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EFFECT OF A COMPETITIVE SEASON ON ANTHROPOMETRY AND THREE-COMPARTMENT BODY COMPOSITION IN FEMALE HANDBALL PLAYERS

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ABSTRACT: The objective of this work was to investigate the anthropometry and 3-compartment body composition characteristics of female team handball players preseason and postseason. Forty-three Caucasian female handball players were recruited for this study. Linear anthropometry, skinfold measurement, and dual-energy X-ray absorptiometry (DXA) were used to investigate body dimensions and composition (fat mass, lean mass, mineral mass) over an 8-month competitive season. A complete dataset (pre- and postseason) was available for 33 handball players. Repeated measure ANOVA showed no change in body mass, BMI, sum of eight skinfolds, and most body circumferences over the season. At the total body level, bone mineral content (BMC) significantly increased postseason (+1.64%, $P<0.0001$), lean mass was unchanged, and fat mass and % fat mass were slightly decreased (-2.24%, $P=0.295$; -0.4%, $P=0.229$, respectively). DXA regional analysis showed that mineral mass was exclusively accrued in the upper and lower limbs postseason (upper + 4.95%, lower +1.7%, $P<0.0001$ for both); lean mass increased in upper (+5.3%, $P<0.0001$) but not lower limbs, and fat mass did not change in either. When handball players were subdivided according to competitive level (elite/sub-elite) or playing position (goalkeeper, back, pivot, wing), no significant between-group difference was found postseason in circumferences, skinfolds, and body composition parameters. In conclusion, anthropometry of female handball players does not change significantly over the competitive season except for some fat redistribution; however, BMC increases in the limbs, and lean mass in upper limbs postseason. These findings are independent of competitive level (elite/sub-elite) and playing position. These results could serve as an important tool in the development of guidelines optimizing in-season training programmes for team handball.

KEY WORDS: DXA, body fat, body lean mass, bone mineral content, competitive level, playing position

INTRODUCTION

Team handball (handball) is a dynamic sport in which players use their hands to dribble, pass, and shoot the ball at the opponent's goal; therefore, handball is characterized by highly developed motor skills such as coordination, speed and agility, endurance, reaction speed, as well as explosive power. Handball is played indoors or outdoors, by both sexes and all ages at amateur, sub-elite, and elite levels. Handball is played all over the world and has been an Olympic sport since 1972. Nevertheless, research on the physiological, physical, and anthropometric profiles of elite and sub-elite handball players is limited. The physical and physiological characteristics as well as the on-court performances of handball players have recently been reviewed [23]; all of these features are to some extent affected by the anthropometric characteristics of athletes [3,15,19,22].

Body composition analysis is frequently carried out in sport to assess changes in physiological status; several techniques are used including skinfold analysis, body density measurements, bioelectrical impedance methods, and dual-energy X-ray absorptiometry (DXA). DXA uses a 3-compartment model to accurately assess body composition in terms of bone mineral content (BMC), lean mass (LM), and fat mass (FM) at the total body as well as regional level [12]. DXA compares well with the more demanding 4-compartment model in estimating body composition of young adults who vary in gender, race, athletic status, body size, musculoskeletal development, and body fatness [20]. The physical composition of the body is relevant in sport performance; in fact, excess adipose tissue acts as dead weight in common physical activities where body mass must be lifted or moved repeatedly against gravity [14]. Also, body fat is inversely related to aerobic capacity, players' power-to-weight ratio, and thermoregulation [7]. The functional performance characteristics of handball players are therefore influenced by differences in body size and composition.

Conditioning for sport is usually broken down into preseason, in-season, and postseason phases. Preseason training aims at maximizing the physical and fitness parameters before the start of the competitive season; in-season, the goal is to maintain the physical and fitness levels achieved during the preseason. It may be suggested that physical status should peak by the end of the preseason phase and be maintained throughout the entire competition period.

Information on the variations in anthropometry of handball players over the competitive season is quite limited. Monitoring the body composition of handball players throughout a competition cycle could provide valuable information to create an anthropometric profile of each individual player. This can also help prevent changes in body composition that may be detrimental to performance, and provide reference body composition values that can be targeted after a period of detraining or injury, and act as an indicator of physiological status and training.

