Journal of Human Sport and Exercise *online*
J. Hum. Sport Exerc.
Official Journal of the Area of Physical Education and Sport.
Faculty of Education. University of Alicante. Spain
ISSN 1988-5202 / DOI: 10.4100/jhse
An International Electronic Journal
Volume 5 Number 2 May 2010

Research Article

BODY COMPOSITION AND FITNESS IN ELITE SPANISH CHILDREN TENNIS PLAYERS

Daniel Berdejo-del-Fresno[1] , Germán Vicente-Rodriguez[2], José María González-Ravé[3], Luis Antonio Moreno[2], Juan Pablo Rey-López[2].

[1]Manchester Metropolitan University, Alsager Campus, United Kingdom. [2]Escuela Universitaria de Ciencias de la Salud, Universidad de Zaragoza, Spain. [3]Facultad de Ciencias del Deporte, Universidad de Castilla de La Mancha, Spain.

Received: 2 September 2009; received in revised form: 11 February 2010; accepted: 5 March 2010

ABSTRACT
The aims of this study were to describe body composition and physical fitness changes during a whole-season in elite children tennis players. A total of 7 elite children tennis players participated in the study. Whole body composition by dual energy X-ray absorptiometry (DXA) and physical fitness were assessed during a season. Subjects increased lean and bone percentage, and decreased abdominal fat and total body fat percentage (all $p<0.05$). From month1 to month5 subjects improved in handgrip right test, standing broad jump and 20m shuttle run test (all $p<0.05$). From month5 to month10 there were not significant differences in physical fitness, although some showed a decline (back-saver sit and reach and shuttle run 20 m test). During the whole season, subjects decreased sit and reach in the left leg, but increased handgrip dominant test and standing broad jump (all $p<0.05$). During a season, children tennis players increased lean and bone percentage, and decreased abdominal and total fat percentage (all $p<0.05$). However, waist circumference and waist to height ratio were not useful to detect body composition changes. In addition, there were asymmetric changes in fitness (maximal isometric strength increased in the dominant hand and flexibility decreased in the contra lateral leg).

***Key words*:** DXA, abdominal fat, flexibility, handgrip, asymmetry.

Reference Data: Berdejo-del-Fresno D, Vicente-Rodríguez G, González-Ravé JM, Moreno LA, & Rey-López JP. Body composition and fitness in elite spanish children tennis players. *J. Hum. Sport Exerc.* 2010; 5(2):250-264.

Corresponding author. Daniel Berdejo del Fresno. 3.25 Abito, 85 Greengate, Salford, M3 7NB, United Kingdom.
Phone: +447532378157
E-mail: daniberdejo@hotmail.com

DOI:10.4100/jhse.2010.52.13

INTRODUCTION

Tennis is popular global sport with 205 nations affiliated to the International Tennis Federation (ITF), and almost 25 million active players in the USA alone (Turner & Pluim, 2007). This interest is equally considered by the scientific community. Unlike many other sports, which may require high levels of physical fitness in a few components, tennis players require high performances in most components (speed, agility, strength, power, aerobic endurance ...) (Kovacs, 2007). As a result, an inadequate planning and/or training will result in lower performances and maybe, an increased risk of injuries. Therefore, it is necessary to obtain a minimum of information of our tennis players (For instance: anthropometric, physiological, fitness data) in order to monitor changes induced by training, identify talent and maintain motivation (Kovacs, 2007). There are some studies conducted in elite senior tennis players. They have analyzed skeletal muscle structure (Mavidis, Vamvakoudis, Metaxas, Stefanidis, Koutlianos, Christoulas, et al., 2007) and function (Ellenbecker & Roetert, 2004; Mont, Cohen, Campbell, Gravare, & Mathur, 1994; Renkawitz, Boluki, & Grifka, 2006), cardiac structure and function (Mansencal, Marcadet, Martin, Montalvan, & Dubourg, 2007; Osborn, Taylor, Oken, Luzano, Heckman, & Fletcher, 2007), aerobic fitness (Girard, Chevalier, Leveque, Micallef, & Millet, 2006; Smekal, Baron, Pokan, Dirninger, & Bachl, 1995) and physiological response to competition (Ferrauti, Pluim, Busch, & Weber, 2003). However, when we focus on children tennis players, the number of studies are quite reduced. The majority of studies in tennis sport have assessed body composition based on anthropometry (Kovacs, Pritchett, Wickwire, Green, & Bishop, 2007; Kraemer, Ratamess, Fry, Triplett-McBride, Koziris, Bauer, et al., 2000; Sanchez-Munoz, Sanz, & Zabala, 2007). Although anthropometry is an easy and useful technique to study body composition, *dual energy X-ray absorptiometry* (DXA) is a more sophisticated method. A small number of researches have used DXA, but they were cross-sectional and were focused on bone (Bass, Saxon, Daly, Turner, Robling, Seeman, et al., 2002; Calbet, Moysi, Dorado, & Rodriguez, 1998; Haapasalo, Kontulainen, Sievanen, Kannus, Jarvinen, & Vuori, 2000; Kannus, Haapasalo, Sankelo, Sievanen, Pasanen, Heinonen, et al., 1995; Kontulainen, Kannus, Haapasalo, Heinonen, Sievanen, Oja, et al., 1999; McClanahan, Harmon-Clayton, Ward, Klesges, Vukadinovich, & Cantler, 2002; Sanchis-Moysi, Dorado, Vicente-Rodriguez, Milutinovic, Garces, and Calbet, 2004). A more limited number of them, have used a longitudinal design (Ducher, Tournaire, Meddahi-Pelle, Benhamou, & Courteix, 2006; Kontulainen, Kannus, Haapasalo, Sievanen, Pasanen, Heinonen, et al., 2001). However, Ducher et al. (Ducher, Tournaire, Meddahi-Pelle, Benhamou, & Courteix, 2006), studied only one densitometric region (radius) and Kontulainen et al. (Kontulainen, Kannus, Haapasalo, Sievanen, Pasanen, Heinonen, et al., 2001) selected adults at baseline.

