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Dxa as a Tool for the Assessment of Morphological Asymmetry in Athletes

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1. Introduction

Symmetry and asymmetry – two opposite phenomenon, does coexist in nature and both are very essential for science. There are many definition of symmetry, depending on research area. In biology, a dominant view is the left-right bilateral symmetry describes health and high genetic quality (Gould & Gould, 1989). In physics, symmetry includes all features of a physical system that exhibit the property of symmetry—that is, under certain transformations, aspects of these systems are "unchanged according to a particular observation" (en.wikipedia.org). In mathematics, the intellectual pursuit of the Universal formulation of symmetry (Group Theory) has led to major discoveries in physics, and to Einstein's general relativity theory (Engler, 2005). In chemistry, left-right balance is a critical component in the notion of symmetry and refers to regular arrangements of molecules and the more symmetrical, the more aesthetic (Muller, 2003). Additionally symmetry and chemistry have been in interplay in spectroscopy, crystallography, reactivity and conformational analysis. Besides, symmetry considerations continua to assist chemistry in systematizing and interpreting observation and in discovering new reactions, molecules, and other material (Hargittai & Hargittai, 2005). In art, symmetry refers to left-right, top-bottom balance (of forms, colors, lines etc) in the composition as a whole being essential component of art's aesthetic quality (Jacobsen et al, 2006).

On the one hand symmetry means proper proportions, harmony, and balance between two elements of some totality and is connected with beauty. On the other hand there is another definition of this term- bilateral symmetry (right-left symmetry). Both of them concern body build (morphological symmetry), but can also refer to some human movements (Starosta, 1990).

According to Frey (1949) "symmetry signifies rest and binding, asymmetry motion and loosening, the one order and law, the other arbitrariness and accident, the one formal rigidity and constrains, the other life, play and freedom".

According to Webster dictionary (Webster, 1991) symmetry is quality of possessing exactly corresponding parts on either side of an axis and in biology – regularity in form or similarity of structure, whereas asymmetry it is lack of symmetry, uneven disposition on each side of an central line or point.

The opposite word to symmetry is asymmetry. Three kinds of asymmetry were distinguished by Wolański (1955): 1/ morphological – differences in size and shape of organs or body parts situated on left or right side of the body; 2/ functional – connected with one of hemispheres domination (usually left); 3/ dynamic – differences between left and right extremities in strength, muscles hardness and elasticity.

Bilateral asymmetry in humans, as was stated by same authors (Zeidel & Hessamian, 2010), was fashioned by millions of years of adaptive evolution and it implies perfection.

There are three types of bilateral asymmetry by Van Valen (1962): 1/directional asymmetry (DA): when some traits develop more on one side than the other, e.g., the human brain; 2/ antisymmetry: asymmetric development is typical, but unpredictable, e.g., larger signaling claw of the male fiddler crabs or handedness in human; 3/ fluctuating asymmetry (FA): "randomly produced deviations from perfect symmetry of two sides of quantitative traits in an individual for which the population mean of R-L differences is zero and their variability is near-normally distributed".

Normal human body asymmetry appear very soon and the manifestation of morphological asymmetry intensify with aging what is connected with functional asymmetry (Malinowski, 2004). Level of asymmetry among population reflects its developmental stability, hence differences between right and left bilateral trait are very good predictor of developmental stability both on the individually and population level. Fluctuating asymmetry has been the most widely used measure of developmental stability (Palmer & Strobeck, 1992).

