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Morphofunctional Anthropometric Asymmetry in Adolescent Tennis Players

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The study aims to assess youth tennis players' anthropometric characteristics and determine the level and direction of the morphofunctional asymmetry. In total, 239 tennis players aged 8-17 years were assessed. Anthropometric measurements were done bilaterally, using Martin-Saller` method. A hand grip test was performed to define static arm strength. Statistical analysis was made by SPSS 16.00. The units of asymmetry were calculated using Nacheva`s equation. Tennis players from both sexes had higher values of forearm muscle mass than the upper arm's muscle mass. There were significant sexual differences, according to hand grip strength, with priority for boys. A moderate level of bilateral differences was reported in the forearm area and muscle-fat ratios. The hand grip strength, which has a high level of asymmetry, also showed large bilateral differences due to the higher loading of the forearm muscles. Tennis training in youth athletes leads to anthropometric asymmetry in the dominant upper limb.

Key words: tennis players; morphofunctional characteristics; asymmetry; adolescents

Introduction

Systematic physical load, mainly on the dominant part of the body, is a prerequisite for asymmetric changes in the bilateral body segments. These adaptive mechanisms of the body aim to preserve the athlete's physical abilities, but on the other hand can be a precondition for injuries and disproportions in the bones, as well as for deformities [9, 10]. Anthropometric asymmetry in sports depends on the type of physical activity and the level of sports discipline [2, 8]. Asymmetric changes are observed in the upper limbs (racquet sports, volleyball, basketball, handball, golf, etc.), mainly in the dimensions of the circumference of the arm and forearm [12] and the size of the epicondylar diameter of the humerus [15].

Different studies associated inter-limb asymmetry greater than 10-15% with increased incidences of injury. Some researchers declared that the asymmetry is more pronounced in the upper extremities than in the lower extremities, with right-sided prevalence [17, 25, 28]. Bilateral differences in morphological parameters (mainly in arm circumference, forearm, epicondylar diameter of the humerus) were observed in athletes practicing different sports, such as tennis, canoeing, golf, baseball and boxing [4, 8, 13, 14]. Tsolakis et al. established the relationship between the presence of asymmetry in the upper and lower limbs and the age of the athlete. The authors concluded that the higher percentage of asymmetry in the upper limbs is manifested at the age of 10-13 years, while in the lower limbs at 14-17 years [27].

Competitive tennis is a combination of shots with different types of ball spin. This is associated with multiple movements in the elbow and shoulder joints. The elbow joint allows flexion from 180 to 40 degrees, where one muscle extensor of the arm counteracts several muscle flexors. In the execution of the reverse blow (backhand), initial blow and overhead blow and those in the air, the optimal execution depends on the speed of extension of the arm in the elbow joint. This type of sport is associated with performing a series of uneven movements and high physical exertion (hitting the ball when serving sometimes exceeds 200 km/h), for a long time (between 60 and 300 min).

A significant number of studies worldwide prove that in tennis, the bilateral differences of the upper extremities and the uneven physical load inevitably lead to an asymmetric accumulation of muscle mass and an unbalance in muscle tones and the consequent disproportions in the skeletal structure [1, 7, 22, 23, 29].

The study aims to assess youth tennis players' anthropometric characteristics and to determine the level and direction of the asymmetry.

Material and Methods

A total of 239 tennis players (152 boys and 87 girls) age 8-17 years were assessed. All tennis players (TP) have training experience in tennis for two years and at least ten hours weekly. All athletes took part in regional, national or international championships. Participants were divided into three experimental groups according to age classification in sports practice (group I: 8-10 years old; group II: 11-13 years old; group III: 14-17 years old). The anthropometric measurements were taken using the classical method of Martin-Saller (1957). Body mass index (BMI) is calculated by a well-known formula using the mean height and weight values. Thirty-three anthropometric features were bilaterally measured because of the asymmetry analysis. Body composition components were determined by means of multi-frequency bioelectrical impedance measurements, which were taken with the use of an InBody (model: 170) analyzer, with eight electrodes. For accurate analysis, the following requirements had to be met: the measurements of each athlete were made at least two hours after a meal and at least 12 hours before training.