The aims of this paper were, therefore, to study the whole body composition and fitness status in elite children tennis players during a whole season.

MATERIAL AND METHOD

We conducted a longitudinal study in order to study body composition and physical fitness changes in elite children tennis players. It allows to characterize tennis players since early stages of competition using more sophisticated methods of body composition and, and provide

 ISSN 1988-5202

information of health related physical fitness tests in this sport. In Figure 1 is summarized the design of our study.

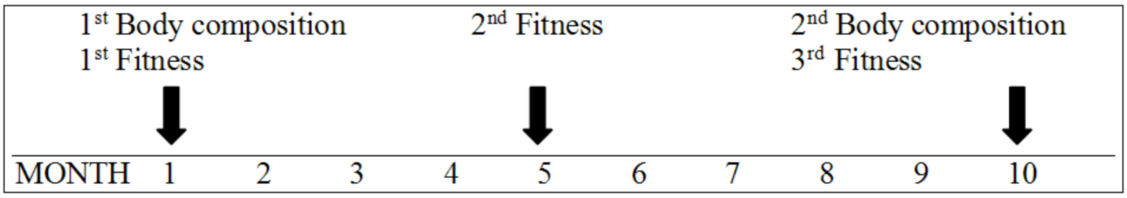

Figure 1. Design of the study.

Subjects

A total sample of 7 children (3 boys and 4 girls, age = 10.83 ± 0.39) from the high-performance centre of Aragon Tennis Federation (Spain), voluntarily participated in the study. They were included in this centre, according to their tennis level. All subjects were classified within the top 100 in the national tennis ranking for their age-group, being one of them, the actual national champion. Parents and children were informed about the aims and procedures of the investigation protocol, as well as the possible risks and benefits before they gave their written consent. The study was carried out according to the Helsinki Declaration and approved by a Local Ethical Committee. The subjects usually trained four days during weekdays and at least, completed one match per weekend. The typical daily training was divided into 2 parts, one hour of fitness training and one hour and half of technical training. Therefore, the total volume of training was 12 hours per week, including match-time (2 hours per week).They started to play tennis at mean age of five years-old.

Procedures

Body composition measurements

Whole body lean, bone and fat masses were assessed by dual-energy X-ray absorptiometry, DXA (Explorer, Hologic Corp.). The intra-rater reliability of DXA for percentage of body fat in adolescents in our laboratory is 0.98 (unpublished observations). In addition, a subregion area was analyzed to assess abdominal fat content. This region was placed between the upper border of the iliac crest and the lower border of the rib (CV<4% in our laboratory).

Two repetitions of height and weight were obtained and the average was recorded. Height was obtained using a stadiometer to the nearest 0.1 cm (SECA, model 225). Body weight was measured to the nearest 0.1 kg, using a balance scale (SECA, model 861). Waist (W), at the end of gentle expiration, midway between the lower rib margin and the iliac crest, was measured to the nearest 0.1 cm using an anthropometric tape (Holtain Ltd.). The index waist to height ratio was calculated as indicator of central obesity. The pubertal status of each subject was determined by self report according to the five Tanner stages (Morris & Udry, 1980).

 ISSN 1988-5202

Fitness assessments
Physical fitness test were selected based on validated batteries commonly used in youth in different cross-sectional and longitudinal studies. These tests have been detailed described elsewhere (Ruiz, Ortega, Gutierrez, Meusel, Sjostrom, & Castillo, 2006). We assessed several fitness components:

- Cardiorespiratory fitness (using the 20-m shuttle run test (Leger, Lambert, Goulet, Rowan, & Dinelle, 1984)). In this test, the initial speed is 8.5 km/h, which is increased by 0.5 km/h per min (1 min equal to one stage). Subjects run in a straight line, to pivot upon completing a shuttle, and to pace themselves in accordance to audio signals given. The test is finished when the subject stop or fail to reach the end lines concurrent with the audio signals on two consecutive occasions. The equations of Leger et al. (1984), were used to estimate the maximum oxygen intake (VO_{2max}).

