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Body Shape, Image, and Composition as Predictors of Athlete's Performance

Arnulfo Ramos-Jiménez, Rebeca Chávez-Herrera,

Aida S. Castro-Sosa, Lilia C. Pérez-Hernández,

Rosa P. Hernández Torres and David Olivas-Dávila

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Abstract

Body shape, image, and composition are three different but related concepts used to describe people. Body shape, also known as somatotype, represents the tangible body, which can be externally observed and measured without destroying or hurting it. On the contrary, body image represents the subjective and intangible human nature, a construct that we try to define by applying validated scientific tools—a set of dimensions easily affected by psychological perception. Instead, body composition represents the physical parts grouped into similar compartments. Due to the fact that it cannot be observed or measured with the naked eye, and in order to reduce measurement error, we try to measure them with the highest and most accurate available technology. Shape, image, and composition affect sport's performance. Sports literature mentions, sometimes interchangeably, form, image, and body composition. So when we refer to them we have to distinguish them. Social, political, economic, cultural, educational, and genetic factors influence them. Technological advances in determining the shape and composition are reliable, but not the ones for body image, which needs further development. In this paper, the interrelation of these three aspects is described, with health and sport's ambit indicators.

Keywords: anthropometry, somatotype, physical exercise

1. Introduction

Humankind has always tried to understand what surrounds it through characterization and division of objects into different groups, that is to say we classify them according to their

particular characteristics of shape, size, color, texture, smell, weight, hardness, density, resistance, flexibility, temperature, etc. Sociopolitical and cultural sciences try to understand mankind though its history, culture, education, socioeconomic status, politics, religion, migration, etc. In the biomedical sciences, we strive to integrate many of these classifications in order to know the individual and social behavior of the human race, their preferences, feelings, and sufferings. Mankind with all of this creates a great quantity of sciences to theoretically facilitate, make more comfortable, and longer its existence.

With the purpose of understanding body structures, how they are organized and affect people, physical and functional anthropology, macroscopic anatomy, and basic and applied psychology intertwine, creating sometimes other sciences, including kinanthropometry. It is within this set of sciences where the present work is carried out.

From the point of view of macroscopic and functional anatomy, the human body consists of different types of cells, grouped and compartmentalized to form tissues, organs, and systems. Said division has allowed kinanthropometry and other sciences to regroup them in different macroscopic structures called components, including bone mass, lean mass, visceral mass, muscle mass, and fat mass. The amount, proportion, and distribution of these components give the body a particular physical form [1]; intervening around these a great number of disciplines and measuring instruments in order to determine them. In nonpathological conditions, the variability of these components between people depends on several factors, among the main ones: genetic aspects, gender, hormonal, pregnancy-related, age, physical activity, physical postures, environmental, and cultural. All of these factors and natural selection have allowed the human body to adapt to its environment [2–6]. In this sense, the literature talks about body shape, body composition, and body image, which are a construct that even though it seems easy to define its description is complex. Body shape would be the objective and technically measurable representation of the exterior of the human body, which are the weight, length, diameter, circumference, and volumes of its various segments. Body composition would be the magnitude and proportion of the different body components mentioned above that in an indirect manner and *in vivo* we try to know. Body image would be the mental and subjective representation of body shape and body composition, in terms of size, shape, proportions, color, texture, position, etc. [7]. This subjective representation of the body, which depends on personal experiences, stems from the consistent and objective view we have of it; however, it is transformed or modified by various factors that will be mentioned. Body shape, composition, and image have great health and social implications. Health implications are those that affect in a positive or negative manner the health of the individual, whereas social implications are those that allow us to assertively or erroneously communicate and interact with others.

The literature reports several methods destined to determine the amount, proportion and distribution of the components that provide body shape. Given the impossibility of measuring them directly on people or due to the danger of high-ionizing radiation exposure in some procedures, the validity of some methods cannot be corroborated *in vivo*. The current methods that are most often used to determine both shape and body components are: anthropometry, digital photogrammetry in 3D on level body surface, bioelectrical impedance (IB), ultrasound, densitometry,

deuterated water (labeled deuterium isotope), deuterated creatinine, spectroscopy, reading magnetic resonance imaging (MRI), computed tomography (CT), and dual-energy X-ray absorptiometry (DEXA). The importance of knowing body shape and its components lies in the association of these with physical development, aging, self-esteem, physical performance, and various metabolic disorders, such as anorexia, obesity, diabetes, osteoporosis, dyslipidemias, and metabolic syndrome, among others [3, 6, 8–11].

