Faculty of Medicine, University of Pristina, in 2002. More than two decades have passed since its completion, and although the core principles of human physiology remain constant, the academic standards, expectations, and interpretive frameworks within medical and sport sciences have evolved significantly.

This updated edition was prepared to align the original research with contemporary scholarly norms in terms of clarity, terminology, formatting, and citation style. The dataset, research design, and statistical analyses remain authentic to the period in which they were conducted (2000–2001), thus preserving the methodological and historical identity of the work. Minor textual revisions have been introduced to enhance precision, without altering the empirical substance or analytical framework.

The goal of this revised edition is not to reinterpret past findings through the lens of present-day knowledge, but to document and contextualize them within their original scientific logic. At the same time, this version includes an afterword that reflects briefly on methodological developments and the growing relevance of anthropometric research in public health and preventive medicine.

It is my hope that this revised edition will serve both as a historical source and as a reference point for ongoing scientific discourse in fields such as medical science, sports studies, and human biology.

Dr. Agron M. Rexhepi
Pristina, 2025

PREFACE

The research presented in this monograph marks the culmination of a long-term personal and scientific journey situated at the intersection of medicine, kinesiology, and human biology. Originally developed as a doctoral dissertation, the study emerged from a desire to explore the functional, structural, and biochemical differences between physically active and inactive individuals within the Albanian male population of Kosovo.

This motivation stemmed not only from a professional interest in integrative human physiology but also from the urgent public health needs of a post-war society. At the time of data collection, Kosovo was undergoing a challenging period of reconstruction and healing. Within this context, the study sought to better understand the biological consequences of physical inactivity and to highlight the rehabilitative potential of structured physical activity.

The work is grounded in empirical field data and incorporates statistical techniques such as discriminant, factor, and regression analyses to interpret variations across morphological, physiological, and biochemical domains. While scientific in its execution, the study was also guided by a deep belief in the practical implications of its findings—for researchers, clinicians, educators, and public health actors committed to promoting physical activity as a foundation of human well-being.

I would like to express heartfelt appreciation to all the participants who volunteered for this study, to the colleagues who offered critical insights, and to the institutions that supported its development. My sincere gratitude goes to those who contributed to the statistical processing and technical refinement of the manuscript.

It is my hope that this work will inform, inspire, and contribute—even modestly—to the growing body of literature that frames physical activity as a vital pillar of health and human development.

ACKNOWLEDGEMENTS

I humbly acknowledge the guidance and mercy of the Almighty, whose presence has continually inspired my academic efforts. I place my full trust in Him and seek guidance solely from Him.

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My appreciation goes to the Directorate of the Health Centre in Pristina and the laboratory staff, whose meticulous contributions made possible the biochemical analyses of 300 test subjects.

I gratefully acknowledge the scientific staff at the Institute of Sports Anthropology, as well as the medical personnel at the Sports Medicine Center in Pristina, for their essential assistance in subject testing.

My thanks also go to the SJRC for their support in the implementation of the doctoral project.

Last but not least, I am deeply thankful to my family, whose unwavering support and encouragement were instrumental in the completion of this work.

Pristina, 2002

LIST OF ABBREVIATIONS

Abbreviation	Meaning
AI	Artificial Intelligence
EPO	Erythropoietin
ATP	Adenosine Triphosphate
AVO2DIFF	Arteriovenous Oxygen Difference
BMI	Body Mass Index
BP	Blood Pressure
CK	Creatine Kinase
CO2	Carbon Dioxide
DBP	Diastolic Blood Pressure
DNA	Deoxyribonucleic Acid
ECG	Electrocardiogram
EMG	Electromyography
FVC	Forced Vital Capacity
Hb	Hemoglobin
HDL	High-Density Lipoprotein
HR	Heart Rate
HRmax	Maximum Heart Rate
LDL	Low-Density Lipoprotein
MAP	Mean Arterial Pressure

O2	Oxygen
PCV	Packed Cell Volume
RER	Respiratory Exchange Ratio
RHR	Resting Heart Rate
RPE	Rating of Perceived Exertion
RR	Respiratory Rate
SBP	Systolic Blood Pressure
SPSS	Statistical Package for the Social Sciences
TA	Tension Arterial
VO2	Oxygen Uptake
VO2max	Maximal Oxygen Uptake
WBC	White Blood Cells

1. INTRODUCTION

Anthropology is a natural science that studies the human being as both a biological and a social entity. It seeks to understand the laws governing human evolution, growth, development, and the geographic distribution of populations, as well as the impact of ecological factors on the formation of human characteristics.