- Flexibility (using the back-saver sit and reach). This test is part of the FITNESSGRAM battery (Welk & Meredith, 2008), and is a modification of the traditional sit and reach test, in order to prevent lower back injuries. The subjects tried to reach forward as far as possible from a seated position with one leg bent at the knee allowing the legs to be evaluated separately. Two alternative repetitions were carried out in each leg (sit and reach_left for the left leg and sit and reach_right for the right leg) and the best attempt per leg was chosen.

- Muscular fitness (using standing broad jump and handgrip strength). In standing broad jump test the subject had to push off vigorously and jump as far as possible trying to land with both feet together. The score is the distance from take-off line to the point where the back of the heel nearest to the land. In handgrip strength test, subjects were placed in a bipedal position with the arm in complete extension without touching any part of the body with the dynamometer (Takey, TKK 5101) except the hand being measured. Because the hand size has been proposed as a determinant of the result, we selected the affordable grip span in accordance with the size hand, based in previous studies in youth (Ruiz, Espana-Romero, Ortega, Sjostrom, Castillo, & Gutierrez, 2006). In both tests, two non-consecutive repetitions were carried out with each hand and the best attempt was chosen. Six subjects were right handed dominant.

- Agility (using shuttle run 4 x 10 m). This test is a modification of the shuttle run (10 x 5-m) test included in the EUROFIT battery (1993). The subjects had to run back and forth four times along a 10 m track at the highest speed possible. At the end of each track section, the subjects had to deposit or pick up a sponge from a line on the floor. Therefore, this allows measurement not only speed of displacement but also agility and coordination. Two non-consecutive repetitions were carried out and the best attempt was chosen.

 ISSN 1988-5202

Statistical Analyses
Descriptive statistics were run on all the variables to check for the assumptions of normality. Group changes were analyzed using student´s paired *t*-test. A *P* value of 0.05 or less was taken as statistically significant differences. Analysis were performed using SPSS version 16.0 (Chicago,IL, USA).

RESULTS

The mean (± SD) height of the subjects was 147.70 ± 0.1 cm, the average weight was 40.36 ± 5.57 kg and the average percent body fat was 23.87 ± 7.14 %, at baseline (month1). Girls were taller (151.92 ± 0.11 cm vs. 142.07 ± 0.02 cm) and weightier (41.3 ± 8.68 kg versus 39.1 ± 7.38 kg) than boys. The subjects increased significantly height, lean percentage and bone percentage and decreased significantly, abdominal fat percentage and fat percentage (Table 1). No significant changes were observed in waist circumference and waist to height ratio. Self-report of maturation status resulted in Tanner II in the whole group at baseline.

Table 1. Body composition changes of the tennis players during the season.

	Month1 n=7		Month10 n=7			
	Mean	SD	Mean	SD	dif	p
Age (years)	10.83	0.39	11.58	0.39	0.75	
Weight (kg)	40.36	7.57	42.2	8.05	1.84	0.007
Height (cm)	147.7	0.1	152.51	0.1	4.81	<0.001
BMI (kg/m^2)	18.48	2.97	18.11	2.8	-0.37	NS
FAT (%)	23.87	7.14	21.27	6.85	-2.6	0.007
LEAN (%)	72.63	6.52	75.04	6.24	2.41	0.009
BONE (%)	3.5	0.65	3.7	0.6	0.2	0.009
ABDOMINAL FAT (%)	17.89	7.46	14.59	5.51	-3.3	0.04
WAIST (cm)	66.11	6.74	66.86	5.26	0.75	NS
WAIST/HEIGHT	0.45	0.05	0.44	0.05	-0.01	NS

Difference (dif), Significant differences (p<0.05)
Whole body weight (Weight, kg)
Body mass index (BMI, kg/m^2)
Whole body fat percentage (FAT %)
Whole body lean percentage (LEAN, %)
Abdominal fat percentage (ABDOMINAL FAT, %)
Whole body bone percentage (BONE, %)
Waist circumference (WAIST, cm)
Waist to height ratio (WAIST/HEIGHT)

 ISSN 1988-5202

From Month 1 to Month 5 subjects significantly improved in handgrip right test, standing broad jump, shuttle run 20m test and maximum oxygen intake (Table 2 and Table 3). No significant differences were obtained in sit and reach_left, sit and reach_right, handgrip non-dominant and agility tests. From Month5 to Month10 no significant differences were obtained in any fitness test (Table 2 and Table 3).

Table 2. Fitness results of the tennis players.

	Month1 n=7		Month5 n=7		Month10 n=7	
	Mean	SD	Mean	SD	Mean	SD
sit&reach_left (cm)	21.71	2.69	21.86	4.26	19.71	1.7
sit&reach_right (cm)	22.29	1.5	23.29	3.25	20.86	1.21
handgrip_non-dominant (kg)	17.99	2.91	17.51	2.6	19.7	4.69
handgrip_dominant (kg)	20.21	2.77	21.96	1.9	22.47	3.35
agility test (sec)	11.42	0.66	11.37	0.7	11.05	0.59
standing broad jump (cm)	163.43	20.25	167.57	21.34	173.71	17.47
shuttle run 20 m (steps)	7.79	1.5	8.93	1.74	8.5	2.29
VO_2max (ml/kg/min)	54.17	3.35	56.53	3.99	54.92	5.3

sit and reach on the left leg (sit&reach_left, cm)
sit and reach on the right leg (sit&reach_right, cm)
handgrip using the dominant hand (handgrip_dominant, kg)
handgrip using the dominant hand (handgrip_non-dominant, kg)
4 x 10 m (agility test, sec)
jump from a static position (standing broad jump, cm)
cardiorespiratory fitness test (20 mt shuttle run, steps)
maximum oxygen intake (VO_2max, ml/kg/min)

