Chapter 2

Kinanthropometry: Structure, Composition, And Function of the Human Body In Sport

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Abstract

Kinanthropometry is a multidisciplinary field that examines the structural and functional aspects of the human body, particularly in the context of sports performance. This scientific approach integrates anthropometric measurements, body composition analysis, and biomechanical assessments to evaluate physical attributes that influence athletic success. By quantifying key physiological parameters, kinanthropometry plays a pivotal role in optimizing performance and designing personalized training interventions. Research highlights the critical role of kinanthropometric indicators—such as stature, body mass distribution, muscle composition, and joint mobility—in determining an athlete's suitability for specific sports. These variables significantly impact factors like endurance, strength, agility, and recovery, shaping both an individual's competitive advantage and training methodologies. Moreover, kinanthropometry facilitates the assessment of body symmetry, motor efficiency, and growth trajectories, ensuring that athletes maintain peak functional capacity throughout their careers. In practical applications, sports scientists and coaches employ kinanthropometric evaluations to refine talent identification processes, establish normative performance benchmarks, and tailor conditioning programs to an athlete's physiological profile. Findings indicate that optimal body morphology and proportionality contribute to sport-specific excellence, reinforcing the necessity of integrating kinanthropometric principles into professional training regimens.

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Ultimately, kinanthropometry serves as a foundational tool in sports science, bridging physiology and biomechanics to enhance athletic performance. Its systematic application not only improves individualized training outcomes but also fosters advancements in sports medicine, rehabilitation strategies, and long-term athlete development models.

Introduction

Introduction to Kinanthropometry

What is Kinanthropometry?

Kinanthropometry is the scientific study of human body dimensions, proportions, composition (fat and lean mass distribution), and structural characteristics in a quantitative manner. These measurements are typically used to provide information about individuals' growth, development, physical fitness, performance capacity, and nutritional status. In sports sciences, kinanthropometry plays a critical role in applications such as training planning, performance monitoring, and determining sport-specific physical profiles. It is closely related to anthropology, physiology, biomechanics, and nutrition sciences, requiring a multidisciplinary approach. Standardized measurement protocols developed by the International Society for the Advancement of Kinanthropometry (ISAK) are widely used to ensure the scientific reliability of measurements (Marfell-Jones et al., 2006; Navas Harrison et al., 2021; Quraishi et al., 2022; Bonilla et al., 2022a).

Relationship with Other Disciplines (Biomechanics, Physiology, Anthropology, Sports Sciences, etc.)

Kinanthropometry is inherently a multidisciplinary field, closely interacting with biomechanics, exercise physiology, anthropology, and sports sciences. Each discipline significantly contributes to the interpretation and application of kinanthropometric data.

- The relationship with biomechanics enables the analysis of movement through measurements such as body segment lengths, mass distributions, and joint angles. For example, an athlete's limb proportions can influence leverage advantages and movement efficiency (Winter, 2009).
- From the perspective of exercise physiology, kinanthropometric data contributes to evaluating metabolic demands and performance capacity through parameters such as muscle mass, fat percentage, and body surface area. These data are particularly linked to oxygen

consumption, heat balance, and fatigue processes (McArdle, Katch & Katch, 2015).

- The connection with anthropology is evident in areas such as the evolutionary development of the human body, morphological differences between populations, and the effects of genetic structures on body composition. Anthropometric data serve as fundamental tools for studying biological diversity across societies (Ulijaszek & Kerr, 1999).
- In the context of sports sciences, kinanthropometry is used in athlete selection, evaluating position suitability, and monitoring training responses. Particularly at the elite level, identifying sport-specific body compositions can directly impact performance (Norton & Olds, 2001).

This interdisciplinary synergy makes kinanthropometry a powerful and functional tool in both academic research and field applications (Stewart, 2007).

Kinanthropometric Measurement Principles

Standard Measurement Methods and Techniques

Kinanthropometric measurements must be conducted in accordance with specific standards to ensure accuracy and reliability. To produce reliable results, fixed anatomical reference points (e.g., acromion, olecranon, iliac crest, etc.) should be carefully identified, the measurer must be trained, and procedures should follow internationally recognized protocols, particularly those of ISAK (Marfell-Jones et al., 2006). During measurements, the individual should be barefoot, wear light clothing, and maintain an upright posture. Pressure applied to the skin should be minimal, the tape measure or caliper must be properly aligned, and each measurement should be taken at least twice. If the difference between measurements exceeds acceptable limits, a third measurement is taken, and the average value is calculated. This approach reduces observer-related variability in the measurement process (Esparza-Ros et al., 2019).