As a first step towards this aim, this study assessed the extent to which physical and body composition characteristics are maintained throughout a competitive season in elite and sub-elite female handball players; in particular, anthropometry, BMC, FM, LM, and percent fat mass (FM%) were measured at preseason and postseason.

MATERIALS AND METHODS

Participants. Forty-three Caucasian (37 Italian, 1 Ukrainian, 1 Slovenian, 1 Romanian, 1 Polish, 2 Argentine of European origin) female handball players were recruited for this study. Our data came from routine testing, which was part of a formal programme of sport science support. Data procurement and handling were in accordance with the Helsinki protocol (as revised in 2008) and participants signed an informed consent agreement. All players were playing in the Italian national championships (elite level, n=26 and sub-elite level, n=17) in four different teams. Measurements were taken at the beginning of the competitive season in October and at the end of the season in May. During the preseason, elite players trained eight sessions a week, 3.5 h per session; sub-elite players trained three sessions a week, 2.0 h per session. In-season, elite players had four sessions a week, 2.0 h per session plus two sessions of weight training (1.5 h each) and a competitive game once a week: sub-elite players had three sessions a week, 2.0 h per session, and a competitive game once a week.

Procedures

Body mass was taken to the nearest 0.1 kg with an electronic scale (Tanita electronic scale BWB-800 MA); stature was measured with a Harpenden stadiometer (Holtain Ltd., Crymych, Pembs. UK) to the nearest mm; body mass index (BMI) was calculated as weight (kg)/height^2 (m). Body circumferences were measured with a fibreglass tape at the upper arm (relaxed), waist, hip, thigh, and calf sites according to standard procedures [13]. Skinfold thickness was measured with a Harpenden caliper (Gima, Milan, Italy) at the triceps, mid-axillary, chest, subscapular, suprailiac, abdominal, front thigh, and calf site according to standard procedures [13,18]. In order to evaluate body fat distribution, the waist-to-hip ratio (W/H) was obtained; also, a centrality index (CI) was calculated for each participant by dividing the sum of appendicular skinfolds (triceps, front thigh, calf) by the sum of the trunk skinfolds (subscapular, mid-axillary, abdomen, supra-iliac, chest). All measurements were taken by the same operator (CM) to ensure consistency.

Total and regional body composition (lean mass, fat mass, and mineral mass) was evaluated by means of DXA using a total body scanner (QDR Explorer W, Hologic, MA, USA; fan-bean technology, software for Windows XP version 12.6.1) according to the manufacturer's procedures. The scanner was calibrated daily against the standard supplied by the manufacturer to avoid possible baseline drift. Whole body scanning time was about seven minutes; the total X-ray irradiation absorbed by a participant was 5 mrem or lower, which is about 10% of standard chest X-ray film. All scanning and analyses were performed by the same operator (CM) to ensure consistency. In our lab the precision error (percent coefficient of variation) of DXA measurements is 1.2, 2.3, 1.4, and 2.0% for total body BMC, FM, LM, and FM% respectively.

Statistical analyses

The Kolmogorov-Smirnov test for normal distribution of the data was negative for all variables. One-way analysis of variance (ANOVA) was used to compare variable means. Changes in the anthropometric or body composition parameters over the season were analysed by two-way repeated measures ANOVA (group x time). Data are reported as means ± SD. Significance level was set at $P<0.05$. The SPSS statistical package (version 16, SPSS inc., Chicago, Ill, USA) was used for all analyses.