Table 3. Fitness changes of the tennis players

	Dif Month5–Month1 n=7		Dif Month10–Month5 n=7		Dif Month10–Month1 n=7	
	dif	p	dif	p	dif	p
sit&reach_left (cm)	0.15	NS	-2.15	NS	-2	0.033
sit&reach_right (cm)	1	NS	-2.43	NS	-1.43	0.094
handgrip_left (kg)	-0.48	NS	2.19	NS	1.71	NS
handgrip_right (kg)	1.75	0.015	0.51	NS	2.26	0.004
agility test (sec)	-0.05	NS	-0.32	NS	-0.37	0.059
standing broad jump	4.13	0.027	6.14	NS	10.27	0.043
shuttle run 20 m (steps)	1.14	0.005	-0.43	NS	0.71	NS
VO_2max (ml/kg/min)	2.36	0.011	-1.61	NS	0.75	NS

Difference (dif), Significant differences (p<0.05)
sit and reach on the left leg (sit&reach_left)
sit and reach on the right leg (sit&reach_right)
handgrip on the left hand (handgrip_left)
handgrip on the right leg (handgrip_right)
4 x 10 mt (agility test, sec)
jump from a static position (standing broad jump, cm)
cardiorespiratory fitness test (20 mt shuttle run, steps)
maximum oxygen intake (VO_2max)

During the whole season subjects significantly improved in standing broad jump and handgrip dominant test (Figure 2). A trend approaching decrease significance was observed in agility test (p=.056). There was a significant decrease in sit and reach_left (Figure 3). No significant differences were obtained in shuttle run 20m test, maximum oxygen intake and handgrip non-dominant test.

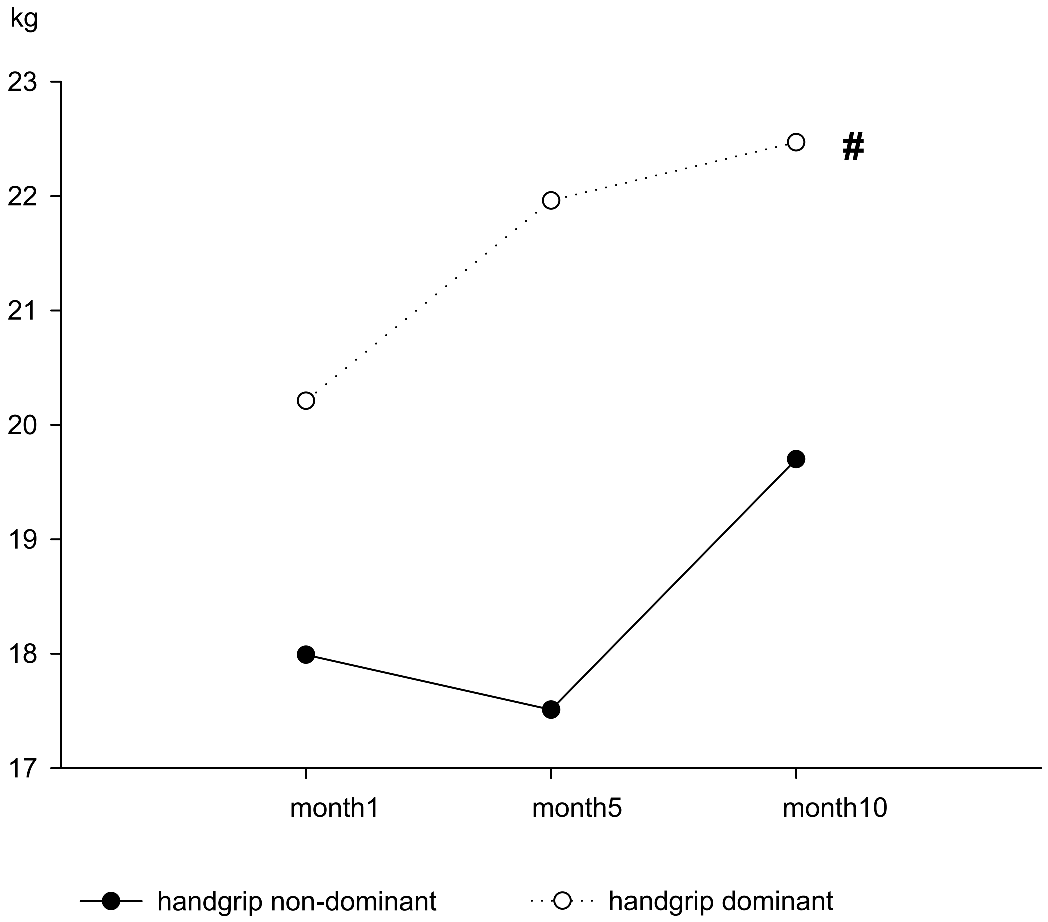

Figure 2. Handgrip changes during a whole-season (# = Significant changes between month 1 and month 10).