Most anthropologists agree that anthropology is a distinct scientific discipline that explores human life and behaviour across time and space (Vlahović, 1972). Contemporary anthropology approaches its questions through a multidisciplinary lens, drawing on information and research methodologies from numerous scientific domains. Institutional perspectives on how anthropology is taught and researched have also been explored at the national level in various countries (Herskovits 1948; Kuper 1973).

Gaining profound and reliable insight into the anthropological features of a population requires collecting extensive data across multiple domains of human status, including morphology, physiology, biochemistry, motor function, cognitive and social behaviour, and conative factors. In today's complex conditions, achieving such a comprehensive aim is far from simple, it demands perseverance, methodological precision, and often, considerable personal and professional sacrifice.

In researching the anthropological status of an individual or an entire population, one must take into account the powerful influence of external factors (geographical, physical, historical, cultural, social, and ecological) on human development (Cvijić, 1966). The scientific study of these influences began with Škerlj (1960) and Vlahović (1972), though earlier anthropometric work, such as the craniometric analysis of prehistoric skeletal remains from Glasinac in the western Balkans by Weisbach (1897, 562–576), provides valuable historical context for understanding population morphology in the region. Later, following extensive research, authors such as Rudan (1986, 231-240) and Howells (1962) asserted that anthropological questions must be approached from a multidisciplinary perspective, particularly in the context of ethnic anthropology, where human diversity is at the core of inquiry.

According to Howells (1962), differences in anthropological characteristics among human populations are largely due to genetic variability. However, Boas (1982) demonstrated that external environmental conditions can also influence biological traits. Therefore, any investigation into morphological or physiological features must consider the joint effect of both genetic and environmental factors. In simple terms, while the genotype defines the potential range of variation, the phenotype (comprising observable traits such as morphology and physiology) is shaped through continuous interaction with the environment. Proser (1964) referred to this phenomenon as the organism's "adaptive capacity".

Among the many ecological influences that may affect human biology are temperature, humidity, altitude, nutrition, and the level of industrialisation. Long-term exposure to such factors may, over generations, bring about changes even at the genetic or chromosomal level, an outcome driven by the mechanisms of natural selection.

Anthropometric traits, whether morphological or physiological, are thus the product of both hereditary and non-hereditary influences. Anthropometric traits, whether morphological or physiological, are shaped by both hereditary and environmental influences. As Osborne et al. (1971, 279–305) emphasised, research in biological anthropology relies on interdisciplinary knowledge, drawing from fields such as anatomy, physiology, genetics, zoology, palaeontology, ecology, mathematics, archaeology, linguistics, chemistry, psychology, and others.

Anatomy plays a central role in clarifying structural variations among individuals. Morphology, on the other hand, investigates body type, growth phases, and how these traits develop under environmental influences. Most morphometric data are obtained using dedicated anthropometric instruments.

However, as Schreider (1967) warned, understanding human variation cannot rely solely on external body measurements or descriptive morphological data. To gain meaningful insights into the structure and functioning of the human body, data from both morphological and physiological domains must be collected and analysed together. Only then can we fully grasp the inseparable link between form and function in the human organism.

1.1. The Importance of Anthropological Research in Medicine

Medical anthropology studies the human being as a holistic psycho-physical entity. As a subfield of general anthropology, one of its core aims is the definition of the biotype (the constitutional profile of the individual) especially in cases of illness. This is of increasing relevance in modern diagnostic approaches.

A person's predisposition to cardiovascular and respiratory diseases is influenced by a complex array of factors, including hereditary disposition (i.e. family history), obesity, hypertension, diabetes mellitus, smoking, elevated serum lipid levels, physical inactivity, emotional stress, and other environmental elements.

Research has shown that there are marked morphological and physiological differences between individuals suffering from chronic non-specific respiratory diseases and those who are clinically healthy (Haxhiu, 1979, 137-147; Behluli, 1987). Defining and comparing the structural profiles of these two categories, understanding their interrelations, and tracking how their traits evolve over time remains an important scientific imperative. Meeting this challenge would enable a more accurate characterisation of the anthropometric status of our population. Such data would support appropriate health interventions and help satisfy the population's bio-psycho-social needs, particularly regarding physical mobility, independent living, and adaptability to varied living conditions.