Potentially human body is divided into two symmetrical parts but in fact there are some deviations (aberrations): 1) internal aberrations: asymmetry of even (kidney) and odd (pancreas, heart, spleen, liver, stomach etc) of internal organs. It refers to size, shape, location, constitution or function, 2) external aberration: refer to extremities asymmetry and handedness. There is strict connection of those aberrations with hemisphere domination (Czachowska-Sieszycka, 1983). The more increasing of the left hemisphere in domination, the more differences in left and right size of the brain. The fact that human brain is asymmetrically organized is known for about 140 years. Platon stated that symmetry is ideal (beauty is symmetrical and proportional) and that there are perfect harmony between one side to the other. That is why anthropologists in XIX w thought that human brain must be symmetrical. Paul Broca debunked this theory (Broca, 1865) and stated that right hemisphere damaged cripple speech rarely but left hemisphere - in most cases. On the basis of this information he found out that speech centers are localized only on the one side of the brain. Nowadays, the research including asymmetry of human brain are more and more advanced due to a new technology. It is valid, because the information about right and left hemisphere asymmetry could also help in better understanding of human body morphological diversification.

2. Morphological asymmetry in sport

In sport there is a need to seek some acts to achievements the highest results, especially in highest level athletes. Among other factors like training methods modification or biological regeneration also certain level of morphological parameters is very important. Body compartments, among other factors, play an important role in physical performance (Petersen et al., 2006). Generally, the body composition of athletes are consider in terms of whole body composition, but research show that regional BMD, FFM and FM distribution is equally important, in relation to training and performance (Bell et al., 2005). Tend to this direction more and more scientists conduct research in this area.

Many researches proved that morphological asymmetry - the difference between the right and the left sides of the body exist in sport (Dorado et al., 2002; Auerbach & Ruff 2006; Starosta, 1990) and it is very important to observe the scale of this phenomenon in order to its elimination if it will be necessary. Morphological asymmetry can concerns both side-to-side differences between extremities, pelvis, trunk and total body with upper and lower body diversification. Analysis concerns mostly body dimension (length of limbs), level of body fat, lean and body density. In humans, some level of asymmetry in body dimensions is rather norm than the exception (Al-Eisa et al., 2004). It is stated that the lifelong preference for one extremity -e.g. the left arm or the left leg -as well as a predilection for a certain direction when turning around or rotating about one's longitudinal axis could lead to asymmetry which occurred in morphological characteristics and which can even be osseous in the case of competitive athletes. The body response on training stimulus will be vary according to its timing, duration and intensity (Malina, 1979).

It is obvious that morphological side–to–side diversification depends on sport specificity. Participation in asymmetric sport disciplines is connected with asymmetric changes in soft tissues (Ducher et al., 2005; Haapasalo et al., 1998). As was noticed, soft tissues indicate greater lateral differences than skeletal measurements (Van Dusen, 1939; Chhibber & Singh, 1970; Kimura & Asaeda, 1974;). Observation from literature suggests that in most cases the upper limb is laterally dominant in size on the right side while the lower limb is larger on the left side (Singh, 1970; McGrew & Marchant, 1997). Some studies stated that asymmetries are more pronounced in the upper extremities in comparison to lower extremities when the right side tends to be larger than the left (Munter, 1936; Tomkinson et al., 2003; Malina & Buschang, 2004; Ulijaszek & Mascie-Taylor, 2005). Malinowski (2004) stated that average, the right arm and forearm are longer, and larger are their circumferences. Left hand is longer and narrowest. The right upper limb is longer about 1 cm in comparison to left one, whereas left lower limb is longer about 10-13 mm. Also left foot, left thigh and calf circumferences are longer.

As was stated by some authors (Manning et al., 2002) small percentage changes in left or right trait size may result in large percentage changes in asymmetries, so precise and the most suitable method is need to evaluated regional morphological diversification among very specific part of population – athletes.

2.1 Methods for regional body composition assessment

There are different methods which could be use to do such analysis, which differ in the time, expense and accuracy of the results. These procedures are subject to some error which can result from measurement procedures, from the equations selected to calculate body fat percent, or from both. A standard error for most procedure is about 3 to 4 %.