RESULTS

The physical characteristics of the sample of female handball players entering the study are shown in Table 1. Ten participants were excluded from the final analysis because of long-lasting injury, moving to another team, or illness; therefore, a complete set of repeated measurements (preseason and postseason) was available for 33 players (23 elite, 10 non-elite). Repeated measure ANOVA (Table 2) showed that body mass and BMI did not change over the season as

TABLE 1. CHARACTERISTICS OF FEMALE HANDBALL PLAYERS AT PRESEASON. ONE-WAY ANOVA

Competitive level	Age (y)	Mass (kg)	Stature (m)	BMI (kg·m^{-2})
Elite (n=26)	26.4 ± 5.77	67.0 ± 7.91	169.2 ± 6.04	23.4 ± 5.33
Sub-elite (n=17)	17.3 ± 2.25*	64.4 ± 10.47	166.0 ± 5.10	23.3 ± 4.01
Aggregate (n=43)	22.8 ± 6.49	66.0 ± 8.97	167.9 ± 5.84	23.3 ± 2.31

Note: * $P<0.0001$ vs. Elite

well as body circumferences; in the trunk, a significant reduction (-2.7%) of W/H ratio was present. Four out of eight skinfolds showed significant changes postseason, the sign of change not being consistent; the sum of eight skinfolds did not change. However, the absolute increase of all limb skinfolds led to a significant postseason increase of CI (+11.4%).

Several significant differences in body composition parameters took place in female handball players postseason (Table 2). In particular, a statistically significant increase was found in total body BMC postseason (+1.64%, P<0.0001). As shown by regional analysis, BMC was accrued exclusively in the limbs (upper, +15.5%; lower, +1.67%. P<0.0001 for both). Total body lean mass did not change postseason; however, a significant regional increase was found in upper limbs (+5.3%, P<0.0001). Total body FM did not change over the season, nor did %FM.

When female handball players were subdivided into elite (n=23) and sub-elite (n=10), a significant difference was found in mean age (26.3±5.86 vs. 16.3±0.82 y in elite and sub-elite, respectively; P<0.0001) in the presence of similar body mass (66.9±8.37 vs. 62.8±12.82 kg, P=0.292) and stature (1.69±0.623 vs. 1.65±0.599 m, P=0.099). Accordingly, all subsequent analyses had age as a covariate. No between-group significant difference was found postseason in circumferences or skinfolds, nor in body composition parameters (Fig. 1).

TABLE 2. ANTHROPOMETRY AND BODY COMPOSITION OF FEMALE HANDBALL PLAYERS AT PRESEASON AND POSTSEASON (N=33). REPEATED MEASURES ANOVA

Body parameter	Preseason	Postseason	F value	P
Body mass (kg)	65.6 ± 9.89	65.2 ± 9.58	0.932	0.342
BMI ($kg \cdot m^{-2}$)	23.23 ± 2.49	23.0 ± 2.32	1.360	0.252
Circumference				
Upper arm (cm)	27.5 ± 2.46	27.8 ± 2.63	2.350	0.135
Waist (cm)	74.2 ± 6.19	73.5 ± 6.02	3.164	0.085
Hip (cm)	100.2 ± 6.74	101.1 ± 5.73	3.316	0.078
W/H	0.74 ± 0.035	0.72 ± 0.037	13.606	0.001
Thigh (cm)	52.7 ± 4.84	52.8 ± 3.92	0.010	0.992
Calf (cm)	37.2 ± 2.46	36.7 ± 1.94	2.123	0.155
Skinfold				
Triceps (mm)	15.9 ± 3.49	16.8 ± 4.22	4.397	0.044
Subscapular (mm)	12.4 ± 4.98	12.2 ± 5.08	0.424	0.519
Chest (mm)	7.7 ± 2.28	8.3 ± 2.58	3.360	0.076
Mid-Axillary (mm)	10.9 ± 4.00	9.9 ± 4.45	4.386	0.044
Abdominal (mm)	20.4 ± 7.43	20.8 ± 7.76	0.327	0.571
Suprailiac (mm)	17.2 ± 6.45	14.7 ± 6.33	19.910	<0.0001
Front thigh (mm)	21.3 ± 5.39	22.8 ± 4.77	5.112	0.031
Calf (mm)	13.6 ± 2.58	14.3 ± 3.40	2.850	0.101
Sum of skinfolds (mm)	102.5 ± 22.15	105.4 ± 26.01	1.281	0.266
CI	0.79 ± 0.21	0.88 ± 0.26	20.199	<0.0001
DXA Body composition				
BMC, upper limbs (g)	269.6 ± 53.02	311.3 ± 54.8	20.277	<0.0001
Fat, upper limbs (g)	1773.3 ± 703.22	1797.9 ± 709.49	1.998	0.167
Lean, upper limbs (g)	4493.8 ± 742.14	4731.3 ± 784.41	36.454	<0.0001
BMC, Trunk (g)	742.8 ± 121.65	743.8 ± 126.89	0.037	0.848
Fat, Trunk (g)	6902.5 ± 3282.08	6586.0 ± 2895.43	2.899	0.098
Lean, Trunk (g)	23013.9 ± 3098.52	22923.6 ± 2892.26	0.444	0.510
BMC, lower limbs (g)	893.7 ± 159.57	908.7 ± 160.21	16.735	<0.0001
Fat, lower limbs (g)	6995.7 ± 1896.46	6911.6 ± 1795.17	0.493	0.488
Lean, lower limbs (g)	15517.0 ± 2251.34	15493.9 ± 2255.92	0.064	0.802
BMC, total body (g)	1933.1 ± 319.28	1964.9 ± 327.66	16.826	<0.0001
Fat, total body (g)	15635.5 ± 5654.63	15285.6 ± 5164.73	1.135	0.295
Lean, total body (g)	43024.7 ± 5842.31	43133.9 ± 5708.61	0.367	0.549
% Fat, total body	25.3 ± 6.20	24.9 ± 5.59	1.116	0.229