During growth and development, both morphological and physiological parameters are in constant flux. This phase is characterised by profound adaptation and systemic transformation (Ivanović, 1985; Rexhepi, 1998). In adulthood, however, many morphological characteristics, especially longitudinal dimensions, tend to remain relatively constant throughout life (*mesostabile dimensions*). These dimensions generally remain stable, whereas mesolabile dimensions — including transverse measurements, body mass and volume, and subcutaneous fat — are more sensitive to external influences. These include levels of physical activity, nutritional status (whether over- or undernutrition), and various pathological processes. Proper management of these factors is essential for maintaining structural integrity, health, and functional capacity.

Engaging in regular physical exercise has a notable effect on muscle development throughout the body, often resulting in increased values in certain anthropometric indicators. These include biacromial width, thoracic circumference, relaxed and flexed upper arm girths, thigh girth, and calf circumference.

Such morphological adaptations are not limited to improving structural parameters, they often have a positive impact on self-image, self-confidence, and general well-being.

On the other hand, malnutrition or chronic illness can negatively affect the distribution and accumulation of subcutaneous fat, disrupt proportionality across body regions, and significantly alter total body mass. On the other hand, malnutrition or chronic illness can negatively affect the distribution and accumulation of subcutaneous fat, disrupt proportionality across body regions, and significantly alter total body mass. The variability of fat distribution across different anatomical regions and its changes with age have been well documented by Wolański, Teter, and Kowalczyk (1985, 223–227), who emphasised that both biological ageing and environmental influences contribute to these patterns.

Several studies have identified that chronic respiratory conditions may also reshape an individual’s morphological traits, with aetiologies influenced by both genetic predispositions and environmental exposures (Haxhiu, 1979, 137-147; Behluli, 1987).

In clinical practice, emphasis is often placed on determining the nature and severity of disease, while the role of inherited and environmental influences (the phenotypic manifestations) may be underappreciated. Nonetheless, index values derived from anthropometric and physiological measurements remain essential tools for assessing the general health status of a population.

Moreover, the exploration of relationships between morphological and physiological variables has significant diagnostic and prognostic value, particularly in identifying constitutional predispositions to respiratory illnesses (Suter 1970; Khosla 1971; Behluli 1987).

1.2. Overview of Research

The anthropological profile of the Albanian population has long been of interest to researchers due to its distinctive biological traits and cultural identity, particularly within the Dinaric region of the Balkans. However, most previous investigations rarely employed a truly multidimensional approach, one that draws from multiple anthropological domains simultaneously. Instead, early contributions to the field were primarily descriptive, lacking both methodological rigour and scientific depth.

The first recorded anthropological description of Albanians was made by François Pouqueville in 1805. Later observations came from scholars such as Pisko (1985), Träger (1901), Durham (1905), and Nopcsa (1912), who offered anecdotal and ethnographic notes rather than systematic scientific studies.

More structured anthropometric research began with Weissbach in 1868, who measured 17 Albanian men in Istanbul, reporting an average height of 1,664 mm. In 1895, Leopold Glück examined 30 Albanians, primarily from Kosovo (Glück 1897), while in 1916, Lebzelter conducted anthropometric measurements on 119 Albanians from both mountainous regions and the Kosovo plain (Lebzelter 1920). During the First World War, Dronchilov studied 112 Albanians from Kosovo and western Macedonia (Dronchilov 1921, 111–137), while Luschan measured cranial dimensions in 130 Albanians residing in Turkey (Luschan 1922).

The most comprehensive anthropological investigation of Albanians prior to the mid-20th century was conducted by Carleton S. Coon in 1930. Coon (1970) collected data from 1,067 individuals and sought not merely to describe the so-called Dinaric type among Albanians, but also to explain its development in relation to cultural, socio-economic, and ecological conditions. His work stands out for its integration of physical measurements with contextual analysis.

In 1967, Živojin Gavrilović conducted anthropometric assessments of both cranial and body dimensions in a sample of 201 Albanians from Deçan, Kosovo, providing further insight into regional morphology (Gavrilović 1981, 33–81).