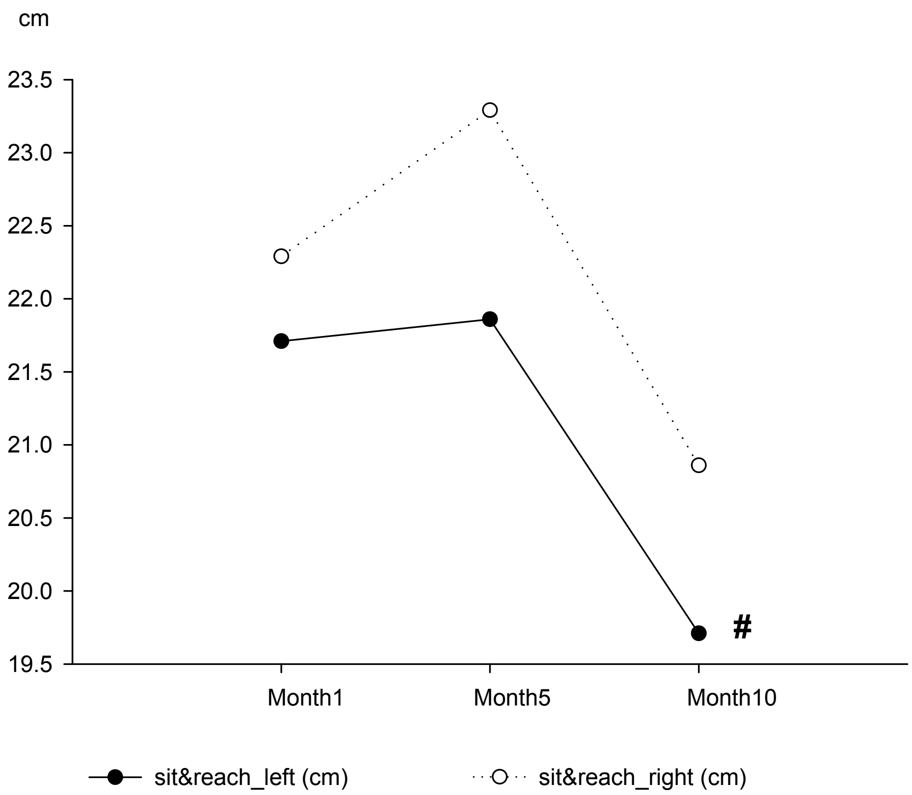

Figure 3. Flexibility changes during a whole-season (# = Significant changes between month 1 and month 10).

DISCUSSION AND CONCLUSION

As far as we know, this is the first study using DXA in order to assess whole body composition changes in elite children tennis players. The main findings of this study were: 1) Waist circumference and waist to height ratio were not useful to assess body composition changes (according to DXA results) in elite children tennis players. 2) The increase in maximal handgrip strength was obtained only in the dominant hand.

 ISSN 1988-5202

Body composition
Comparing our sample with eleven years-old Australian tennis players who regularly attained a semi-final position in the Western Australian Lawn Tennis Association tournaments, our boys sample had the same height, but were 5.6 kg heavier. In girls, our sample was 6.8 cm taller and 4.9 kg heavier (Ackland & Blanksby, 2001). From Month1 to Month10, there were significant increases in percentage of bone mass 5.71 % (0.2 units) and lean body mass 3.32 % (2.41 units). Total body fat mass percentage and abdominal fat percentage significantly decreased 10.89 % (2.6 units) and 18.45 % (3.3 units), respectively. These decrements in fat mass were not reflected by anthropometric values (waist circumference and waist to height ratio). Because our children were growing we corrected the natural trend to increase waist using the index waist to height ratio. However, this index neither changed significantly. This suggests that changes in waist circumference or waist to height ratio could not be appropriate indicators for fat distribution in this specific population.

There are not reference values for body composition in children tennis players by DXA.
If we compare the girls tennis players with another group of Caucasian girls with similar chronological age (eleven years-old) and maturation status (88% had Tanner I-II) (Baker, Birch, Trost, & Davison, 2007), the percentage of body fat was lower (23.65% ± 3.7 versus 27.47% ± 6.89 in the tennis and normal girls, respectively). An unexpected result was that boys tennis players were slightly fatter than the girls tennis players (24.17 ± 4.86 versus 23.65% ± 3.7). This was due to one boy was overweight. When this boy was excluded of the boys sample, the percentage of fat values were lower than girls (20.7 ± 5.9). Therefore, in this age-group of boys tennis players, a low body fat content is not a requisite to achieve high performances.

Fitness level
Although we are aware of these tests are not the most specific as would be necessary based on the nature of tennis game, our tests were selected in order to describe the health-related fitness of this specific sport children. The non inclusion of a control group, do not afford us to measure the effect of tennis practice on different fitness tests. However, this study affords to quantify longitudinal changes and compare with children with similar chronological age or maturational status.