Regarding body image, its study is mainly done through graphical representations of the whole body, segments, or specific parts, likewise through the use of self-image. Typically, these images are selected, or modified by different methods (manual or electronic) in order to achieve specific patterns, perceive distortions of the image itself, or achieve the ideal form and image of how we want to perceive ourselves or want to look like [12]; although, we also find in the literature questionnaires which offer the reader different answer options to define their body image [13]. The validity of many of these methods is under discussion, especially due to errors in the selection and administration of the instruments and the population studied; but also by errors in the analysis and interpretation of them [14].

This paper analyzes the three concepts outlined above. Which although interrelated, they are different, these are: body shape, body image, and body composition. We analyzed equally how each one relates to physical and athletic performance.

2. Theoretical framework

2.1. Body shape

Body shape is also known as somatotype. This was initially described by Matiegka in 1921 [15], who divided body structure into four basic components: bone mass, subcutaneous fat mass, muscle mass, and residual mass. Years later, body shape was retaken by the American psychologist William Herbert Sheldon [16], who from around 4000 human photographs reconstructed the somatotype, thus creating three qualitative dimensions related to the three embryonic germ layers: (1) endomorph related to the endoderm, which largely forms the digestive tract, (2) mesomorph related to the mesoderm, which gives rise to muscle mass and bone mass, and (3) ectomorph related to the ectoderm, which forms the nervous system. Theoretically according to Sheldon, endomorphs have a slow metabolism predisposed to accumulate body fat thus making them more likely to be quiet, mesomorphs have a normal metabolism but are predisposed to develop large muscles which predisposes them to be active and rough, and ectomorphs have an accelerated metabolism that makes them lose fat mass and muscle mass, presenting thin and fearful appearances [16]. Sheldon as a psychologist tried to analyze behavior through body shape, probably taking up the ideas of Joung about the types of thinking, feeling, and perception. Subsequently, these qualitative and unscientific ideas from Sheldon were taken up and perfected by Barbara Heath (Sheldon's assistant) and Lindsay Carter, who perfected Sheldon's numerical system by developing an anthropometric system to give a scientific and quantitative character to Sheldon's somatotype [17]. Currently, this anthropometric system has been retaken by the International Association for Standardization
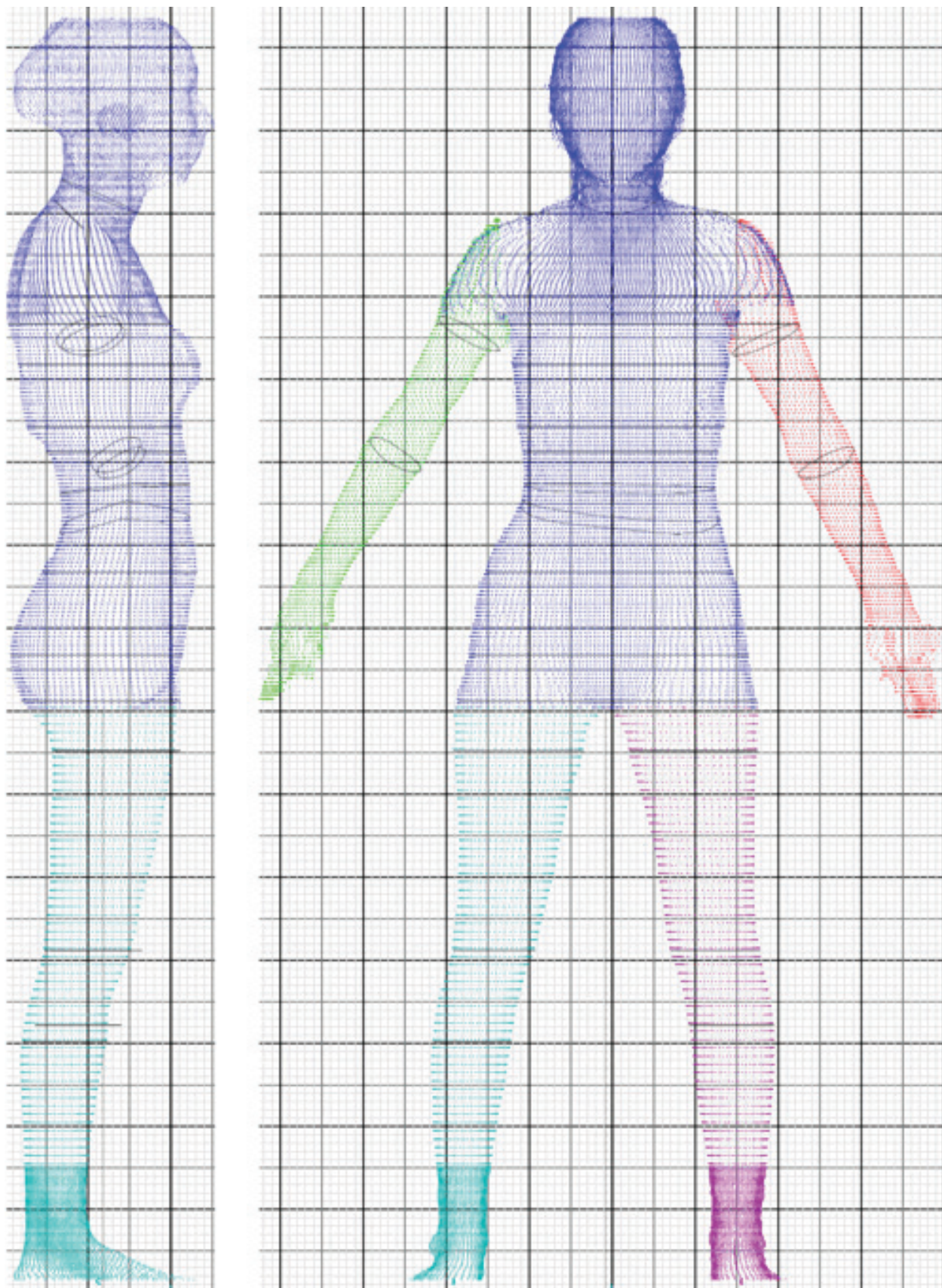
Figure 1. Body shape by Scanner in 3D (TC2-18 3D Body Scanner, USA). A small square corresponds to 1 cm^2.