Note: W/H, waist-to-hip ratio; CI, centrality index; BMC, bone mineral content

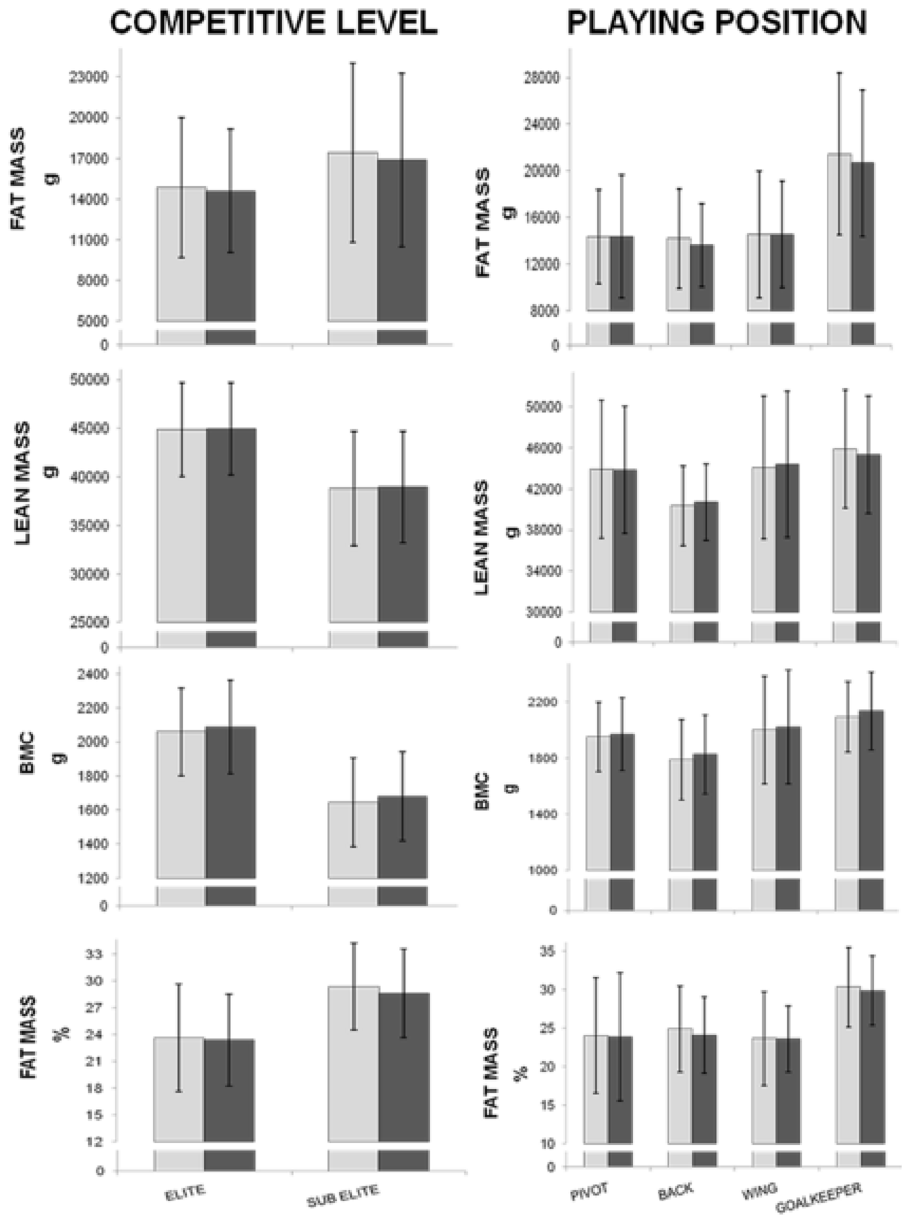

FIG. 1. DXA BODY COMPOSITION IN FEMALE HANDBALL PLAYERS (N=33) BEFORE (WHITE BARS) AND AFTER (GREY BARS) AN 8-MONTH COMPETITIVE SEASON ACCORDING TO COMPETITIVE LEVEL (ELITE VS. SUB-ELITE; LEFT PANELS) OR PLAYING POSITION (PIVOT, BACK, WING, GOALKEEPER; RIGHT PANELS). NO SIGNIFICANT DIFFERENCE IS PRESENT
Note: BMC, bone mineral content

When the whole sample of female handball players was subdivided according to playing position (goalkeeper, n=5; back, n=12; wing, n=10; pivot, n=6) no significant difference was found postseason in circumferences or skinfolds, nor in body composition parameters (Fig. 1).

DISCUSSION

Results of physical and body composition characteristics investigation in female handball players at preseason and postseason demonstrates the following points:

1. Most anthropometric parameters do not change significantly over the competitive season except for some fat redistribution;
2. BMC increases in the limbs, and LM in upper limbs postseason;
3. These findings are independent of competitive level (elite/sub-elite) and playing position.

The first finding of this work is that body mass and BMI of female handball players are similar preseason and postseason, suggesting no significant effect of in-season activity on these gross bodily parameters. Previous studies showed similar results in both female [9] and male [8] handball players. In the same papers [8,9], a 2-compartment model using skinfold analysis was used to estimate body composition. Herein we expand on novel, detailed anthropometric and body composition characterization of handball players pre- and postseason also using the reliable DXA analysis; in fact, skinfold analysis has previously been shown to significantly underestimate FM% vs. DXA [6]. The proportions of FM and LM of the human body can be measured more accurately by increasing the level of compartments considered as part of the whole body from a 2-C to a 3-C model, using DXA.

In the trunk region, the combination of a slight, consistent (albeit non-significant) increase of hip circumference and a similar decrease of waist circumference led to a significant reduction of the W/H ratio postseason; this finding, together with the significant decrease of the suprailiac (-14.5%, $P<0.0001$) and mid-axillary (-9.4%, $P<0.044$) skinfold and a tendency to increase (+7.4%, $P=0.076$) of the chest skinfold suggest possible redistribution of fat in this region over the season; this is paralleled by some reduction (-0.3 kg; $p=0.098$) of trunk FM postseason in the presence of unchanged BMC and LM (Table 2). The presence of some redistribution in body subcutaneous fat is suggested by significant changes in CI postseason (Table 2); however, these findings need confirmation in a larger sample of handball players.