The most traditional method to assess the size of particularly body segments is anthropometry. It uses circumferences, SKF thicknesses, skeletal breadth and segment lengths for total and regional body composition evaluation (Heyward & Wagner, 2004). Some standardized procedures should be taken into consideration to increase the accuracy and reliability of measurements like taking three measurements within ± 0.2 for body segments with relatively small girths (calf, arm, forearm) and three measurements within ± 1.0 cm for longer body segments like waist, abdomen and buttock; or using a small sliding caliper with greater precision to measure breadth of smaller segments (elbow, wrist) and so on (Wilmore et al., 1988). Schell and co-authors (Schell et al., 1985) emphasized that asymmetry of paired dimensions is a big methodological problem in anthropometry. Additionally, analysis of asymmetry should be done with advanced statistical tests. Moreover, interpretation of given results must be done with cautions especially, if observed differences are so small that could be lower than technical errors of measurement (Moreno et al., 2002).

There are also some newer methods to assess regional diversification of some tissues. Traditional BIA method, allows to assess only whole body composition (wrist-to-ankle), however segmental BIA (SBIA) system based on eight symmetrically re-positioned electrodes can give information about resistance and reactance values from right and left arms and legs and torso (www.rjlsystem.com/pdf-files/segmental_bia.pdf). Because of human body segments are not uniform in length or cross-sectional area, there will be different resistance to the flow of current through them (Heyward & Wagner., 2004). Fuller and Elia (1989) stated that those body segments which have small cross-sectional areas have simultaneously the greatest effect on impedance. The resistance ratio of upper limb-trunk-lower limb theoretically equal 13.8 : 1 : 11.8. SBIA measuring particularly body segments like upper and lower limb or trunk may be a good method for person with altered fluid distribution, so also for athletes (Organ et al., 1994). Segmental muscle changes for example during physical activity are visible by studying the individual arms and legs as a comparative percentage or a percent change over time. Segmental measurements can be successful made by traditional electrodes Akern Sre (Florence, Italy) or by segmental body composition analyzers (Omron, Tanita, BioSpace) which incorporate foot and hand contact points (where standing person holding two rods with fingers and thumb of each hand) what has disadvantage: high resistance of the body ankle and wrist are included in the measurements. Additionally the ankle, wrist, lower leg and forearm contribute more than 50 percent of the measurement (Scheltinge et al., 1991).

MRI (Magnetic Resonans Imaging) – another method to assess regional diversification, can be used to assess whole mass and muscle content of any body area, giving high-quality images of different tissues (Malina et al., 2004). Also computerized tomography CT is often used in regional determination of body segments with body fat, muscle and bone area assessment (Buckley et al., 1987; Forbes et al., 1988; Jordao et al., 2004). Magnetic resonance imaging and computed tomography are regard as the reference methods for regional body composition assessment but routine use of them is impeded by access, high cost, and in case of CT, significant exposure to ionizing radiation. Some authors propose then DXA (Dual Energy X-ray absorptiometry) as a more valid and precise method for measuring total and regional body composition (Chen et al., 2007; Andreoli et al., 2009). Generally, DXA, CT and MRI methods are consider to be a standard for precision and accuracy for body composition measurements (Chettle & Fremlin, 1984; Ellis, 2000). DXA is primary method to estimate body composition of the total body and specific regions (bone mineral, fat-free soft tissue and fat). The main assumption of absorptiometry method relies on measuring attenuation of X-rays with high-and-low-photon energies what is dependent on the thickness, density and chemical composition of the underlying tissue (Pietrobelli et al., 1996). Two kinds of absorptiometry were distinguished: single-photon absorptiometry and dual-photon absorptiometry which were precisely described in Lukaski comprehensive study (1987). It was stated that both technologies provide highly reproducible estimates of lean tissue mainly in adults, because the coefficient of variation for them for repeated measurements is less than 2 %. The advantage of DXA technology is reduced of radiation exposure and more readily available data about changes in bone mineral content in whole and regional skeleton. As was stated by Webber (1995) the x-ray exposure is low and corresponding to natural radiation and radioactivity received during 5 days of normal living. Additionally, this method is more relevant in longitudinal study to track changes in body composition (Malina et al., 2004) because of the good precision of particular DXA device (about 1% for BMC and 2-3% for total body fat) for assessing whole body composition (De Lorenzo et al., 1998).