A hand grip test (European Test of Physical Fitness - EUROFIT) defines static arm strength. The right hand grip strength (RHGS, kg) and left hand grip strength (LHGS, kg) are measured using a standard calibrated handgrip dynamometer at a standing position with the shoulder adducted and neutrally rotated and elbow in full extension. The statistical analysis was done using the software package SPSS 16.00 for Windows (IBM, USA). Paired T-test ($p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$) was applied to assess the bilateral differences of the anthropometric traits. The age- and sex-related differences were defined by the use of One-Way ANOVA, as well as Post hoc procedures for multiple comparisons (Tukey, HSD-test) and independent T-test, respectively ($p \leq 0.05$, $p \leq 0.01$, $p \leq 0.001$). The asymmetry coefficients (units of asymmetry, UA) of the assessed anthropometric features are calculated by Nacheva`s equation (1986), modified by us. Percentile method was applied to determine the normative values to the units of asymmetry in adolescent tennis players (**Table 1**) and the profile of the morphofunctional anthropometric asymmetry was established. The TP and their parents completed informed consent and voluntarily participated in the study. The study protocol was reviewed and approved by the Ethical Committee of the Institute of Experimental Morphology, Pathology and Anthropology with Museum-Bulgarian Academy of Sciences (Protocol № 3/11.04.2018) and was conducted in agreement with the principles stated in the Declaration of Helsinki for human studies [30].

Table 1. Normative values to the level of asymmetry (units of asymmetry, UA) in adolescent tennis players.

	min	**max**
Relative symmetry	0.00 UA	0.49 UA
Weak asymmetry	0.50 UA	1.49 UA
Moderate asymmetry	1.50 UA	3.49 UA
High asymmetry	3.50 UA	7.49 UA
Very high asymmetry	7.50> UA	

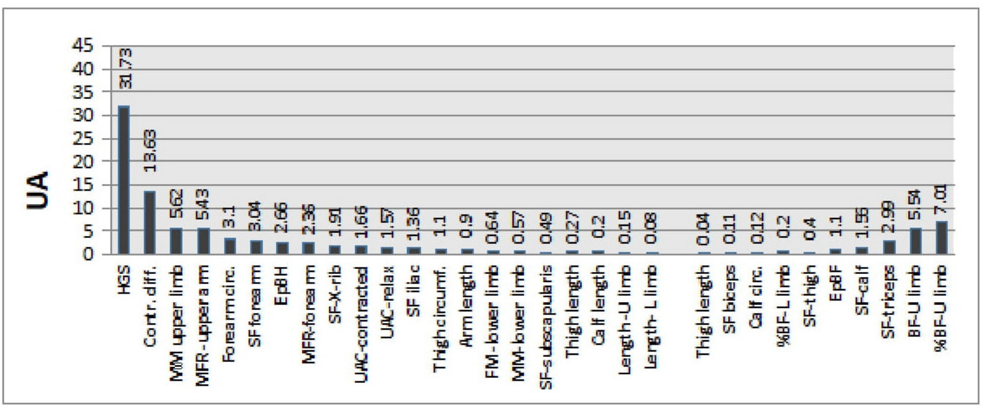
Results and Discussion

Contemporary findings emphasize the complexity of asymmetries and their relationships with physical and sports performance and highlighting the need for further research [3, 11, 16, 26]. The current study presents the bilateral differences in morphological variables of adolescent tennis players.

Optimal linear growth of the body shows age- and sex-specific dependence [19, 20, 21]. The results obtained in the current study confirmed those of the other scientific researches on physical development of youth and adolescents shown in increasing the sizes of anthropometric features highlighted in 8-10 years old girls and 14-17 years old boys [18, 20].

The linear growth of the body increases significantly throughout the assessed age period from 140.10 cm to 174.02 cm in boys and from 144.23 cm to 168.25 cm in girls, at the ages 8-17. Well expressed sexual differences were observed in the first and third age groups, with priority for boys ($p<0.05$). Body weight is 32.70 kg in boys and 37.38 kg in girls from the first age group ($p<0.05$) and reached 60.64 kg (in males) and 60.91 kg (females) in the third age group. The mean values of BMI also differ significantly between sexes. At the age period 8-10 years the average values for BMI in male TP are 16.62 kg/m^2 and girls TP in this age group are distinguished by a significantly higher BMI (17.90 kg/m^2) ($p \leq 0.01$). In the period 11-13 years the BMI in both sexes reaches almost the same values (19.15 kg/m^2 - boys, 19.72 kg/m^2 - girls). The largest sex-related differences are found in the period 14-17 years, when the BMI reaches values of 20.08 kg/m^2 in boys and 21.66 kg/m^2 in girls ($p \leq 0.001$).