Anthropometric Instruments and Equipment

In order to obtain accurate and reliable anthropometric data, the devices used must be calibrated, ISAK approved and in accordance with international standards. The main instruments used for measurement are as follows: Stadiometer: Used to measure height and sitting height. Anthropometric tape measure: It should be made of flexible but non-stretchable material, used for circumference measurements. Skinfold callipers: Used for skinfold thickness measurements. Calibrated devices providing constant pressure (10 g/mm²) are preferred (e.g. Harpenden callipers). Slide callipers or bone diameter callipers: Used for width and diameter measurements (e.g. humeral or femoral condyle diameter). Digital weighing scale: It should be able to measure body weight with an accuracy of at least 0.1 kg. Maintenance records of measuring instruments should be kept and calibration should be performed at regular intervals. Especially in high-precision evaluations performed in elite athletes, device quality can directly affect the results (Lohman et al., 1988; Norton & Olds, 2001; Eston & Reilly, 2009).

International Protocols (ISAK Standards)

The International Society for the Advancement of Kinanthropometry (ISAK) has established globally accepted standard protocols for kinanthropometric measurements. In the ISAK system, practitioners are classified into levels based on their training: Level 1 (basic practitioner), Level 2 (advanced practitioner), and Levels 3-4 (instructor and researcher). These levels are graded according to the scope of measurement and competence in data interpretation.

Under the ISAK measurement protocols:

- ***Restricted Profile (Restricted Profile)***: Includes 17 basic measurements (e.g., height, weight, circumferences, skinfolds).
- ***Full Profile (Full Profile)***: Includes 43 measurements.
- ***Extended Profiles***: Include 60+ measurements.

These standards enable measurements conducted by different researchers or institutions to be comparable, facilitating the collection of scientifically valid datasets for applications such as growth and development monitoring, athlete profiling, and nutritional status tracking (Ackland et al., 2012; Silva & Vieira, 2020; Bonilla et al., 2022a).

Basic Anthropometric Components

Stature and Sitting Height

Stature is the vertical length of an individual from the floor to the highest point of the head and is a key indicator of skeletal growth. Genetic factors, nutritional status, and environmental conditions are the primary determinants of height. Height is typically measured in a standing position with the head aligned in the Frankfurt plane. In anthropometric measurements, height serves as a reference value for various ratio analyses (e.g., leg length to total height ratio) and is a critical parameter for tracking developmental processes with age. Sitting Height is the vertical length from the hips to the top of the head when an individual is in a seated position. This measurement is used to evaluate the ratio of lower body (legs) to upper body (trunk and head). It is particularly important for analyzing growth patterns in children, such as the rate of leg length increase. Additionally, the sitting height to stature ratio can be a determining factor in assessing suitability for specific sports (e.g., rowing, cycling, swimming) (Malina et al., 2004; Massard et al., 2019).

Body Weight

Body Weight is the force corresponding to an individual's total mass under Earth's gravitational pull. It is typically expressed in kilograms (kg) in practice, though it is physically a force measured in Newtons (N). Weight should be measured using a professional digital or mechanical scale, ideally in the morning on an empty stomach and under consistent conditions. Body weight alone provides limited information about health or physical fitness, as it does not distinguish between fat and lean mass. Therefore, it is commonly used as a fundamental input for body composition analyses. It is directly required for calculations such as body density, methods like BIA (Bioelectrical Impedance Analysis), DEXA (Dual-Energy X-Ray Absorptiometry), and BMI (Body Mass Index). In athletes, the interpretation of body weight should consider components such as muscle mass, bone density, and fluid balance (Ackland et al., 2012; Fogelholm et al., 1994).

Environmental Measurements

Circumference measurements are anthropometric assessment methods used to determine the perimeter lengths of specific anatomical regions of the body. These measurements provide direct information about muscle hypertrophy (increase in muscle volume) and fat accumulation. They are also highly useful for monitoring musculoskeletal health, physical fitness levels, and changes in body composition. Circumference measurements should be performed using a flexible but non-stretchable anthropometric tape measure, applying minimal pressure on the skin. During measurement, the body should be relaxed, with muscles not contracted. The standardization of measurement points should follow the protocols of the International Society for the Advancement of Kinanthropometry (ISAK).

The most commonly used circumference measurements are:

- ***Arm Girth***: Measured below the deltoid muscle, at the widest point of the biceps. It is used to assess muscle development and the effects of upper extremity training. It also serves as a reference for evaluating sarcopenia (muscle loss) in older adults.