Kistrop with co-authors (Kistrop et al., 2000) found that measuring total and regional body composition by DXA can improve the prediction of energy expenditure what could be a valid information for athletes who try to lose fat mass or gain lean muscle.

Each method has its own advantages and disadvantages, also DXA. Some authors observed (Calbet et al., 1998) that this method giving a general idea about the specific sport loading influence on BMC. On the other hand it is not possible to assess the effect of sport participation to particular bones during DXA analysis because it includes all bone structures. There are also some concerns about measurements bias related to the impact of a significant change in the lean tissue hydration. Some study however show not significantly alters the estimates for the bone, lean and fat mass (Pietrobelli et al., 1998). Another problem is that thicknesses are different depends on body regions and individual body shapes, so there could be large variation in percent fat in DXA study (Steward & Hannan, 2000b; Lohman & Chen, 2005). When comparing results of regional body composition from DXA scanners of different manufacturers, caution must be done because of some factors which are different among both of them like: pixel size, X-ray voltages or algorithms for shape and edge detection (Tothill et al., 1994; Steward & Hannan, 2000a). As was stated by some authors (Lohman & Chen, 2005) differences between DXA instruments from leading manufactures like Hologic, Lunar and Norland were 7% for body fat and about 15% for bone mineral content, some times ago. Nowadays, DXA software are more and more accurate with new calibration modes increasing precision and accuracy (O'Connor, 2006). iDXA (Lunar) for example have a little bit precision with total-body assessment and almost identical values in regional BMD measurements in comparison to Lunar Prodigy (Faulkner, 2006). Despite all limitations DXA is a widely used method, owing to its ease of use, availability, low-radiation exposure, good accuracy and reproducibility for the assessment of regional body composition. It is also seems to be less dependent on biological consistency than other methods (Haarbo et al., 1991; Kohrt, 1995) and is most useful for research purposes (Speiser et al., 2005). It was documented that regional adiposity by DXA is potentially more accurate than anthropometry measures, and more practical than computed tomography or magnetic resonance imaging scans (Henche et al., 2008). Taking into account all of those data, DXA seems to be one of the most suitable method for evaluation side-to-side morphological diversification among athletes.

2.2 Morphological asymmetry of athletes - research overview

Many studies with athletes body asymmetry exploited anthropometric method. Malina and Buschang (2004) observed greater hypertrophy in the musculature of the dominant side in athletes. Also another authors (Calbet et al., 2001; Dorado et al., 2002) found, on the example of golfers, that they had muscle hypertrophy in the dominant compared with non-dominant arm under training influence. The right-left differences in morphological parameters (mainly in forearm girth, arm girth, elbow width) were observed also in 134 athletes aged 21-32 years, engaged in many different asymmetric movement sports like tennis, canoeing, kayaking and boxing (Krawczyk et al., 1998). According to those research, most significant asymmetry was found among tennis players, then in kayakers, canoeists, rowers and skaters and concerned mainly forearm girth. The extreme directional asymmetry in the use of the limbs among tennis players is connected with physiological and anatomical changes in those body segments (Lucki, 2006). On the basis of 25 male collegiate tennis players age 19-24 from four NCAA Division I she stated that there was significant asymmetry between the limbs, related to cross-sectional measurements (circumferences, widths). Some authors (Maughan et al., 1986) observed greater proportion of muscle and smaller proportion of fat in dominant arm than the opposite limb in tennis players. Numerous studies indicated increased bone density in the dominant limb among tennis players (Ruff et al., 1994; Ducher et al., 2005; Lucki & Nicolay, 2007). Analysis of the bilateral asymmetry among collegiate (19-24 years old) tennis players showed that forearm circumferences of the dominant limb was greater than in the opposite limb (3-10% in female and 2-13% in male tennis players) (Lucki & Nikolay, 2007). Jone's (Jones et al., 1977) study examining site-specific accretion of bone of professional tennis players, with differences being up to 30%. Tarociński (1977) stated that difference in circumferences of the left and the right upper extremities was 1-2 cm in male athlete (age 12-15) playing tennis for four years, whereas in Marchwicki study (1927) those differences was smaller and equal 0,3 – 1,1 cm. also among young tennis players. In lower extremities, in turn, there was smaller diversification with left leg advantage (Tarociński, 1977). Similar finding was done later on the example of baseball players (Komi 1996; Bubanj & Obradovic, 2002).