of Kinanthropometry (ISAK), extending it internationally so through body measurements it will be able to determine problems with growth, development, aging, health status, as well as ergometers, and athletic-sports performance, among others (**Figure 1**).

Other authors have tried to classify body shape based on the distribution of certain body components. Bouchard [18] in the late twentieth century classified body shape based on four patterns of obesity: Pattern (1) with excess body fat and distributed in a balanced way throughout the body, pattern (2) with excess body fat and distributed mainly in the abdominal region (android type), pattern (3) with excess body fat and distributed mainly deep in the abdomen, and pattern (4) with excess body fat and distributed primarily in the gluteal muscles and thigh bone (gynaeoid type).

Differences in body shape between species, including humans, respond to the need of adjustment and survival to their environment; mainly against the weather [19], the geography [20], and food availability [21], also being present differences between genders (sexual dimorphism). Referring to the weather, and in order to maintain thermal homeostasis, individuals from cold environments are wider in comparison to thinner individuals who live in warm environments [22]. Faced with geography, wideness instead of height is also affected; however, an established pattern that indicates geography characteristics favoring the increase or decrease of corpulence has not been detected [22]. Finally, due to the technological domain of agriculture, food preservation and its ease of transportation; food availability should no longer influence morphological changes in humans [22]. However, according to the World Food Program [23], one in four children from developing countries presents stunted growth due to malnutrition. Likewise, the Food and Agriculture Organization of the United Nations [24] reports the existence of developing countries where more than 35% of the population still suffers from chronic malnutrition, including Namibia, Zambia, Central African Republic, and the Democratic People's Republic of Korea. Given the fact that malnutrition depends on the country's capacity to feed its population, morphological changes are also influenced by political and economic situations. On the other hand, due to the large number of immigrating populations, the differences due to geography and climate have begun to get lost; however, genetic, cultural, and socioeconomic patterns are those that currently dominate in the determination of body shape [25].