Within Albanian scholarship itself, the earliest reflections on human form can be found in the philosophical essays of Sami Frashëri, *Yine İnsan* [*Man*] (Frashëri 1886/1999). A more scientific contribution emerged in 1985 with Aleksandër Dhima's seminal work, *Gjurmime antropologjike për shqiptarët* (*Anthropological Traces of the Albanians*), which integrated both descriptive and quantitative data on body and cranial morphology, including traits such as eye colour, eyelid type, body hair, muscle structure, and core anthropometric indices (Dhima, 1985).

A turning point in the scientific study of human morphology came with the application of factorial analysis, a multivariate statistical technique that enables researchers to uncover latent structures (or biological factors) underlying measured anthropometric variables. These may arise within a single domain or span across multiple anthropological spaces.

This method was widely adopted in anthropological research, including early studies by Rees (1950, 619–632), Lorr and Fields (1954, 182–185), and Hammond (1957, 223–241). In 1969, Momirović et al. applied factorial analysis to 40 morphological variables in a sample of 4,040 adolescents aged 12 to 22. They extracted four core biological dimensions: longitudinal skeletal growth, body mass and volume, skeletal breadth, and subcutaneous adipose tissue.

Skibińska (1977, 73–78) identified three dimensions from measurements of the body, limbs, and head: limb length, extremity dimensions (hands and feet), and general skeletal width.

Kurelić et al. (1975), in a study involving 3,400 adolescents aged 11 to 17, used 18 morphological variables and identified three primary factors: body volume, skeletal size, and subcutaneous fat.

Young and Ismail (1976, 84–93), in a study involving 50 male participants assessed before and after a four-month physical training programme, examined the correlations between morphological, physiological, biochemical, and psychological traits. Their findings revealed strong interrelationships among these domains.

Bala (1980, 15-22) analysed 35 morphological variables in 17-year-old girls and identified six dimensions: body volume and fat, longitudinal skeletal size, craniofacial structure, joint size, transverse skeletal development, and chest width.

Gjinolli, in his study involving 314 pupils aged 11 to 12, identified two principal factors: one associated with skeletal size (both longitudinal and transverse dimensions), and another combining body mass, girths, and adipose tissue (Gjinolli 1997).

Behluli (1987), analysing a sample of 2,246 males aged 17 to 75, found that Kosovar males were generally tall, with large and broad heads, high cranial circumferences, and wide foreheads. His factorial analysis yielded seven distinct dimensions: transverse skeleton, longitudinal skeleton, respiratory function, facial structure, cranial structure, nasal morphology, and arterial blood pressure.

Rakovica (1990, 50-56), in a study of 242 students aged 17 to 18, identified three dimensions from 16 morphological variables: subcutaneous fat, longitudinal skeletal size, and body volume and mass.

Aliu (1991), working with adolescents aged 15 to 17, used 18 variables to identify three latent dimensions: circular skeletal size, subcutaneous fat, and transverse skeletal development.

Rexhepi (1998), in a study involving 1,286 children aged 7 to 10, identified three biological dimensions encompassing skeletal structure, arterial blood pressure, and respiratory–pulse function.

Bahtiri (2001), researching 12-year-old boys, extracted two dimensions: one combining longitudinal and transverse skeletal size with body weight, and the other reflecting circular measurements and subcutaneous fat distribution.

Across this broad spectrum of factorial research, at least four latent biological dimensions have emerged consistently:

1. Longitudinal skeletal growth
2. Transverse skeletal development
3. Body mass and volume
4. Subcutaneous adipose tissue

Depending on the population sample and scope of measurement, additional factors (such as cranial morphology or extremity proportions) have also been identified. Collectively, these studies deepen our understanding of the latent biological structure of the human body and highlight the richness of morphological variation within the Albanian population.

Collectively, these studies deepen our understanding of the latent biological structure of the human body and highlight the richness of morphological variation within the Albanian population.

This study also draws upon classic anthropological literature in order to preserve the historical continuity of scientific analysis and to highlight the evolution of knowledge concerning the anthropological characteristics of the Albanian population. The inclusion of such foundational sources is intentional, as they offer irreplaceable insights derived from direct observation, fieldwork, and early scientific methods. By contextualising these works alongside contemporary findings, the research ensures both historical depth and analytical rigour.