Upper arm circumference did not change postseason; despite the slight, significant increase of the triceps skinfold (+5.5%, $p=0.044$), DXA analysis showed no significant increase of FM in upper limbs (+1.39, $P=0.167$). Instead, both BMC and LM significantly increased (+15.5%, $P<0.0001$; +5.3%, $P<0.0001$, respectively); the increase in BMC and LM is similar in the right and left upper limb (left: +4.1%, $p<0.0001$ and +5.3%, $p<0.0001$, respectively; right: +5.7%, $p<0.001$; +5.2, $p<0.0001$, respectively). These findings indicate that playing handball over an 8-month competitive season improves bone quality and muscle mass in upper limbs, which are both used by handball players irrespective of dexterity. In lower limbs, anthropometric measurements do not show obvious changes postseason except for a moderate increase of the front thigh skinfold (+7.0%, $P=0.031$), and this is supported by non-significant variations in DXA-measured FM and LM in lower limbs (Table 2). However, a slight but significant BMC increase is found in lower limbs. Therefore, in our sample of female handball players BMC is increased in upper and lower limbs at the end of the competitive season. It is well known that exercise positively affects bone mass and quality [4,11,17]. Handball is a weight-bearing sport involving frequent sprints, rapid directional changes and stops, provoking high mechanical stress on lower limb bones; moreover, upper limbs are mechanically overloaded in this sport, as they are involved in throwing, fall landings, and ball blocks; accordingly, greater BMC was found in the whole body and enhanced bone mineral density (BMD) in the right upper extremity and femoral neck as well as enhanced BMC and BMD in the lumbar spine, pelvic region, and lower extremity in young (14.2 ± 0.4 y) girls who had been playing handball for 3.9 ± 0.4 y in comparison with controls [21]. In field hockey, a sport where the arm is regularly used to hit the ball, it was found that senior players developed higher bone mass density in the right vs. left forearm through the competitive season [1]. Data presented here confirm and extend previous findings in handball players, showing the beneficial effect of a competitive season on limb BMC as well as upper limb lean mass; this effect seems to be independent of weight training because similar increments in BMC were present in elite (weight training 2 times a week) and non-elite players (no weight training) (data not shown). Therefore, in addition to the accurate assessment of FM and LM, the use of DXA in this study enabled the quantification of BMC changes in handball players that occur across a competitive season, which has not previously been reported in the literature.

Overall, our data show some improvement in the physical characteristics of female handball players through an 8-month competitive season; this is in agreement with previous findings [9] using a 2-compartment model for body composition analysis. There is a paucity of studies using the 3-compartment model to evaluate body composition of athletes through the competitive season. Earlier work [16] showed reduction of FM but not increase of fat-free mass in 18 male and female rowers through a rowing season, possibly due to dietary habits. Recently, a limited difference was found in DXA-measured body composition parameters in women collegiate athletes from preseason to postseason as well as a different pattern of change across sports (softball, basketball, volleyball, and swimming) [2]. In males it has been shown that in elite soccer players positive changes in body composition observed preseason were lost by the middle of the competitive season, but were restored in the subsequent start of preseason training [5]. Instead, increase in BMC but not LM, FM, and FM% from preseason to mid-season was found in elite rugby league players; LM, FM, and FM% but not BMC increased from mid-season to postseason [10]. Body mass did not change over the course of the competitive season. Therefore, it seems that body composition changes over the season are to some extent sport-specific.

Interestingly enough, in our group of female handball players the competitive level (elite or sub-elite) had no effect on body composition changes preseason to postseason. We previously showed that in the whole preseason handball player sample (n=43) anthropometric and body composition characteristics were more favourable in the elite players [15]. Although results in non-elite players should be considered with caution because of the limited group size, our data suggest that a higher amount of in-season training is not able to significantly affect per se the physical characteristics of handball players. Similarly, no playing position-specific variation was found postseason in the presence of several significant differences preseason [15], suggesting that in-season training and competition is associated with consensual physical changes within roles.

Ideally, these results could serve as an important tool in the development of guidelines optimizing in-season training programmes for team handball.