During the whole season the tennis players significantly decreased in sit and reach_left test and improved in standing broad jump and dominant handgrip test (Table 2). The mean strength values obtained in the dominant hand (20.21 ± 2.77 in month1 and 22.47 ± 3.35 in month10) were slightly better compared with a reference Spanish children sample (20.3 ± 4.2 in boys 19.1 ± 4.4 in girls). In contrast in the non dominant hand, the results were similar (Table 2). It is important to highlight that the researches in both studies used the same dynamometer and protocol. These changes could be related with either the technical training process and the arm used during the competitions. Likely, tennis game develops more specifically the strength values of the dominant arm, during the training and match-time. In racquet sports, there is evidence of structural changes (Bass, Saxon, Daly, Turner, Robling, Seeman, et al., 2002) (greater humeral cortical area of the loaded versus the non loaded arm) and composition modifications (20% greater arm tissue mass, BMC + fat + lean mass) (Calbet, Moysi, Dorado, & Rodriguez, 1998) in the dominant compared with the contra lateral arm.

 ISSN 1988-5202

The increase in standing broad jump in the tennis players reflects the influence of the growth, but we believe that the typical fitness training in tennis (plyometric, speed) can have produced additional gains. When the performance is compared respect to a representative sample of school children (11-12 years old) of the region of Aragon (Spain) (Casajus, Leiva, Villarroya, Legaz, & Moreno, 2007), the tennis players had an exceptional fitness level. The reference mean values of standing broad jump were 152.3 ± 19.8 in boys, and 140.5 ± 21.9 in girls. The tennis players had a superior performance: mean values were 163.43 ± 20.25 (Month1) and 173.71 ± 17.47 (Month10). The explosive movements involve in tennis can develop the ability to jump above the average values. But we can not rule out that the superior performance was due to genetic bias.

Although sit and reach (both legs are flexed at the same time) is often used to evaluate flexibility in schools (Fogelholm, Stigman, Huisman, & Metsamuuronen, 2007; Volbekiene & Griciute, 2007) and competitive sports clubs (Kovacs, Pritchett, Wickwire, Green, & Bishop, 2007), we decided to measure each leg separately. The tennis children decreased flexibility values during the season, with a 9.21% significant decline in the left leg (-2 cm). This involution in flexibility ability during the life span is ample known. According to Kovacs (2006), tennis players show a reduced flexibility in both hamstrings compared with other athletes. This poor hamstring flexibility may be explained by the need to be in a “low ready position” (hamstrings shortened) for long periods. The reference children in our region reached 15.8 ± 5.3 in boys, and 19.3 ± 5.2 in girls (Casajus et al., 2007). Our boys reached 21.67 ± 1.53 cm in the left leg and 23 ± 1 in the right leg. Similarly, girls obtained 21.75 ± 3.59 cm in the left leg and 21.75 ± 1.71 in the right leg. Hence, our children were above from the mean reference values. It is necessary to investigate the causes of the asymmetric performance between hamstrings at the final season.

Tennis has been classified as a anaerobic predominant activity requiring high levels of aerobic conditioning to avoid fatigue and aid in recovery between points (Kovacs, 2006). No significant differences were obtained in 20m shuttle run test and maximum oxygen intake. The later could be due to the type of training undertaken or maybe the training status of our sample. The seven children had a predominant anaerobic training during the season. They trained two specific aerobic sessions per week during month 1 until month 3. Later, since month 4 they reduced to one session/week. Therefore, a more frequent intensive aerobic training could have enhanced the maximum oxygen intake significantly. The training status is another possibility that can explain the lack of improvement. (Gonzalez Jurado, Beaus, Guisado, Naranjo, Molina, & De Teresa, 2005) studied the effect of two modes of training in children tennis players. Although the endurance group (n=15, age=11.67± 1.5) improved more the VO_{2max} than the resistance group (n=16, age=12 ± 1.46), the changes did not reach significance. Then, the sample studied by us, could have achieved their genetic limits of adaptation. The VO_{2max} data are in total concordance with the values reported by González Jurado et al. (2005). They included the shuttle run 20m test and found 54.88 ml/kg/min and 51.91 ml/kg/min, in the resistance and endurance group respectively. The reference step mean values in normal-weight children in our region are below (6.2 ± 1.7 in boys and 4.9 ± 1.5 in girls) (Casajus et al., 2007), compared with our results (8 ± 1.73 in boys and 7.62 ± 1.55 in girls). Besides genetic influences, the huge volume of training (12 hours per week) can be leading to this exceptional cardiorespiratory fitness.

 ISSN 1988-5202

It is recommended that tennis players strive for VO_{2max} values greater than 50 ml/kg/min (Kovacs, 2006). Thus, this threshold is ample reached during the whole season.

In conclusion, we have presented body composition and fitness changes in elite children tennis players followed during a whole season. We provide, for the first time, changes in whole body composition by DXA in Spanish children tennis players.

PRACTICAL APLICATIONS

The present results show the waist circumference and waist to height ratio were not useful to assess body composition changes in highly trained children tennis players. During a season, there was a significant decrease in sit and reach test, but only in the left leg. The only improvements were standing broad jump and handgrip strength in the dominant hand. However, the cardiorespiratory fitness test values were not significantly different during the whole season. This could reflect the specific adaptation to the training stimuli induced by tennis game. These results must be used to improve the process of training in tennis children.