Abraho and Mello (2008) made comparison of the young athletes playing tennis for at most two years (age 6-10 years) with the male instructors between 22 y and 37 years of age engaged in this sport discipline at least eight years. They noticed the increase of the incidence of right somatic measures superior to the left, because the excessive time of training of asymmetric sport. This situation has influence on postural deviation according to those research.

When one considers that carrying loads with the preferred hand means a stress on the arm muscles of the same side and a simultaneous activation of the contra-lateral muscles for the stabilization of one's balance, these functional asymmetries become plausible. It is also remarkable that hurdlers, high jumpers and pole vaulters exhibit higher muscle contractility in their swing leg than in their take-off leg (Absauomov, 1976) because of the higher mechanical load. Kruger et al (2005) determined the degree of upper body morphological asymmetry in 19 elite international male javelin throwers, age of 26,4 ± 4.4 years. They found larger variables on the dominant side for thirteen of the fourteen variables (especially for triceps skinfold 5.9%, half-chest girth 4.9%,, forearm girth 3.9%, biceps skinfold 2.5%) what could have health consequences and performance limiting effects. The morphological asymmetry in the upper body of fast bowlers in cricket was observed in Grobbelaar study (Grobbelaar et al., 2000). It concerns the relaxed arm (3.8 %), tensed arm (4.7%), forearm (2.8%) and ½ chest circumferences (6.4%).

The morphological characteristics of fencers show a typical asymmetry of the limbs as a result of the asymmetrical sport activity practicing what is advantage in gaining success. Fencing produces typical functional asymmetries that emphasize the very high level of specific function, strength and control required in this sport discipline (Roi et al., 2008). Muscle mass of dominant lower limb of high-class fencer is bigger than contrlateral limb (Nystrom et al., 1990). Tsolakis et al (2006) stated, on the example of fencers, that there was difference in morphological asymmetry of arm and leg depended on age, where arm asymmetries were specific for the age of 10-13 years, whereas leg asymmetries were observed among 14-17 year-old athletes. Because of asymmetrical nature of this sport, some specific injuries are characteristics in the shoulders, the back and the pelvic girdle, so there is necessity of including prevention in daily fencers training (Kucera & Henn, 2003).

Manning and Pickup (Manning, & Pickup, 1998) stated that the national league athletes would be more symmetric, because symmetry is positively related with physical performance in adult males. Besides, symmetric males run faster than asymmetric males (Manning & Pickup, 1998). According to Chinn study "Morphological asymmetry is more pointed out in high level athlete in case of asymmetrical sport disciplines" (Chinn et al., 1974). Tomkinson et al stated (2003) that there are no differences in variance in fluctuating asymmetry between adult basketball and soccer, competing at two different standards (professional national league and semi-professional state league).

There is also some assumption that symmetry positive correlated with body size what mean that the larger men is (higher and heavier), the more symmetric he is. But in women body size correlated negatively with symmetry (Manning, 1995). Additionally this author observed positive correlation between body mass index (BMI) and asymmetry among women (the bigger BMI= the bigger asymmetry). On the other hand some research indicated that the bigger person (both men and women)– the greater asymmetry (Graham et al., 1998).