- ***Calf Girth***: Taken at the widest part of the gastrocnemius muscle. It is used to monitor lower extremity muscle mass, particularly for sports like running and cycling.
- ***Hip Girth***: Measured at the widest point of the gluteal region. It is commonly used in waist-to-hip ratio (WHR) calculations and is a key indicator for estimating cardiometabolic risks related to abdominal obesity.
- ***Waist Girth***: Measured slightly above the navel, at the narrowest part of the waist. It is used to estimate visceral fat levels and classify obesity. According to the World Health Organization, values above 94 cm for men and 80 cm for women indicate health risks (WHO, 2008).
- ***Chest Girth***: Measured at the level of the nipples or with controlled inspiration/expiration to assess thoracic circumference. It is used to evaluate respiratory capacity, chest muscle development, and postural abnormalities.
- ***Thigh Girth***: Measured at the widest point of the thigh muscles. It is effective for assessing responses to strength, endurance, and power training.

These circumference measurements are utilized not only in sports performance analysis but also in clinical assessments, growth and development monitoring, and early detection of conditions such as sarcopenia or malnutrition in older adults. Additionally, formulas based on circumference measurements can be used to estimate body fat percentage or lean mass (Ross & Marfell-Jones, 1991; Alaeddinoglu & Kaya, 2016).

Skin-fold Thickness

Skinfold thickness is an indirect yet practical method for estimating body-fat percentage by measuring the thickness of the skin and the underlying subcutaneous fat. Measurements are taken with a specially calibrated skinfold caliper. Common sites include:

- Triseps (back of the upper arm)
- Subskapular (below the shoulder blade)
- Suprailiak (above the hip)
- Biseps (front of the upper arm)
- Uyluk (front of the thigh)
- Baldır (back of the lower leg)

The total skinfold thickness can be converted to body-fat percentage using various equations (e.g., Jackson–Pollock or Durnin–Womersley). However, the accuracy of this method depends on the examiner's level of training and strict adherence to ISAK standards (Marfell-Jones et al., 2006; Carter, 1984).

Body Segment Lengths

Body segment lengths represent the linear distances between specific regions of the body. These measurements are used in biomechanical analyses, posture assessments, growth-pattern studies and the determination of sport-specific body proportions. Key segment lengths include:

- *Arm Length*: Distance from the acromion to the wrist
- *Leg Length*: Distance from the hip prominence to the ankle
- *Thigh and Shank Length*: Separate measurement of lower-limb segments
- *Trunk Length*: Sitting height or the distance from the sternum to the pelvis

These measures are also important for constructing segmented body-mass models (for example, when calculating segmental moment arms). Moreover, certain sports can gain an advantage from particular segment lengths—for instance, arm length in swimming or trunk length in rowing (Zatsiorsky & Seluyanov, 1983; Tóth et al., 2014; Dempster & Gaughran, 1967).

Breadth and Diameter Measurements

Breadth and diameter measurements are anthropometric variables used to assess the transverse dimensions of the skeleton. They reflect the size of the genetically determined skeletal frame and are closely linked to body type, strength capacity and biomechanical advantages. Taken over hard tissues, they represent bone breadth. Measurements are performed with a caliper, and careful location of specific anatomical landmarks is required for high repeatability (Marfell-Jones et al., 2006; Gaito & Gifford, 1958; Pekel et al., 2006).

Common measurement sites:

- *Biacromial Breadth*: Distance between the right and left acromion processes. Indicates upper-torso breadth and is linked to performance in sports such as swimming and rowing.

- *Biepicondylar Humerus Breadth*: Distance between the medial and lateral epicondyles at the distal end of the humerus; reflects skeletal structure at the elbow.
- *Biepicondylar Femur Breadth*: Distance between the medial and lateral condyles of the femur at knee level; influences lower-limb load-bearing capacity and knee stability.
- *Wrist and Ankle Diameters*: Used in determining bone frame size and in somatotype classifications (endomorph–mesomorph–ectomorph).

These measurements are used particularly for somatotype determination, estimating bone mass, comparing muscle-mass development with skeletal adequacy, and conducting biomechanical analyses (Carter & Heath, 1990; Wiggermann et al., 2019).