Figures 1 to 6 present data for the profile of morphofunctional asymmetry of the 8-17-year-old TP. The active physical load of certain muscle groups of the dominant upper extremity in tennis players leads to a decrease in body fat mass (BF), with better-developed muscle mass (MM). Moderate bilateral differences were reported in the forearm area (forearm circumference, forearm skin fold) and muscle-fat ratios of the arm and forearm. The established high degree of asymmetry in hand grip strength is indirect evidence of the large bilateral differences in this part of the upper limbs. With increasing age, the asymmetry in the studied anthropometric signs decreases and these changes are more pronounced in males. Contrary to our results Chapelle et al. assessing youth TP according to their maturity offset, sex and training volume displayed a significantly higher lean mass asymmetry in males with the increase of the age. The authors also found an increment of bone mineral density asymmetry in relation with maturity status [5].



HGS-hand grip strength; **Contr. diff.**-contractile difference; **MM upper limb**- muscle mass upper limb; **MM-lower limb**- muscle mass lower limb; **BF-U limb**-body fat upper limb; **%BF-U limb** - percent body fat of the upper limb; **FM -lower limb**- fat mass lower limb; **%BF-L limb**- percent body fat of the lower limb;**MFR -upper arm**- muscle-fat ratio upper arm; **MFR-forearm-** muscle-fat ratio of the forearm; **UAC-contracted** - upper arm circumference-contracted; **UAC-relax-**upper arm circumference- relax; **EpBH-** epicondylar diameter of humerus; **EpBF-** epicondylar diameter of the femur; **Forearm circ.** -forearm circumference; **Thigh circumf.**- thigh circumference; **Calf circ.-** calf circumference; **Length - U Limb-** length upper limb; **Length- L limb** -length lower limb; **SF-thigh-** thigh skinfold; **SF-calf**- calf skin fold; **SF-triceps**- triceps skinfold; **SF-X-rib-** X-rib skinfold; **SF biceps-** biceps skinfold; **SF-subscapularis -** scinfold subscapularis; **SF forearm-** forearm skinfold; **SF iliac-** iliac skinfold

Fig. 1. Profile of morphofunctional anthropometric asymmetry in 8-10 years old male tennis players

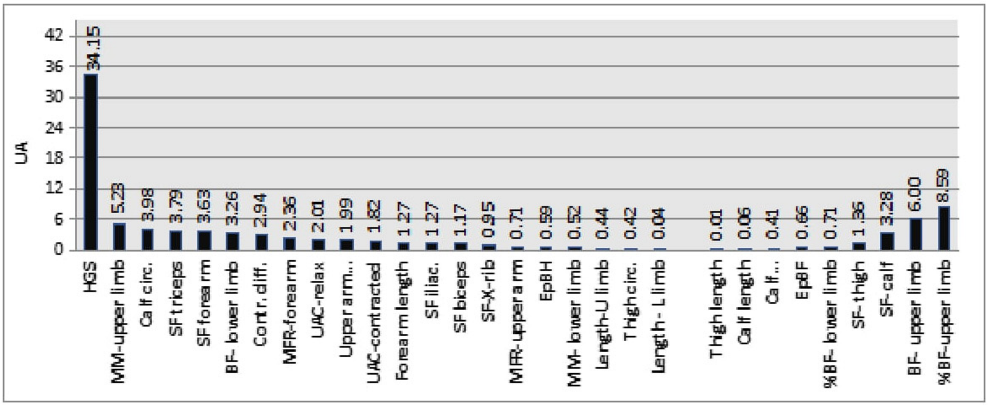


Fig. 2. Profile of morphofunctional anthropometric asymmetry in 11-13 years old male tennis players

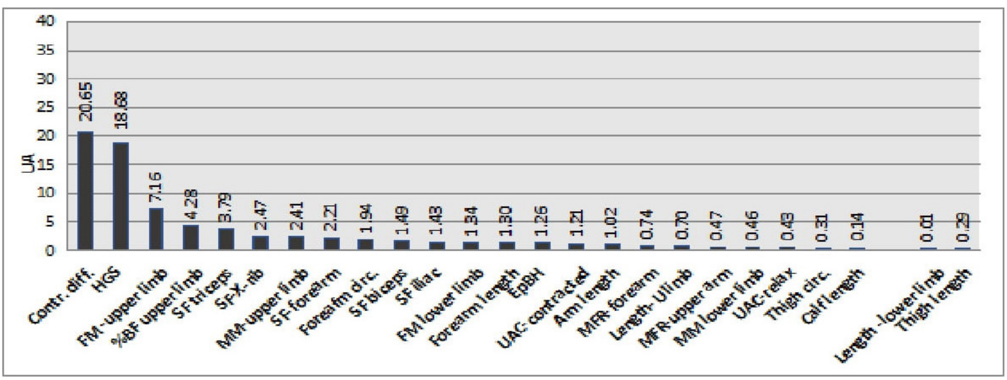


Fig. 3. Profile of morphofunctional anthropometric asymmetry in 14-17 years old male tennis players