Acknowledgements
The authors would like to thank coaches, players and the institution (Federación Aragonesa de Tenis) for their support and collaboration on this project.
JPR is supported by a grant from Fundación Cuenca Villoro.

REFERENCES

1. ACKLAND TR, BLANKSBY BA. Gender and activity comparison of body composition among Australia children. In: Jürimäe T, Hills A.P. Editors. *Body composition assessment in children and adolescents*: Med Sport Sci. Basel, Karger; 2001, 115-31. [Abstract] [Back to text]
2. BAKER BL, BIRCH LL, TROST SG, DAVISON KK. Advanced pubertal status at age 11 and lower physical activity in adolescent girls. *J Pediatr*. 2007; 151(5):488-93. [Full text] [Back to text]
3. BASS SL, SAXON L, DALY RM, TURNER CH, ROBLING AG, SEEMAN E, et al. The effect of mechanical loading on the size and shape of bone in pre-, peri-, and postpubertal girls: a study in tennis players. *J Bone Miner Res*. 2002; 17(12):2274-80. [Abstract] [Back to text]
4. CALBET JA, MOYSI JS, DORADO C, RODRIGUEZ LP. Bone mineral content and density in professional tennis players. *Calcif Tissue Int.* 1998; 62(6):491-6. [Abstract] [Back to text]
5. CASAJUS JA, LEIVA MT, VILLARROYA A, LEGAZ A, MORENO LA. Physical performance and school physical education in overweight Spanish children. *Ann Nutr Metab*. 2007; 51(3):288-96. [Abstract] [Back to text]
6. COMMITTEE OF EXPERTS ON SPORTS RESEARCH EUROFIT. *Handbook for the EUROFIT Tests of Physical Fitness*. Counsil of Europe. Strasburg, GE1993. [Abstract] [Back to text]
7. DUCHER G, TOURNAIRE N, MEDDAHI-PELLE A, BENHAMOU CL, COURTEIX D. Short-term and long-term site-specific effects of tennis playing on trabecular and

cortical bone at the distal radius. *J Bone Miner Metab*. 2006; 24(6):484-90. [Abstract] [Back to text]
8. ELLENBECKER TS, ROETERT EP. An isokinetic profile of trunk rotation strength in elite tennis players. *Med Sci Sports Exerc*. 2004; 36(11):1959-63. [Abstract] [Back to text]
9. FERRAUTI A, PLUIM BM, BUSCH T, WEBER K. Blood glucose responses and incidence of hypoglycaemia in elite tennis under practice and tournament conditions. *J Sci Med Sport*. 2003; 6(1):28-39. [Abstract] [Back to text]
10. FOGELHOLM M, STIGMAN S, HUISMAN T, METSAMUURONEN J. Physical fitness in adolescents with normal weight and overweight. *Scand J Med Sci Sports*. 2007; 9. [Abstract] [Back to text]
11. GIRARD O, CHEVALIER R, LEVEQUE F, MICALLEF JP, MILLET GP. Specific incremental field test for aerobic fitness in tennis. *Br J Sports Med*. 2006; 40(9):791-6. [Full text] [Back to text]
12. GONZALEZ JURADO JA, BEAUS J, GUISADO R, NARANJO J, MOLINA E, DE TERESA C. Análisis de los efectos de la preparación física basada en el trabajo de fuerza, sobre la potencia aeróbica en tenistas jóvenes. *MD Revista científica en medicina del deporte*. 2005; 1(Enero):3-10. [Back to text]
13. HAAPASALO H, KONTULAINEN S, SIEVANEN H, KANNUS P, JARVINEN M, VUORI I. Exercise-induced bone gain is due to enlargement in bone size without a change in volumetric bone density: a peripheral quantitative computed tomography study of the upper arms of male tennis players. *Bone*. 2000; 27(3):351-7. [Full text] [Back to text]
14. KANNUS P, HAAPASALO H, SANKELO M, SIEVANEN H, PASANEN M, HEINONEN A, et al. Effect of starting age of physical activity on bone mass in the dominant arm of tennis and squash players. *Ann Intern Med*. 1995; 123(1):27-31. [Full text] [Back to text]
15. KONTULAINEN S, KANNUS P, HAAPASALO H, HEINONEN A, SIEVANEN H, OJA P, et al. Changes in bone mineral content with decreased training in competitive young adult tennis players and controls: a prospective 4-yr follow-up. *Med Sci Sports Exerc*. 1999; 31(5):646-52. [Abstract] [Back to text]
16. KONTULAINEN S, KANNUS P, HAAPASALO H, SIEVANEN H, PASANEN M, HEINONEN A, et al. Good maintenance of exercise-induced bone gain with decreased training of female tennis and squash players: a prospective 5-year follow-up study of young and old starters and controls. *J Bone Miner Res*. 2001; 16(2):195-201. [Full text] [Back to text]
17. KOVACS MS. Applied physiology of tennis performance. *Br J Sports Med*. 2006; 40(5):381-5; discussion 6. [Full text] [Back to text]
18. KOVACS MS. Tennis physiology: training the competitive athlete. *Sports Med*. 2007; 37(3):189-98. [Abstract] [Back to text]
19. KOVACS MS, PRITCHETT R, WICKWIRE J, GREEN JM, BISHOP P. Physical performance changes after unsupervised training during the fall/spring semester break in competitive tennis players. *Br J Sports Med*. 2007; 11. [Abstract] [Back to text]
20. KRAEMER WJ, RATAMESS N, FRY AC, TRIPLETT-MCBRIDE T, KOZIRIS LP, BAUER JA, et al. Influence of resistance training volume and periodization on

physiological and performance adaptations in collegiate women tennis players. *Am J Sports Med*. 2000; 28(5):626-33. [Abstract] [Back to text]