Studies of scientists from many disciplines suggest that age, sex and environmental stress like extreme unilateral work are the most influential factors for morphological asymmetry (Wolański, 1962; Singh, 1970; Mascie-Taylor et al., 1981; Malina, 1983). Some authors also found (Hetland et al., 1998) that there are different factors significantly contributed to the regional body composition. On the basic of 108 (86 recreational and 22 elite runners) male long-distance runners they stated that training was the strongest determinant in the legs and the arms, whereas androgenic activity was important in the abdominal region. Some data suggest that persistent unilateral training may also influence specific bone lengths and width. As was stated by Buskirk et al (1956) on the example of seven tennis players (nationally level), the athletes had greater length and width of bones of the dominant hands and forearms than the non-dominant extremity. Authors suggested that those laterality differences were results of vigorous exercise on the bone growth during the adolescent years. Similar findings were done by Prives (1969).

In Jones et al study (1977) there was a significant hypertrophy of cortical bone of the humerus in the dominant arm compared to the non-playing arm of 84 male professional tennis players. There were sex differences in cortical thickness of the dominant arm compared to non-dominant arm among athletes (man had 35% greater cortical thickness of the dominant arm, whereas women - 28%). Hypertrophy of the humeral cortex has been reported also in the throwing arms of professional baseball pitchers (King et al., 1969).

Asymmetry could have different value and it is stated that when it access some level, it may hinder some special activity practice, could negatively affect the health (being connected with functional asymmetry and some changes for example in the area of backbone). According to Wilk et al study (2002) therapist should focus on restoring the functional shoulder asymmetry during rehabilitation of shoulder injuries in the case of throwing athlete. Asymmetries between lower limbs during athletic movements are thought to increase the risk of injury and compromise performance (Cronin, 2010). In the case of athletes who are engaged with sport discipline including one-sided hips rotation (tennis, golf, squash) and suffer from LBP, more lower limbs asymmetry and pelvic asymmetry (LLD-leg length discrepancy) were observed (Egan et al., 1995; Van Dillen et al., 2008). Some authors asked the question if the asymmetry lead to the back pain or did the back pain lead to the asymmetry (Bussey, 2010). This is not yet determined evolutionary dilemma. She stated that asymmetries may be functional adaptations, meaning that the body has successfully adapted to the asymmetrical loading demands of the sport in order to decrease the excessive strain in some tissues. Similar finding did previously Koszczyc (1991) who observed that shoulder and whole upper limb asymmetry (which can appear in progressive stadium of ontogeny) could be effect of body adaptation to increased mechanical loads. Bussey (2010) conducted the study based on 60 women divided into three groups consisted of elite athletes at the national and international level (bilateral group: triathlon, cross-country running, single scull rowing ; unilateral group: field hockey, ice hockey, speed-skating) and control group. She speculated that some level of pelvis asymmetry may be a natural effect of lateral dominance which decrease with bilateral activities like running or cycling or increase with unilateral nature of sport discipline like hockey.

Field hockey is one-side dominant sport. It means that athletes have preference of one side of the body over the other. There are many different specific movements in this discipline. Many of them involve a rapid rotation of the hips, shoulders and arms for example push-in movement (Kerr & Ness, 2006). This movement stated with the body counter-rotated right side of the body is behind the left side (with respect to the direction of ball trajectory). Similar findings was described by Mc Laughlin (1997). Kerr found that pelvic and shoulder girdle maximum angular velocities occurred concurrently from left arm to the right arm. Many published studies focused on many components of field hockey like the hit (Burges-Limerick et al., 1991), the push (Alexander, 1983), the slap shot (Cresswell & Elliott, 1987), the push-in and trap phases of the penalty corner (Kerr & Ness, 2006), describing specificity of characteristic movements, which could appeared in athletes morphology.