Relative symmetry or slight asymmetry was found in the majority of the assessed limbs lengths and widths. The bilateral differences in most of the examined anthropometric signs are with a predominant right-sided asymmetry of the upper limb and left-sided in the lower limb. Sanchez-Muñoz et al. found certain asymmetric manifestations in the dimensions of the epicondylar diameters of the femur and humerus in females in favor of the dominant limb [23].

In male tennis players, all limb circumferences have right-sided asymmetry, except leg circumference (which is left-sided); in girls, all circumferences of the upper limb are right-sided, while in the lower limb all circumferences show left-sided asymmetry. A moderate manifestation of body asymmetry (UA≥1.50) was observed in most of the upper limb circumferences. Schluga and Filho et al. reported larger sizes in the dominant part of the body, with significant differences observed in forearm circumference (4.76%) and hip circumference (2.32%) [24].

The assessment of bilateral differences in BF assessed by the thickness of seven skin folds (SF) in both sexes showed the greatest asymmetry in four of them - triceps SF, biceps SF, forearm SF and calf SF. The asymmetry of the upper limb is characterized by the skin fold of the triceps (most strongly manifested at the age of 14-17 years) and forearm skin fold (biggest bilateral differences in 11-13-year-old boys and 14-17-year-old girls) while in the lower limb the biggest differences are reported in the calf skin fold in the age 11-13 years (boys) and 14-17 years (girls).

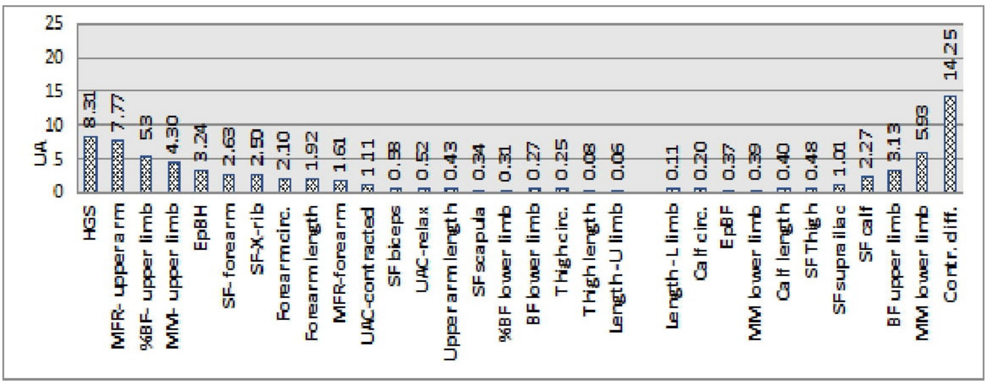


Fig. 4. Profile of morphofunctional anthropometric asymmetry in 8-10 years old female tennis players

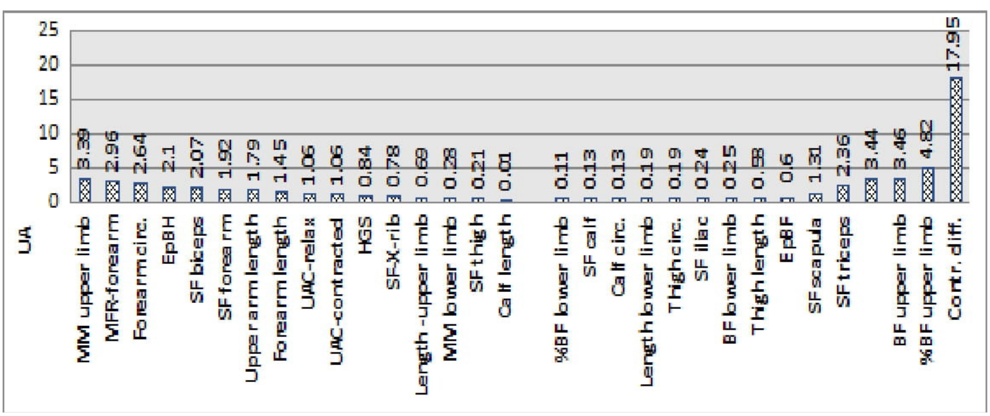


Fig. 5. Profile of morphofunctional anthropometric asymmetry in 11-13 years old female tennis players