Currently, in a globalized world where commercial pressures are superimposed over rational judgment, the idea that being thin is favored [26], turning into a pathology the trend of extreme thinness, which leads to malnutrition, anorexia, and bulimia, especially in women [27]. Conversely, in some Arab countries (Saudi Arabia, Kuwait, and Bahrain) opposing cultural ideas on thinness exist, in which being robust is synonymous with beauty and sexiness, obesity levels being 39% for men and 50% for women [28]. However, due to interculturalization and Westernization, these young people also have the highest rates of eating disorders (~45% of young people in the case of Kuwait), who wish to be thinner [29].

2.1.1. Body shape and physical sport's performance

Body shape and physical-athletic performance are closely related, that is to say that changes in one necessarily affect the other. In addition, body shape is different both among sports and

between categories and positions within a sport; each sport and its position requires from its athletes specific morphological characteristics; some dominate over others, even within each sport [30–32]. For example, football athletes are taller and leaner (meso-endomorphs), basketball players are tall and lean (meso-ectomorphic), body-builders are muscular (meso-endomorphs), long distance runners are thin, etc. [33–35], with roundness or endomorphic somatotype (synonymous with abundant fat mass), being the less fortunate feature for physical sport's performance. In this sense, being tall and lean offers competitive advantages in football [34], basketball [36], volleyball [37], soccer [38], swimming [39], and athletics [40], among others. In the same manner, Gabbett et al. [37] report that elite volleyball players tend to be taller and leaner than novice players. Rebelo et al. [38] report that soccer elite players are taller than the nonelite players. On the other hand, aerobic endurance sports, for which athletes have to mobilize their body over long distances, show that it is convenient to have small and thin bodies. For example, Moro et al. [40] reported that compared with cyclists, triathletes have lower body weight (75 vs. 79 kg) and less fat (6% vs. 8%). Arazi et al. [41] found in cross-country runners average heights of 1.75 cm and body fat percentages of 8%, with meso-ectomorphic somatotypes (1.4–4.1–3.6). Moreover, Vernillo et al. [42] found that world class Kenyan athletes display extreme sport's thinness; that is, very low endomorphy and mesomorphy and relatively high ectomorphy (balanced ectomorphy, 1.5–1.8–3.9), with body fat percentages of 4.6% (assessed by anthropometry). Comparatively, Belli et al. [43] found that mountain ultramarathon runners have meso-endomorphic (3.4–5.2–1.7) somatotypes, with fat percentages of 13%, noting that the higher endomorph content helps them obtain a good performance during their sport's execution, and withstand the physical requirements to run 217 kilometers.

Along with the previous information, systematic training over time, coupled with professionalized sports, is constructing body shape toward a mesomorphic constitution, with a slight endomorphic decrease [44].

As it has been observed, one way of analyzing both body shape and sports performance is through the somatotype. In sports that require the use of body weight as a form of attack, endomorphy exceeds five units. Mesomorphy is preferred in all other sports with values greater than 5 units, and rarely less than 3 units, especially in elite athletes [32], except for some distance runners as Kenyans. This tells us that when referring to somatotype, mesomorphy is the best predictor of physical and athletic performance [30].

2.2. Body image

Body image is a complex construct that encompasses several dimensions, including perceptions of the operation (appropriate or not) of our body, and attitudes we take to respond effectively to daily life activities; all of this according to our experience, self-awareness and self-perception [8]. In other words, it is not only the mental representation of our external physical appearance, but also the concepts, attitudes, and feelings we have about our body (height, size, proportions, weight, color, voice, posture, etc.), which allow us to interact with the environment and raise affective emotions, either of tranquility and happiness or anxiety and stress [45].