Krzykała (2010) studied the effects of specific one-side dominant training on morphological asymmetry, on the basic of twenty competitive male field hockey players 18-34 years of age. All athletes had played representative hockey at a senior (national) polish level of the game. Average training years of all competitors was 17 y and hesitated between 13 y and 24 y. The anthropometric characteristics in both sides of the body was done by dual energy x-ray absorptiometry, using LUNAR PRODIGY ADVANCE (GE, Madison, WI, USA) densitometer with enCORE software (GE Helthcare v.10.50.086). There were significant differences in body mass density of the legs (1.576 ± 0.0909 g/cm^2 vs. 1.611 ± 0.1062 g/cm^2, respectively: p= 0.0086) and of the trunk (1.111 ± 0.0609 g/cm^2 vs. 1.137 ± 0.0729 g/cm^2, respectively: p=0.0008). In turn there were no differences between right arm 1.017 g/cm^2 and for left arm 1.014 g/cm^2 as well as between total bone mineral density (the right and the left sides of the body) (1.326 ± 0.0741 g/cm^2 vs. 1.338 ± 0.0754 g/cm^2, respectively: p=0.1310). The larger amount of body density was in the left legs, left trunk and total body of athletes. The individual differences between the left and right sides of a particularly body segment show that the biggest diversity among them was in the case of legs. Significant differences in side-to-side lean morphology were observed in every measured parameter. The lean of the arms, legs, trunk and total was higher in the left side of the body. The lean of right arm was 3738 ± 454.9 g vs. 4046 ± 420.7 g for left arm respectively (p=0.0000), lean of right leg was 10578 ± 1050.9 g vs. 10904 ± 1054.5 g, respectively (p=0.0000). Also lean amount was larger in the left side of trunk in comparison to the right (difference: 14371 ± 1580.6 g to 13996 ± 1436.7 g). Significance difference was observed in total lean (30444 ± 2759.5 g for right vs. 31208 ± 2814.5 g for left total, respectively (p=0.0073). There was clear similarity in arms and legs among field hockey players, as opposed to the trunk and total LEAN. Similar findings were observed in a case of body fat analyzing. Across all body segments, the amount of morphological asymmetry was significantly greater in the left side of the body.

In a study of thirty competitive young adult Rugby Union players, Bell et al (2005) observed the arm-lower body contrast in lean soft tissue mass suggesting, that upper and lower limbs contribute equally to playing performance. Also bone mineral mass (BMM) was different according to playing position. The legs were dominant in forwards (-0.76) and the trunk in backs (0.67). The measurements were done using DXA (Hologic QDR/1000W. software version V5.73). Using DXA (QDR-1500, Hologic Corporation, Waltham, MA) in ten healthy postmenopausal tennis players Sanchis-Moysi et al (2004) observed linear relationship between the extent of years of training and the magnitude of the inter-arm difference in bone size- participation in tennis after menarche is connecting with greater bone size and mass in the loaded arm. Some data suggested also that muscle mass is independent predictor of regional and total BMD on the example of gymnasts and elite swimmers with DXA method (Taaffe et al., 1995). Also Calbet et al (2001) study showed a high correlation between the BMD and the muscle mass in the left leg among 33 right-leg dominant male soccer players. Nevil et al (2003) considered the effects of specific training on BMD asymmetry between arms and legs among Caucasians athletes from ten sport disciplines (runners, cyclists, triathletes, racket players, rock climbers, swimmers, rugby players, rowers, kayakers and bodybuilders), at a university or higher level, trained for a minimum of four hour per week, for a minimum of three years. Using DXA on a Hologic QDR 1000W (Bedford, MA) scanner they stated that the differences between the dominant and non-dominant arms were significant but different depends on sport. For example it was greater in the racket players and lesser in the rowers. In the case of right and left legs, there was no asymmetric difference in BMD between them for all athletes combined nor within individual sport disciplines.