21. LEGER L, LAMBERT J, GOULET A, ROWAN C, DINELLE Y. Aerobic capacity of 6 to 17-year-old Quebecois--20 meter shuttle run test with 1 minute stages. *Can J Appl Sport Sci*. 1984; 9(2):64-9. [Abstract] [Back to text]
22. MANSENCAL N, MARCADET DM, MARTIN F, MONTALVAN B, DUBOURG O. Echocardiographic characteristics of professional tennis players at the Roland Garros French Open. *Am Heart J*. 2007; 154(3):527-31. [Abstract] [Back to text]
23. MAVIDIS A, VAMVAKOUDIS E, METAXAS T, STEFANIDIS P, KOUTLIANOS N, CHRISTOULAS K, et al. Morphology of the deltoid muscles in elite tennis players. *J Sports Sci*. 2007; 27:1-6. [Abstract] [Back to text]
24. MCCLANAHAN BS, HARMON-CLAYTON K, WARD KD, KLESGES RC, VUKADINOVICH CM, CANTLER ED. Side-to-side comparisons of bone mineral density in upper and lower limbs of collegiate athletes. *J Strength Cond Res*. 2002; 16(4):586-90. [Abstract] [Back to text]
25. MONT MA, COHEN DB, CAMPBELL KR, GRAVARE K, MATHUR SK. Isokinetic concentric versus eccentric training of shoulder rotators with functional evaluation of performance enhancement in elite tennis players. *Am J Sports Med*. 1994; 22(4):513-7. [Abstract] [Back to text]
26. MORRIS NM, UDRY JR. Validation of a self-administered instrument to assess stage of adolescent development. *J Youth Adolesc*. 1980; 9:271-80. [Abstract] [Back to text]
27. OSBORN RQ, TAYLOR WC, OKEN K, LUZANO M, HECKMAN M, FLETCHER G. Echocardiographic characterisation of left ventricular geometry of professional male tennis players. *Br J Sports Med*. 2007; 41(11):789-92; discussion 92. [Abstract] [Back to text]
28. RENKAWITZ T, BOLUKI D, GRIFKA J. The association of low back pain, neuromuscular imbalance, and trunk extension strength in athletes. *Spine J*. 2006; 6(6):673-83. [Abstract] [Back to text]
29. RUIZ JR, ESPANA-ROMERO V, ORTEGA FB, SJOSTROM M, CASTILLO MJ, GUTIERREZ A. Hand span influences optimal grip span in male and female teenagers. *J Hand Surg [Am]*. 2006; 31(8):1367-72. [Abstract] [Back to text]
30. RUIZ JR, ORTEGA FB, GUTIERREZ A, MEUSEL D, SJOSTROM M, CASTILLO MJ. Health-related fitness assessment in childhood and adolescence: a European approach based on the AVENA, EYHS and HELENA studies. *J Public Health*. 2006; 14:269-77. [Abstract] [Back to text]
31. SANCHEZ-MUNOZ C, SANZ D, ZABALA M. Anthropometric characteristics, body composition and somatotype of elite junior tennis players. *Br J Sports Med*. 2007; 41(11):793-9. [Abstract] [Back to text]
32. SANCHIS-MOYSI J, DORADO C, VICENTE-RODRIGUEZ G, MILUTINOVIC L, GARCES GL, CALBET JA. Inter-arm asymmetry in bone mineral content and bone area in postmenopausal recreational tennis players. *Maturitas*. 2004; 48(3):289-98. [Abstract] [Back to text]
33. SMEKAL G, BARON R, POKAN R, DIRNINGER K, BACHL N. Metabolic and cardiorespiratory reactions in tennis-players in laboratory testing and under sport-specific conditions. *Wien Med Wochenschr*. 1995; 145(22):611-5. [Abstract] [Back to text]

34. TURNER MS, PLUIM BM. Anyone for tennis? *Br J Sports Med*. 2007; 41(11):701-2. [Abstract] [Back to text]
35. VOLBEKIENE V, GRICIUTE A. Health-related physical fitness among schoolchildren in Lithuania: a comparison from 1992 to 2002. *Scand J Public Health*. 2007; 35(3):235-42. [Abstract] [Back to text]
36. WELK GJ, MEREDITH MD. *Fitnessgram/Activitygram Reference Guide*. Dallas, TX:The Cooper Institute. 2008. [Full text] [Back to text]

 ISSN 1988-5202