Analysis of Body Composition and Its Components

Body composition refers to the partitioning of total body mass into fat mass (FM) and fat-free mass (FFM). Fat mass includes subcutaneous and visceral storage fat as well as the essential fat required for vital functions. Fat-free mass comprises all non-fat tissues such as skeletal muscle, bone, organs and body water. The ratio between these components directly influences performance capacity, metabolic efficiency, endurance and overall health—particularly in athletes. To assess body composition, models with different levels of precision have been developed. The two-component model divides body weight only into FM and FFM. The three-component model further separates FFM into body water and dry fat-free mass. The four-component model classifies the body into FM, water, protein and mineral, capturing inter-individual variation more accurately and serving as the most reliable option in clinical or elite-sport settings (Heymsfield et al., 2015; Wang et al., 1992; Kuriyan et al., 2018). Ideal distributions vary by sport: for example, a low fat percentage is crucial in aesthetic events, whereas high muscle mass is more critical in strength sports (Ackland et al., 2012).

Comparison of Densitometry, BIA, and DXA Methods

Among the methods used to assess body composition, densitometry, bioelectrical impedance analysis (BIA) and dual-energy X-ray absorptiometry (DXA) are the most frequently applied techniques. Although each has its own advantages and limitations, their practicality and accuracy differ (Ackland et al., 2012; Heymsfield et al., 2015). Densitometry (hydrostatic weighing) is a classical method with a strong scientific basis, calculating body density through underwater immersion. Despite its high accuracy, its need for specialised equipment and submersion makes it impractical for field use. BIA estimates body-fat percentage by measuring the electrical conductivity of body fluids; its portability, speed and ease of use are clear advantages in field settings, but its precision can decline because it is directly affected by the individual's hydration status (Kyle et al., 2004). DXA is an advanced imaging technique that regionally separates fat, muscle and bone and is widely regarded as the current "gold standard." However, its high cost and ionising radiation limit broader application. The traditional skinfold-caliper method estimates fat percentage by measuring subcutaneous skinfold thickness. Although inexpensive and easy to apply, its accuracy depends on the examiner's experience and rigorous protocol standardisation (Tewari et al., 2018; Zambone et al., 2020; Achamrah et al., 2018; Marra et al., 2019; Bonilla et al., 2022a). The explanations, advantages and limitations of these methods are compared in Table 1.

Table 1. Comparison of body-composition analysis methods

Method	Description	Advantages	Limits
Densitometry	Body density is calculated by underwater weighing	High accuracy, classical method	Requires submersion; limited accessibility
BIA	Electrical resistance through body water is measured	Practical, portable, fast	Affected by hydration status
DXA	Fat, muscle and bone masses are distinguished	High accuracy; regional analysis possible	Expensive; involves radiation
Skinfold Caliper Method	Subcutaneous fat thickness is measured to estimate fat percentage	Economical; suitable for field use	User-dependent; relies on standard protocols

BIA: Bio-Electrical Impedance Analysis; DXA: Dual-Energy X-ray Absorptiometry

Somatotype Evaluation: Endomorphy, Mesomorphy, and Ectomorphy

Somatotype is a classification system that quantitatively describes the morphological structure of the human body and is based on three main components. The most widely used model is the system developed with the Heath-Carter method, which relies on the three primary morphological components of endomorphy, mesomorphy and ectomorphy (Carter & Heath, 1990; Martínez-Mireles et al., 2025; Cinarli & Kafkas, 2019). Endomorphy represents individuals who have a high tendency to store fat and display soft, rounded body contours. Mesomorphy reflects a physique dominated by muscle mass, broad shoulders, an athletic appearance and high strength. Ectomorphy describes slender individuals with long limbs, light bone structure and low levels of body fat. Each person's somatotype results from different proportions of these three components, and these proportions are usually expressed with scores ranging from 1 to 7 (e.g., 2-5-3 = low endomorphy, high mesomorphy, moderate ectomorphy). When determining somatotype, more than ten anthropometric variables (body mass, height, skinfold thicknesses, girths and breadths) are typically measured in line with ISAK protocols. Somatotype classification not only describes physical appearance but also serves as an important reference for creating sport-specific performance profiles, selecting athletes, analysing positional suitability and planning training. For example, ectomorphic individuals are better suited to sports requiring low force and high endurance, such as long-distance running, whereas mesomorphic individuals hold advantages in sports that demand explosive strength and high muscle density, such as sprinting, wrestling and weightlifting. Endomorphic individuals may offer certain benefits in sports that require high force production, but the impact of fat mass on performance must be carefully monitored (Norton & Olds, 2001; Esparza-Ros et al., 2025; Parnell, 1954).

