

Changes in Body Composition, During the Season, in Highly Trained Soccer Players

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Abstract: Body composition (BC) and other functional parameters are the main predictors of fitness state in both trained and non-trained subjects. The selected parameters of the BC (% of body fat (%BF), fat free mass (FFM), body cell mass (BCM), extracellular mass (ECM), and ECM/BCM relationship; all these parameters were determined by the whole body multi-frequency bioimpedance method) were determined four times per year in 45 top soccer players (January, March, July and December) (mean age = 21.9±3.1 years, height = 179.5±4.0 cm, mass = 75.3±6.0 kg, %BF = 10.4±1.7 %, FFM = 67.6±4.1 kg, ECM/BCM = 0.67±0.03, $VO_{2peak} \cdot kg^{-1} = 62.7 \pm 3.8 \text{ ml} \cdot kg^{-1} \cdot \text{min}^{-1}$, $v_{peak} = 17.7 \pm 0.6 \text{ km} \cdot h^{-1}$ - 1st evaluation). The %BF was altered during the training year by 9.9±1.8%, FFM by 3.9±1.8%, BCM by 8.0±1.4% and ECM/BCM by 13.8±2.1%. The increase in body mass during a season is caused by increase in FFM and BCM and reflects qualitative alterations in training; mainly increase of training based on speed and strength. We may conclude that the parameters that characterize the BC may better reflect the changes in the quality and quantity of the imposed training load and/or training state than the maximal functional variables in highly trained soccer players and thus may be used like a supplementary criterion of imposed training effectivity.

Keywords: Body composition, bioimpedance, body cell mass, body mass, soccer players.

INTRODUCTION

Soccer is one of the most popular sports in the world, and its popularity is continuing to increase. There is still much uncertainty and debate surrounding its physiological requirement because emphasis is on skills to neglect of fitness, conservative training methods and the difficulty of studying the sport scientifically.

There is ample evidence to suggest that the position of the soccer players is related to both their energy demands and their physiological characteristics [1-5]. The frequently presented values for total distance covered in a game of above 10 km and maximal oxygen uptake over $60 \text{ ml} \cdot kg^{-1} \cdot \text{min}^{-1}$ suggest a moderate overall aerobic demand [4, 6-11].

The physical composition of the body is an important component of fitness. The excess adipose tissue is not active and encumbers athletes with useless weight [12]. This contributes to greater energy expenditure during a match and also decreases performance in terms of power and acceleration [4]. A professional player should keep his body composition close to an "ideal" value all season. For these reasons it is crucial for coaches to have knowledge and equipment to assess body composition. Anthropometric measurements have received widespread recognition in elite soccer player community. It is a fact that teams - players are characterized

by a relative large heterogeneity in body size. Several studies on anthropometric characteristics have been reported in the literature [13-15], but some of them only provided measurements at the beginning and at the end of the season.

Conditioning professionals should maintain optimum body composition throughout the season in all players, especially in a sport like soccer where excess fat mass and insufficient fat free mass could have a negative implication for performance. The reduction in the percentage of body fat and a simultaneous increase in the fat free body mass are significantly correlated with soccer players performance and, more specifically, with the repeated high intensity running ability and also with the amount of high intensity work performed during soccer games [12, 16].

Evaluation of changes in cardiorespiratory or metabolic variables during submaximal exercise may help to explain the adaptation (actual training state) of athletes to their training stimulus [4-17]. This is because maximal functional variables in homogeneous groups of trained subjects cannot adequately evaluate changes in the state of training. The changes observed in the maximal values of functional variables during the year are almost at the borderline of measurement error [7, 8].

The quality and/or an effect of imposed training process could be assessed by the changes of some functional variables that are influent by training. An assessment of body composition (BC) is necessary to properly identify a subject's predispositions for physical performance [15, 18, 19]. This assessment can then be used to estimate not only

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subject's ideal body mass but it is able to contribute to better formulate a training and diet regimen [20]. Periodic BC assessment can be used to assess the effectiveness of exercise and diet interventions or monitor changes in BC associated with growth and maturation and/or with highly intensive physical training.