Body image develops in the early years of life [46], where, probably, parents, siblings, and relatives are the first ones to shape children's body image [47]. Given the easy access to media since the first years of life (television, video games, and the Internet), it is possible for these to also be taking part in the creation of body image at an early age [48]. Harrison et al. [49] reported when studying attitudes about obesity in children 4–6 years old, that children have preferences for being thin and have psychosocial and sports disadvantages due to being obese.

Body image is positively or negatively affected by various psychosocial factors, such as health, sport's competitions, physical exercise, and nutrition, which modify how we perceive and evaluate ourselves [50]. Its distortion among the population is variable, and differs among sex, age, ethnicity, and type of population [51–53]. Regarding gender differences among athletes, women, compared to men, have higher levels of dissatisfaction with their sport's body shape and greater eating disorders [54]; in addition, while men are more concerned about sport's performance and improving their physical abilities, women care about being thin and having less body fat, making them prone to caloric restrictions, along with the intake of dietary supplements for weight loss [55]. Studying the general population, women have also been found to have greater body image distortion than men (~10% higher, 11–72% vs. 8–61% for women and men, respectively), with some body parts being more affected than others. For example, in women, abdomen, hips, and legs are the most affected (50–71%), whereas in men it is the chest and muscle tone (32–45%). Regarding age, dissatisfaction with body image increases along with years, especially among women [51]. Olvera et al. [56] while studying Hispanic and Caucasian tweens reported that teenage boys prefer to have taller bodies while girls thinner ones. On the other hand, Ferraro et al. [57] mention that even in older adults differences between gender are observed, for example, when women were asked how they perceived their body image they answered "a little big," whereas men of the same age responded "just the right size." In the case of elderly women, this can have unhealthy results like unnecessary diets, excessive weight control, and low self-esteem [50]. Being subjected to caloric restriction at older ages can lead to malnutrition, favoring the loss of muscle mass and muscle dysfunction (both problems already present in older adults), thereby increasing the presence of infections, accidents, fractures, and a set of diseases associated to malnutrition in adulthood [58]. As for the differences between ethnic groups, separate studies in U.S. population have observed that African American women have lower self-image problems than other ethnic groups, being the order as follows: African American < Asian < Caucasian < Latin; in addition, African Americans and Caucasians see themselves as being thinner than the other groups [52, 59]. Nevertheless, studies with African American college women found that they assigned higher priority to their hair and skin tone compared to Caucasian women [60]. Hair and skin tone are outstanding features for the African American population, which means that evaluations of body image should somehow include skin color and hair. Finally, it has also been reported that women in rural areas have a more positive body self-image than those from urban areas [53].

In this paper, we consider that a healthy body image is one that being healthy is well accepted by oneself (feeling comfortable with your body), on the other hand, an unhealthy one is a negative self-image, which is not accepted even though is healthy. Treatments to improve body image are diverse, including diets, exercise, surgery, cosmetic, and psychological or psychiatric treatments

[7]. Normally, the effects on body image are favored by economic (labor), social (competition), family, colleagues, and peer pressures. In addition, they are associated with other conditions, including bulimia, anorexia, and body dysmorphic disorder [45], causing these pressures extreme thinness, especially in women, and bigorexia and anabolic steroid use in men [45].

2.2.1. Body image and physical sport's performance

It is recognized that the mere fact of playing a sport improves the perception of body image [61]; this is possibly because the athlete's bodies resemble more of an aesthetic ideal [62]. From the point of view of the duration of exercise, Hausenblas and Downs [63] mention that athletes have a more positive body image compared to the general population. Ginis et al. [64] observe that 8 weeks of exercise, and improvement of physical abilities, increase self-esteem ($R \sim 0.50$), with self-esteem benefits being higher in aerobic exercise types compared to anaerobic. Williams et al. [65] note that only 6 weeks of circuit weightlifting, along with increased muscle strength, reduces anxiety and improves body image. In terms of frequency, Homan et al. [66] observed that people who exercise more often exhibit higher self-esteem (appreciate their body as it is); moreover, regardless of their body shape they are probably more identified with exercise. In addition, it has even been observed that even a single session of exercise increases self-esteem in people [67]. Varnes et al. [68] in a systematic review found that most studies report higher self-esteem in athletes than in nonathletes; however, differences found between athletes of different disciplines are not consistent. For example, Latorre-Roman et al. [69] found greater body dissatisfaction and physical exercise dependence among triathlon and swimming athletes, and lower in athletics and cycling athletes, all of them involved in endurance sports. Instead, Goltz et al. [70] found no differences between sports, but they did with body fat content, where athletes with higher percentage of fat presented greater dissatisfaction with their body image. Finally, it is also recognized that body image problems are easier to discover and analyze among female athletes, than in males, so probably these problems are underassessed and underdiagnosed in men, being this one of the main reasons of stress in athletes of both sexes to maintain body weight and aesthetics [71].