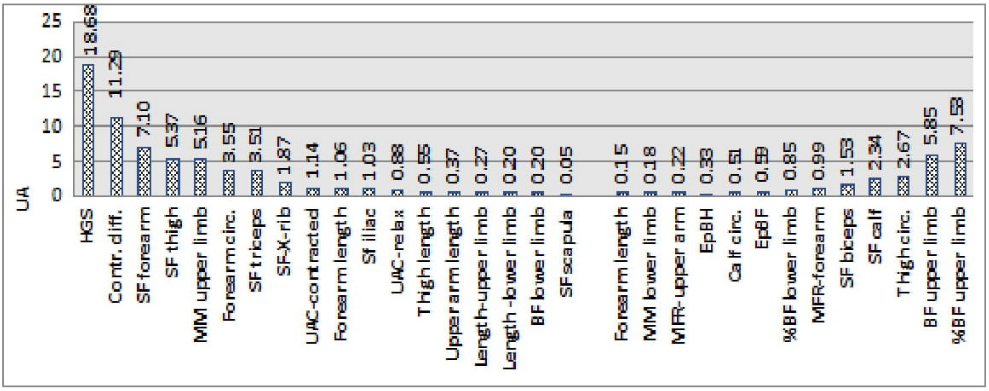


Fig. 6. Profile of morphofunctional anthropometric asymmetry in 14-17 years old female tennis players

Conclusions

In conclusion, we found that tennis is a sport that may cause asymmetric distribution of fat mass and lean mass, especially in the upper limbs.

The methodology applied by us provides objective information about the interrelationship in the system "type of sports activity – morphofunctional characteristics – health status".

References

1. **Abrahão, A., M. Ricardo, D. Mello.** Anthropometric differences between the hemispheric body right and left of adult and children tennis instructors to beginners in the sport and incidence of postural deviations. – *Fitness & Performance Journal*, **7**(4), 2008, 264-270 [in Portuguese].
2. **Auerbach, B. M., C. B. Ruff.** Limb bone bilateral asymmetry: variability and commonality among modern humans. – *J. Hum. Evol.,* **50**, 2006, 203-218.
3. **Bell, D. R., J. L. Sanfilippo, N. Binkley, B. C. Heiderscheit.** Lean mass asymmetry influences force and power asymmetry during jumping in collegiate athletes. – *Journal of Strength and Conditioning Research,* **28**, 2014, 884–891.
4. **Calbet, J. A. L., C. Dorado, P. Diaz-Herrera, L. P. Rodríguez-Rodríguez.** High femoral bone mineral content and density in male football (soccer) players. – *Med. Sci. Sports Exerc.,* **33**(1), 2001, 1682-1687.
5. **Chapelle, L., E. D'Hondt, N. Rommers, P. Clarys.** Development of upper-extremity morphological asymmetries in male and female elite youth tennis players: A longitudinal study. – *Pediatric Exercise Science*, **36**(2), 2023, 91-97.
6. **Ceroni, D., X. E. Martin, C. Delhumeau, N. J. Farpour-Lambert.** Bilateral and gender differences during single-legged vertical jumpperformance in healthy teenagers. – *Journal of Strength and Conditioning Research,* **26**, 2012, 452–457.