The McClanahan et al (2002) study investigated the effects of participation in different sports (NCAA Division I-A baseball, basketball, football, golf, soccer, tennis, cross-country, indoor/outdoor track and volleyball) on side-o-side diversification in bone mineral density (BMD) of the upper and lower limbs. On the basic of 184 collegiate athletes both sexes, and using dual energy X-ray absorptiometry, they revealed greater BMD of the right arms compared with the left arms for all teams. The largest differences were found in the case of men's and women's tennis and men's baseball. The differences in the lower limbs were less common in men and no significant in women.

One limb performance during some certain activities causes its higher fitness level than another limb. Thus training limb become dominate limb, in spite of athletes predisposition to right handedness, left handedness or ambidextratity (Starosta, 1990). Chilibeck et al (2000) asked the question if more bone deposition is a result of greater use of dominant limbs during physical activity or it is connected with fact that the dominant limb is genetically larger. They noticed, using dual energy x-ray absorptiometry, that a greater lifetime of preferential loading of the dominant arm is connected with a greater differences between arms in older group. Also earlier research reported greater mineralization for the dominant humerus but not for dominant radius and ulna, compared to the non-dominant ones, among baseball players 8-19 years of age (Watson, 1973). Additionally, they observed differences in the mineral content between the dominant and non-dominant increasing with age. Tomkinson study show that the increased metabolic rate that accompanies training will tend to increase fluctuating asymmetry in males athletes, at least if the training were conducted during the athlete's growth phase, when disturbances will have the greatest effect (Tomkinson et al., 2003).

3. Conclusion

All above information indicate that DXA is suitable method in athlete study. It allows to gain many valid data about not only overall but also regional body composition. Additionally it is precious method in longitudinal study of body composition assessment, tracking regional changes of some tissues during training program.

That kind of information could be important in a better understanding morphological characteristics of athletes, talent development, sports results improvement and with some injuries prevention. Further longitudinal research in this area could provide deeper insight into characteristic responses on specific training that require asymmetrical limb (side of body) use. Information about side-to-side differences in bone density may be valid for example for strength and conditioning professionals who want to include bilateral training programs minimizing stress-related injuries and maximizing sport results (McClanahan et al., 2002). It could be important to individualized symmetrization process among the athletes, because they do not have the same level of morphological differences. It is obvious that this process should be done methodologically (Starosta, 1990). After the few first stages, movements symmetrization could be used during training and the competitions, what could give quite big advantage over the opponents during the game. It relays on development through the training less fit side of the body and preservation harmony between symmetrical and asymmetrical movement (motor) preparation (Starosta, 1990).

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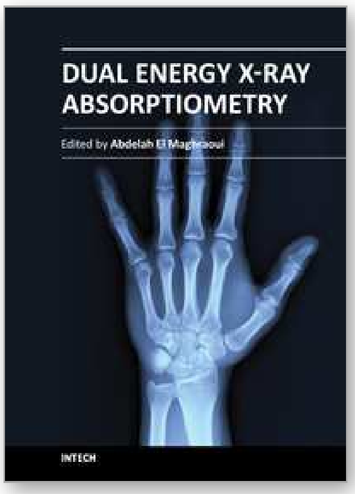

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The World Health Organization (WHO) has established dual-energy x-ray absorptiometry (DXA) as the best densitometric technique for assessing bone mineral density (BMD) in postmenopausal women and has based the definitions of osteopenia and osteoporosis on its results. DXA enables accurate diagnosis of osteoporosis, estimation of fracture risk and monitoring of patients undergoing treatment. Additional features of DXA include measurement of BMD at multiple skeletal sites, vertebral fracture assessment and body composition assessment, including fat mass and lean soft tissue mass of the whole body and the segments. This book contains reviews and original studies about DXA and its different uses in clinical practice (diagnosis of osteoporosis, monitoring of BMD measurement) and in medical research in several situations (e.g. assessment of morphological asymmetry in athletes, estimation of resting energy expenditure, assessment of vertebral strength and vertebral fracture risk, or study of dry bones such as the ulna).