With technological advancement, body image processing has been refined, currently with the use of sophisticated equipment and computer programs that facilitate their interpretation and integration. In addition to it being integrated with the third concept to be discussed in this paper called "body composition." Among the equipment that facilitates this integration we have computed magnetic resonance, high-resolution tomography, X-ray densitometry, topographic photogrammetry, and multifrequency bioelectrical impedance.

2.3. Body composition

As mentioned above, for its study, we divided the human body in different compartments. This compartmentalization is not recent; Hippocrates (460 BC) somehow had already divided the human body into four fluids or basic substances called humors: blood (affectionate), phlegm (indifferent), yellow bile (bad temper), and black bile (depressive) [72]. Later, Galen (~200 AD) took these ideas and created four other psychological classifications or temperaments associated with the first: choleric (grumpy and irritable), melancholic (analytical and quiet), sanguine (optimistic and social), and phlegmatic (relaxed and calm) [73]. However, Wiltse

et al. [74] mention that formal knowledge of the human body and its compartments probably started with systematic human dissections made in the third century BC by Herophilus, known as the father of anatomy. It was not until the renaissance, after breaking the religious myths about the divinity of the body that modern anatomist Vesalius made new dissections, constructing important maps of the inside of the human body [75]. With the aid of current technological advances, we can now quantify, through precise images the interior of the human body; however, these methods are associated to some health risks. Thus, the determination of body composition is simplified by fractionating the body. For this purpose, various levels of compartmentalization are proposed: molecular (water, nitrogen, calcium, potassium, sodium, and chlorine), tissues (fat mass, bone mass, muscle mass, and residual mass), and the combination of several of these, called multicompartment models. A full explanation of these models, their considerations, and equations are found in Fosbøl et al. [76].

Currently, we quantify *in vivo*, both components of the human body and the relationships between them coupled with the changes produced by various factors. A brief summary of the documents published on body composition, as well as a brief history of methods for quantification, from Hippocrates until the late twentieth century, is presented in *History of the study of human body composition: A brief review* [77].

As shown, body composition has been well investigated. The importance of the study lies in its high correlation (R^2 0.50–0.79) with diverse health parameters [78] and sport's physical performance [79]. Due to the complexity of *in vivo* study, some authors have evaluated fresh cadavers, thereby creating equations for making estimations and clinical interpretations [80–82]. Due to the difficulty of *in vivo* study, body composition's determination remains imprecise, although their correlations can reach 0.8, when several methods of determination are being simultaneously studied [83]. This indicates a 64% of convergence between methods. Therefore, we recommend using different methods, in which each one observes the body from a different angle, to provide a more complete view of it. Nevertheless, it has been observed that when different methods are used, each one of them adds a measurement error, increasing total imprecision. However, measurement error is minimized with the use of increasingly accurate and standardized instruments.

For their technological capabilities, the most accurate methods for determining body composition are: computed tomography with 92% accuracy [84], nuclear magnetic resonance with 99% confidence [81], and DEXA between 66 and 85% reliability (for femur fractures) [85]. Other methods include air displacement plethysmography (Bod Pod) and underwater weight, which through the measurement of body density estimate with equations the body composition. The remaining methods we found have been validated with the ones that have been previously mentioned. For example, anthropometry versus DEXA with 84% correlation [86], ultrasound versus computed tomography with 45–82% correlation, ultrasound versus Bod Pod with 85% correlation [87], anthropometry versus NMR with 77% correlation, and bioimpedance versus NMR with 86% correlation [88], among others.