Thus, there is a clinical need to measure not only percentage of body fat (%BF), but fat distribution, muscle mass, total body water (TBW), body-water compartments (extracellular - ECW, and intracellular water - ICW), body-water volumes changes, extracellular mass - ECM, body cell mass - BCM, and bone mass as well [20-22].

In highly trained subjects the continuous monitoring of BC may contribute to regulation of training load in the training process and positively affect their form. The monitoring of BC may also be beneficial for the determination of an adequate volume of load in the design of exercise diagnostics [4].

Measuring BCM contents for the evaluation of muscle mass and protein tissue states in dependence of physical training and/or nutrition state is well accepted [22-25].

The importance of BC in soccer player performance remains unclear; however, it is a primary concern in conditioning programs throughout a season at all levels of competition. The inherent physical stress of practice sessions and competition during a season may modulate actual body composition [26].

Numerous tools and methodologies have been developed to measure various BC parameters. The bioelectrical impedance analysis seems to be one of the most commonly used methods in the field conditions. According to Ostojic [27] in athletes were found non-significant difference in body fat percentage determined by skinfold and whole body bioimpedance method.

Regardless of which instrument was used to assess the BC, the method is only as good as the measurement technique and prediction or conversion formula applied. The conversion formulas and prediction equations selected use must be restricted to the populations from which they were derived to remain valid.

Data on variations in these parameters during the training year, not only at start and end training year, in soccer players are practically non-existent. The aim of this study was to assess the quantitative and qualitative changes in imposed training with help of selected BC and functional variables alterations in highly trained Czech adult soccer players during the training year.

METHODS

Participants

We tested 45 trained Czech soccer players (19 defenders, 15 midfielders, 11 forwards) underwent the BC and laboratory functional evaluation at pre-, mid-, end-, and post-season in order to evaluate changes in BC and aerobic fitness on the treadmill during the training year. All subjects have been playing at least three years in the Czech 1st league and

more than 85% of these players were/are members of Czech national team.

We continuously monitor the training data, which were evaluated on the weekly cycles. We focused on fitness (endurance, speed and strength) and game training data.

Procedures

The selected parameters of the BC (%BF, FFM, ECM, BCM and ECM/BCM, all were determined by the whole body multi-frequency bioimpedance measurement) four times per year (January, March, July and December).

Participants wore shorts and were asked to remove any metal and jewelry from their persons. Height determined by stadiometry and scale mass were recorded to the nearest 0.5 cm and 0.1 kg, respectively (Seca 702, Seca GmbH & Co. KG, Hamburg, Germany).

Body composition was measured using a bioelectrical impedance analyzer (B.I.A. 2000M, Data Input, Germany). The subjects refrained from physical activity, sauna, or alcohol consumption within 12 hours prior to the measurement of BC. During the measurement, the subjects lay supine on the examination table with arms away from the body with no shoes, socks, or any jewelry. Resistance and reactance were measured at four frequencies - 1, 5, 50 and 100 kHz (B.I.A. 2000M, Data Input, Germany) on the right side of the body by tetrapolar electrode configuration (four electrodes, two on the hands and two on the feet in accordance with manufacturer's specification). The subjects remained lying until the completion of the measurement, and then resistance and reactance were recorded, which were later used to estimate muscle mass, ECM, BCM and ECM/BCM using body composition software (Nutri 4, Data Input, Germany). The calculation of %BF, FFM was realized by using prediction equations that were validated for athletes with help of DEXA according to Stewart and Hannan [28] and Wittich *et al.* [29].

Peak oxygen uptake was evaluated by means of an incremental exercise test to subjective exhaustion on a treadmill at 5% inclination [7, 8]. The respiratory variables and gas exchange were measured using an open system with the help of TEEM 100 diagnostic equipment.