2. Purpose of the Research

The purpose of this research is to examine and compare the morphological, physiological, and biochemical characteristics of athletes and non-athletes, using both manifest and latent variables. The study aims to enhance our understanding of how physical training affects the human body across multiple dimensions, by addressing the following principal objectives:

- To describe and compare the morphological, physiological, and biochemical profiles of athletes and non-athletes;
- To determine the anthropometric values that define the physical status of both groups;
- To identify statistically significant differences in morphological characteristics between athletes and non-athletes;
- To assess meaningful changes in physiological parameters before, during, and after submaximal physical exertion;
- To examine alterations in biochemical indicators during the recovery phase in both groups;
- To analyse the latent structure underlying the morphological, physiological, and biochemical domains in the study population;
- To explore the interrelationships and reciprocal influences among the identified latent factors.

In line with these objectives, the following research hypotheses have been formulated:

H–1: There is a statistically significant correlation among morphological, physiological, and biochemical variables within the manifest space.

H–2: At rest, physiological parameters differ significantly between athletes and non-athletes.

H–3: During submaximal physical exertion, physiological responses exhibit significant differences between the two groups.

H–4: Physiological values measured during the recovery phase differ significantly between athletes and non-athletes.

H–5: Biochemical markers recorded during recovery differ significantly between athletes and non-athletes.

H–6: The integration of morphological, physiological, and biochemical variables enables the extraction of latent dimensions that reflect distinct information from each respective domain.

H–7: Within the latent space, it is possible to predict the influence of the system of predictor variables on the criterion variable.

The chapters that follow provide a detailed presentation of the materials and methods employed, along with the analytical procedures used to test the stated hypotheses. The study concludes with a synthesis of the findings and a discussion of their broader implications for public health and physical education.

3. Materials and Methods

3.1. Samples

This study adopts a comprehensive approach to investigating the anthropological profile of athletes and non-athletes by examining three principal domains: morphological, physiological, and biochemical characteristics. The research sample comprised 300 Albanian males from Kosovo, aged between 18 and 30 years.

The participants were divided into two distinct groups:

- The athlete group consisted of 150 individuals actively engaged in competitive sports, including football, athletics, basketball, handball, cycling, karate, boxing, and tennis.
- The non-athlete group comprised 150 individuals from various civilian professions who did not participate in regular sports activities.

Data collection was carried out between 2000 and 2001 and involved 87 biometric measurements per subject, ensuring a high degree of precision and reliability in the recorded data.

To assess physiological and biochemical responses, both groups underwent a submaximal physical exertion test using an ergometric bicycle, following a continuous protocol of increasing intensity, commonly referred to as Astrand's submaximal test. The workload was calibrated to maintain a submaximal heart rate exceeding 170 beats per minute (±10 bpm), thereby ensuring a controlled but physiologically demanding exercise stimulus.

- Morphological variables were measured in the early morning, prior to any physical activity.
- Physiological variables were assessed at three intervals: before, during, and after the submaximal test.
- Biochemical variables were recorded during the recovery phase following physical exertion.

This structured protocol enabled the researchers to obtain meaningful comparative data and to evaluate the interactions between physical activity and biological function.

3.2. Variables

3.2.1. Instruments for Measuring Morphological Variables

Each participant underwent detailed assessments involving 25 core morphological variables. All measurements were conducted using classical, well-calibrated anthropometric instruments, in strict accordance with the methodological standards of the International Biological Programme (Weiner and Lourie 1969), as well as the practical guidelines outlined in the field of biological anthropology (Buzina 1975). Ensuring the reliability and scientific validity of the findings required a high level of precision in anthropometric data collection, as emphasised by Solarić et al. (1975), who demonstrated that standardised anthropometric protocols yield high inter-observer reliability. To this end, all instruments were selected in line with the procedures recommended by Martin (1928), whose foundational osteological manual remains a key reference in the standardisation of anthropometric techniques.

- Weighing scale – accurate to 100 grams, used for consistent and reliable measurement of body weight.
- Stadiometer / Anthropometer and Abbreviated Anthropometer – accurate to 1 millimetre, for measuring standing height and body length dimensions.
- Pelvimeter – accurate to 1 millimetre, used to assess pelvic width and related diameters.
- Non-elastic measuring tape – accurate to 1 millimetre, for standardised measurement of body circumferences.
- Skinfold calliper – accurate to 0.2 millimetres, used to measure subcutaneous fat thickness and assess body composition.

The use of high-quality, properly maintained equipment ensured the integrity of the measurements and reinforced the scientific value of the study.

The figure below illustrates the standard anthropometric equipment employed in accordance with international protocols. This includes the stadiometer, pelvimeter, non-elastic measuring tape, skinfold calliper, and