2.3.1. Body composition and physical sport's performance

Body composition has always been found to be associated to physical and athletic performance; the development of each of its components is specific to each sport. Gonzalez-Neira

et al. [89] when studying anthropometrically female soccer players, found that the ones with higher weight and higher body mass index (BMI) had lower aerobic capacity ($R^2 \sim 055$, $p < 0.05$). Marinho et al. [90] observed while studying Jiu-Jitsu athletes, that slight but significant decreases in body fat percentage in elite athletes versus nonelite (~2.5%, $p < 0.05$). Guiraudou and collaborators [91] found while studying Rugby players, that fat mass, rather than muscle mass, is the one that is related to sports performance ($R^2 = 0.61$, $p < 0.01$), with central body fat being a predictor of better performance. In the same manner, Belli [43] reports that in ultra-marathon runners, fat content in the lower limbs and abdomen has a negative impact on performance. In some sports, minor modifications of certain components can be crucial, both before and during competitions. For example, in contact and physical-constructivism sports, weeks before competition, athletes experience a marked weight loss (5–10% of body weight) to adjust to the competition weight [92]. This is done by decreasing their caloric intake by about 1% per week, plus dehydrating 24–48 hours before competition [93]. However, if these procedures are not well controlled, they can lead to negative effects on physical performance, especially if body fluids losses are greater than or equal to 5% of the body weight [94].

Regarding muscle mass, da Silva de Souza et al. [95] have observed in elite Brazilians body-builders' average body fat percentages of 9.6%, while muscle mass percentages of 52%, with a balanced mesomorphic somatotype (1.8–8.1–0.7). Mielgo-Ayuso et al. [96] have observed that in female volleyball players, regardless of the position they play, more muscle mass correlates with greater muscle power (R^2 0.11–0.77).

In regards to the development of muscle strength and power, both biochemical-molecular and biophysical characteristics are necessary. Biochemical aspects relate to fiber type, either slow twitch (type 1, red or oxidative) or fast twitch (type 2, white or glycolytic), where type 2 fibers are the fastest [97]. As for the biophysical aspects, we refer to length, thickness, pennation angle of muscle fibers, and insertion distance of the muscle with respect to fulcrum [97, 98], in which greater length and thickness of the muscle fiber translates to increased power and speed development [99]. On the contrary, a greater pennation angle correlates with less muscular power and speed [99]. For example, Terzis and collaborators [100], while studying hammer throw athletes, noted that elite athletes versus nonelite had greater quantity of muscle type 2 fibers and a greater cross-sectional area in the said fibers (60% vs. 49% and 66% vs. 51% for type of fibers and cross-sectional area, respectively); moreover, they found that athletic performance of these athletes is positively correlated with both the parameters ($R^2 = 0.17$ and $R^2 = 0.86$, for fiber type and muscle cross-sectional area).

3. Conclusions

Technological and scientific advances to assess shape and body composition continue to become more reliable and valid throughout the years. Therefore, now it is time to strengthen the development of techniques and procedures for assessing body image. These three aspects, together with sports performance should be analyzed together to keep the athlete in optimal conditions, not only for competition, but also for health and quality of life. However, as it has been discussed, it is often tedious, costly, and difficult to achieve comprehensive assessment,

due to the fact that most athletes do not have access to the technological and scientific methods for such assessments to be performed. Because of this, we are still far from achieving maximum sporting achievements.

Author details

Arnulfo Ramos-Jiménez[1]*, Rebeca Chávez-Herrera[1], Aida S. Castro-Sosa[1], Lilia C. Pérez-Hernández[1], Rosa P. Hernández Torres[1] and David Olivas-Dávila[2]

*Address all correspondence to: aramos@uacj.mx

1 Instituto de Ciencias Biomédicas, Universidad Autónoma de Ciudad Juárez, Av. Plutarco Elías Calles y Hermanos Escobar s/n, Ciudad Juárez Chihuahua, México

2 Universidad Mayor, Santiago of Chile, Chile

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