STATISTICAL ANALYSIS

The means and standard deviations were used for presentation of assessed data. The Pearson correlation and Student t-test for paired values were used for statistical analysis of data. A p-value was set a priori of <0.05 to determine statistical significance. Institutional ethics approval was obtained from the Faculty of Physical Education and Sports Charles University Ethics Committee.

RESULTS

The seasonal variations of selected body composition variables are presented in Table 1. No significant differences were found in selected BC variables at the beginning and the season end. The statistical significance in followed variables in season is presented in Table 2.

Table 1. Seasonal variations of selected body composition and functional variables that were determined in 45 highly trained Czech soccer players.

	January	March	July	December	Δ max (%)
Body mass (kg)	75.3±6.0	75.6±5.9	77.4±5.8	75.0±6.0	3.1±0.5
Height (cm)	179.5±4.0	179.4±4.1	179.5±4.0	179.5±4.0	---
Body fat (kg)	7.9±2.4	7.3±2.1	7.3±2.2	7.6±2.5	7.6±1.9
%Body fat (%)	10.5±1.9	9.7±2.0	9.5±1.8	10.2±1.7	9.9±1.8
FFM (kg)	67.4±4.1	68.3±3.8	70.1±3.9	67.4±4.0	3.9±1.8
ECM (kg)	26.9±1.1	26.5±1.0	26.3±0.9	26.8±1.2	1.9±0.7
BCM (kg)	40.6±1.7	41.9±2.5	44.4±2.5	41.2±2.8	8.0±1.4
BCM in %BM (%)	66.3±1.8	63.3±2.0	59.2±1.8	65.1±1.7	10.7±0.8
ECM/BCM	0.66±0.03	0.63±0.02	0.58±0.04	0.65±0.04	13.8±2.1
VO _{2peak} .kg ⁻¹ (ml)	62.7±3.8	64.9±4.0	63.7±4.1	62.3±3.7	4.0±0.8
v _{peak} (km.h ⁻¹)	17.5±0.6	18.1±0.7	18.4±0.6	17.7±0.7	5.1±1.2

1 – January, 2 – March, 3 – July, 4 – December

Table 2. Statistical significance of selected BC and functional variables assessed with help of paired t-test in highly trained soccer players during the season.

	1 - 2	1 - 3	1 - 4	2 - 3	2 - 4	3 - 4
Body mass (kg)	NS	0.005	NS	0.005	NS	NS
Height (cm)	NS	NS	NS	NS	NS	NS
Body fat (kg)	NS	0.005	NS	NS	NS	0.005
%Body fat (%)	NS	0.005	NS	NS	NS	0.005
FFM (kg)	NS	0.005	NS	0.005	NS	0.005
ECM (kg)	NS	NS	NS	NS	NS	NS
BCM (kg)	NS	0.005	NS	0.005	NS	0.005
BCM in %BM (%)	0.05	0.001	NS	0.005	NS	0.001
ECM/BCM	NS	0.005	NS	NS	NS	0.005
VO _{2peak} .kg ⁻¹ (ml)	NS	NS	NS	NS	NS	NS
v _{peak} (km.h ⁻¹)	NS	0.005	NS	NS	NS	NS

0.05 - p < 0.05, NS – non significant

The highest body mass, fat free mass and BCM and lowest values of %BF and ECM/BCM relationship were detected in July. This increase was affected by a significant increase of speed and strength training load – the increase began at 5.3% during the 1st evaluation and ended at 12.5% of total volume of training loads at the 3rd evaluation. These alterations could be explained as the “improvement of muscle mass quality”, and may be used in practice for evaluation of intensive training effect; loads with higher content of movement intensities.

Maximal seasonal variations in BC variables (%BF was altered by 9.9±1.8%, FFM by 3.9±1.8%, BCM by 8.0±1.4%, ECM/BCM by 13.8±1.9%) were significantly higher than alterations in other functional variables (VO_{2peak}.kg⁻¹ 4.0±0.9% and v_{peak} about of 5.1±1.4%).

We did not find any significant differences in BC variables between defenders, midfielders, and forwards. These data were significantly better than the data in goalkeepers.