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REFERENCES

1. Beck B.R., Doecke J.D. Seasonal bone mass of college and senior female field hockey players. J. Sports Med. Phys. Fitness 2005;45:347-354.
2. Carbuhn A.F., Fernandez T.E., Bragg A.F., Green J.S., Crouse S.F. Sport and training influence bone and body composition in women collegiate athletes. J. Strength Cond. Res. 2010;24:1710-1717.
3. Chaouachi A., Brughelli M., Levin G., Boudhina N.B., Cronin J., Chamari K. Anthropometric, physiological and performance characteristics of elite team-handball players. J. Sports Sci. 27:2009;151-157.
4. Chilibeck P.D., Sale D.G., Webber C.E. Exercise and bone mineral density. Sports Med. 1995;19:103-122.
5. Egan J., Wallace T., Reilly T., Chantler P., Lawlor J. Body composition and bone mineral density changes during a premier league season as measured by dual-energy X-ray absorptiometry. Int. J. Body Comp. Res. 2006;4:61-66.
6. España-Romero V., Ruiz J.R., Ortega F.B., Artero E.G., Rodriguez G.V., Moreno L., Castillo M.J., Ruiz J.R. Body fat measurement in elite sport climbers: comparison of skinfold thickness equations with dual energy X-ray absorptiometry. J. Sports Sci. 2009;27:467-477.
7. Gabbett T.J. Science of rugby league football: a review. J. Sports Sci. 2005;23:961-976.
8. Gorostiaga E.M., Granados C., Ibañez J., González-Badillo J.J., Izquierdo M. Effects of an entire season on physical fitness changes in elite male handball players. Med. Sci. Sports Exerc. 2006;38:357-366.
9. Granados C., Izquierdo M., Ibáñez J., Ruesta M., Gorostiaga E.M. Effects of an entire season on physical fitness in elite female handball players. Med. Sci. Sports Exerc. 2008;40:351-361.
10. Harley J.A., Hind K., O'Hara J.P. Three-compartment body composition changes in elite rugby league players during a super league season, measured by Dual-Energy X-ray Absorptiometry. J. Strength Cond. Res. 2011;25:1024-1029.
11. Karlsson M.K. Skeletal effects of exercise in men. Calcif. Tissue Int. 2001;69:196-199.
12. Laskey M.A. Dual-energy X-ray absorptiometry and body composition. Nutrition 1996;12:45-51.
13. Lohman T.G., Roche A.F., Martorell R. Anthropometric Standardization Reference Manual. Human Kinetics, Champaign, IL, 1988.
14. McLeod W.D., Hunter S.C., Etchison B. Performance measurement and percent body fat in the high school athlete. Am. J. Sports Med. 1983;11:390-397.
15. Milanese C., Piscitelli F., Lampis C., Zancanaro C. Anthropometry and body composition of female handball players according to competitive level or the playing position. J. Sport Sci. 2011;29:1301-1309.
16. Morris F.L., Payne W.R. Seasonal variations in the body composition of lightweight rowers. Br. J. Sports Med. 1996;30:301-304.
17. Nichols D.L., Sanborn C.F., Essery E.V. Bone density and young athletic women: an update. Sports Med 2007;37:1001-1014.
18. Norton K., Olds T. Anthropometrica. Univ. New South Wales Press, Sydney 1996.
19. Van den Tillaar R., Ettema G. Effect of body size and gender in over arm throwing performance. Eur. J. Appl. Physiol. 2004;9:413-418.
20. Van Der Ploeg G.E., Withers R.T., Laforgia J. Percent body fat via DEXA: comparison with a four-compartment model. J. Appl. Physiol. 2003;94:499-506.
21. Vicente-Rodriguez G., Dorado C., Perez-Gomez J., Gonzalez-Henriquez J.J., Calbet J.A. Enhanced bone mass and physical fitness in young female handball players. Bone 2004;35:1208-1215.
22. Visnapuu M., Jürimäe T. Relations of anthropometric parameters with scores on basic and specific motor tasks in young handball players. Percept. Motor Skills 2009;108:670-676.
23. Ziv G., Lidor R. Physical attributes, physiological characteristics, on-court performances and nutritional strategies of female and male basketball players. Sports Med. 2009;39:547-568.