Kinanthropometry in Relation to Growth and Development

Biological Age and Its Monitoring

Biological age is a measure that reflects an individual's physiological and developmental status independently of chronological (calendar) age. During childhood and adolescence, people who share the same chronological age can nevertheless differ markedly in bone development, the emergence of secondary sexual characteristics, stature increase, muscle mass and overall body composition. In athlete evaluation, accounting for biological age is essential for fair performance comparisons and for planning appropriate training loads. One of the most common approaches to tracking biological age is bone-age assessment. This method interprets hand–wrist radiographs against Greulich–Pyle or Tanner–Whitehouse atlases, comparing an athlete's skeletal maturation with reference norms. Alternative indicators include dental development, growth-curve analyses and observation of secondary sexual characteristics. In adolescence, identifying the period of peak height velocity (PHV)—the phase of fastest stature growth—offers a valuable marker of biological maturity (Malina et al., 2004; Lloyd et al., 2014; Salter et al., 2021). Accurate determination of biological age plays a critical role in managing early specialisation, preventing overload-related risks and aligning performance expectations in child and youth athletes (Bale et al., 1992; Çabuk & Ulupınar, 2024).

Kinanthropometry and Sports Performance

Sport-Specific Anthropometric Characteristics

When sports are compared, kinanthropometry reveals each discipline's distinctive morphological "fingerprint" for success. In basketball, long body segments and a wide shoulder girdle give advantages in rebounding and blocking, whereas football favours a more compact yet agile build; this contrast is documented by elite basketball players' significant superiority over equally ranked footballers in both height and volume□related measures. Handball players adapt to explosive upper-limb force through larger arm–shoulder and hip girths, while in water polo, centre players rely on a high mass-and-breadth combination for contact dominance, and perimeter players use a lighter, more agile morphology for speed. Importantly, even in under-14 talent-development groups, sport-specific anthropometric divergence begins early, even after controlling for biological maturation differences (Ziv & Lidor, 2014; Masanovic et al., 2018; Gusic, 2017). Wrestlers construct a "strength fortress" of short-to-medium stature, high mesomorphy, wide biepicondylar breadths and pronounced muscle girths—crucial for positional advantage and contact stability (Baić et al., 2022). Weightlifters—especially young elite women—display a compact profile ideal for explosive lifting mechanics, characterised by a short-leg/long-torso ratio, large bone breadths and substantial segmental muscle mass (Işik et al., 2025). In taekwondo, long lower-limb segments and low body-fat percentage create an ecto-mesomorphic mix that favours kicking range and speed (Can et al., 2023). Karate practitioners develop a balanced somatotype with low endomorphy and moderate mesomorphy, producing a low fat level suited to versatile, explosive movements (Rossi, 2021). As highlighted in recent multi-sport somatotype reviews, these patterns show that every discipline has its own "performance phenotype," and that athlete selection, positioning and training design must always consider the individual morphological profile (Martínez-Mireles et al., 2025).

Current Trends and Future Perspectives

Digital Anthropometry and 3D Body Scanning

Digital anthropometry is a modern approach that measures body dimensions and shape with computer-assisted systems, usually contact-free and with high precision. Replacing traditional manual tools such as tapes and calipers, this method—especially when supported by 3-D body scanners—provides millimetre-level, detailed and repeatable results. Three-dimensional scanners typically rely on laser, structured-light or photogrammetry technologies. Measurement time is short (10–60 s), the procedure is non-invasive, and all data can be archived, visualised and analysed in digital form. Digital anthropometry has a wide range of applications, from garment design and ergonomics to health screening and athlete profiling. In sport science it is used to determine body volume, symmetry, postural alignment and segmental proportions. It offers major advantages for identifying postural disorders, musculoskeletal asymmetries and sport-specific body shapes. In addition, 3-D scans allow the comparative tracking of body changes over time, providing a powerful tool for objectively evaluating training responses (Wells et al., 2008; Heymsfield et al., 2018; Ashby et al., 2023).

Measurement Analysis with Artificial Intelligencei

Artificial-intelligence (AI) analysis systems are revolutionising the interpretation of kinanthropometric data because they can learn from large datasets, build models and generate predictions. Machine-learning and deep-learning algorithms, in particular, speed up analyses that traditional methods would limit, lower error rates and enable person-specific assessments. AI can automatically process 3-D scanning outputs such as body volume, segmental ratios, fat distribution and asymmetry analyses. It can also examine past measurements to produce advanced insights—growth and development forecasts, performance projections and injury-risk analyses. For instance, by using athletes' previous body-composition data, AI-based models can predict future training responses or optimal weight ranges. This technology now plays an increasing role in athlete monitoring, health screening, physiotherapy planning and the personalisation of exercise programmes. In addition, AI systems save time and improve accuracy by automatically classifying measurements, analysing them against normative values and visualising the results for the user (Kazemipoor et al., 2020; Bonilla et al., 2022b; Reis et al., 2024).

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