7. **Del-Fresno, D., G. Vicente-Rodriguez, J. M. González-Ravé, L. A. Moreno, P. Rey-López.** Body composition and fitness in elite Spanish children tennis players. – *J. Hum. Sport Exerc.*, **5**(2), 2010, 250-264.
8. **Dorado, C., J. Sanches -Moysi, G. Vicente, J. A. Serrano, L. R. Rodríguez, J. A. L. Calbet.** Bone mass, bone mineral density and muscle mass in professional golfers. – *J. Sports Sci.*, **20,** 2002, 591-597.
9. **Ducher, G., D. Courteix, S. Meme, C. Magni, J. F. Viala, C. L. Benhamou.** Bone geometry in response to long-term tennis playing and its relationship with muscle volume: a quantitative magnetic resonance imaging study in tennis players. – *Bone*, **37**(4), 2005, 457-466.
10. **Hides, J., W. Stanton, M. Freke, S. Wilson, S. McMahon, C. Richardson.** MRI study of the size, symmetry and function of the trunk muscles among elite cricketers with andwithout low back pain. – *British Journal of Sports Medicine*, **42**, 2008, 809–813.
11. **Jordan, M. J., P. Aagaard, W. Herzog.** Lower limb asymmetry in mechanical muscle function: A comparison between ski racers with and without ACL reconstruction. – *Scandinavian Journal of Medicine in Science and Sports*, **25**(3), 2015, 301-309.
12. **Kannus, P., H. Haapasalo, M. Sankelo, H. Sievanen, M. Pasanen, A. Heinonen, P. Oja, I. Vuori.** Effect of starting age of physical activity on bone mass in the dominant arm of tennis and squash players. – *Ann. of Internal Med.*, **123**, 1995, 27-31.
13. **Komi, P. V.** *Strength and power in sport. – The Encyclopaedia of sports medicine, volume III,* Wiley-Blackwell, 1996, 284-288.
14. **Krawczyk, B., M. Skład, B. Majle.** Lateral asymmetry in upper and lower limb measurements in selected groups of male athletes. – *Biol. Sport*, **15 (1),** 199833-199838.
15. **Leone, M., G. Lariviere.** Anthropometric and biomotor characteristics of elite adolescent male athletes competing in four different sports. – *Science & Sports,* **13** (1), 1998, 26-33.
16. **Liu, T., J. L. Jensen.** Age-related differences in bilateral asymmetry in cycling performance. - *Research Quarterly for Exercise and Sport*, **83**, 2012, 114–119.
17. **Malina, R.M., C. Bouchard, O. Bar-Or.** *Growth, maturation and physical activity,* 2nd edition, Human Kinetics, 2004.
18. **Mitova, Z.** Anthropological characteristics of physical development, body composition and body protection in 9-15 year old children and adolescents from Sofia. – *PhD Thesis*, 2009, Sofia. [in Bulgarian].
19. **Nikolova G., D. Dantchev.** Age changes in the basic anthropometric characteristics of the average Bulgarian females. – *Series on Biomechanics*, **37**(1), 2023, 5-12.
20. **Nacheva, A., Y. Zhecheva, I. Yankova, Z. Filcheva.** Physical development of children and adolescents in Bulgaria, at the border between the XXth and XXIst centuries. – "Prof. M. Drinov" Academic Publishing House, Sofia, 2012. [In Bulgarian].
21. **Nikolova G., D. Dantchev.** Gender dependence of the geometric and mass-inertial characteristics via a 3D biomechanical model of the human body. - *Series on Biomechanics,* **36**(1), 2022, 113-119.
22. **Rogowski, I., G. Ducher, O. Brosseau, C. Hautier.** Asymmetry in volume between dominant and nondominant upper limbs in young tennis players. – *Pediatric Exercise Science*, **20**, 2008, 263–272.
23. **Sánchez-Muñoz, C., D. Sanz, M. Zabala.** Anthropometric characteristics, body composition and somatotype of elite junior tennis players. – *Br. J. Sports Med.*, **41**, 2007, 793-799.

24. **Schluga- Filho, J. L., M. R. Ribas., L. O. Nogueira, J. C. Andrade, P. Fernandes, J. C. Bassan.** Motor and morphological profile of tennis players from 11 to 15 years old. – *Rev. Andal. Med*., **9**(3), 2016, 114–118.
25. **Tomkinson, G. R., L. A. Léger, T. S. Olds, G. Cazor**. Secular trends in the performance of children and adolescents (1980–2000): an analysis of 55 studies of the 20 m shuttle run test in 11 countries. – *Sports Med.,* **33**(4), 2003, 285–300.
26. **Trivers, R., B. Fink, M. Russell, K. McCarty, B. James, B. G. Palestis.** Lower body symmetry and running performance in elite Jamaican trackand field athletes. – *PLOS One*, **9**, 2014, 1–8.
27. **Tsolakis, C. H., C. H. Katsikas.** Long term effects of a combined physical conditioning and fencing training program on neuromuscular performance in elite fencers. – *Int. J. Fitness*, **2**(1), 2006, 35-42.
28. **Ulijaszek, S. J., C. G . N. Mascie-Taylor.** *Anthropometry: the individual and the population,* New York, Cambridge University Press, 2005.
29. **Vergauwen, L., A. J. Spaepen, J. Lefevre, P. Hespel.** Evaluation of stroke performance in tennis. – *Med. Sci. Sports Exerc*., **30**(8), 1998, 1281-1288.
30. **World Medical Association.** Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects. – *WMJ*, **54**(4)**,** 2008, 122-125.