In functional variables the data in midfielders were significantly higher ($p < 0.05$ in all cases) than data in defenders and forwards. Data in all players from field were better than data in goalkeepers.

The mean values of ECM/BCM relationship that were determined in other groups of athletes by the same way like data in soccer players are presented in Table 3.

Table 3. Mean \pm s_p values of ECM/BCM relationship determined by whole body multi-frequency bioimpedance method in trained Czech athletes of different sport events.

	Men/N	Women/N
Ice hockey	0.58 \pm 0.03/386	0.69 \pm 0.03/42
Soccer players	0.64 \pm 0.04/493	0.70 \pm 0.02/51
Cross country skiers	0.67 \pm 0.02/201	0.70 \pm 0.03/101
Biathlon	0.68 \pm 0.03/156	0.71 \pm 0.04/85
Tennis	0.70 \pm 0.04/62	0.74 \pm 0.04/34
Endurance runners	0.71 \pm 0.03/126	0.75 \pm 0.03/74
Swimmers	0.72 \pm 0.05/34	0.76 \pm 0.04/31
Non-trained	0.78 \pm 0.05/563	0.82 \pm 0.03/345

The dependence of peak oxygen uptake on relationship ECM/BCM by the 1st evaluation has a form:

$$VO_{2\text{peak}} \cdot \text{kg}^{-1} \text{ (ml)} = -55.584 \cdot \text{ECM/BCM} + 99,590, r^2 = 0.701, S_{EE} = 2.24 \text{ ml}, p < 0.005$$

The coefficient determination in these relationships altered in dependence on season – according to alterations in quantity and quality of imposed training load. In January $r^2 = 0.705$, March $r^2 = 0.712$, July $r^2 = 0.721$, and December $r^2 = 0.708$.

The values of BCM in relative description like a percentage of BM are lying practically in the range from 60 to 65% of BM that was presented by Andreoli *et al.* [2003].

In 1st evaluation we found the significant dependence of peak oxygen uptake on BCM in the form:

$$VO_{2\text{peak}} \cdot \text{kg}^{-1} \text{ (ml)} = 1.002 \cdot \text{BCM (kg)} + 21,235, r^2 = 0.581, S_{EE} = 2.91 \text{ ml}, p < 0.01$$

The coefficient determination in these relationships altered in dependence on season similarly like in above presented dependence of peak oxygen uptake on ECM/BCM. In January $r^2 = 0.581$, March $r^2 = 0.611$, July $r^2 = 0.631$, and December $r^2 = 0.590$, and thus probably reflects the seasonal alteration in quantity and quality of imposed training load.

DISCUSSION

Body composition is a key consideration in the physical make-up of professional soccer players [5], and significantly reflects the quantitative and qualitative changes in imposed

training. From this point of view we found the highest changes in these variable in pre- a past-season evaluation.

Body mass measures in this study were similar to those previously reported for older soccer players [1, 5, 13-16, 19, 30-34]. In addition, the %BF was similar to that reported in other studies [8, 20, 22, 26, 35]. These results confirm that high-level soccer players are, according to BC variables, relatively homogeneous [4]. The significant increase in BM from PRE to POST might be reasoned as being detrimental to competitive performance; however, 60% of the increase in body mass was explained by a gain in lean tissue [5-12].

Unfortunately, we did not find, in published literature available to us, information about changes in ECM and BCM in trained soccer players during a training year, so our data cannot be compared. If comparing the soccer players' data with sports that are energetically and characteristically similar, as in ice hockey, see Table 3, we can find similar parameters. These parameters are clearly the result of the nature and character of training used in games – mainly intermittent loads with high intensity of exercise [6, 8].

The main finding of the present study was that body fat content of elite professional soccer players significantly dropped during the conditioning and competitive period and increased during the off-season, furthermore that the functional variables (*i.e.* peak oxygen uptake) are strongly dependent on “quality” of muscle mass, mainly on the BCM and/or ECM/BCM relationship.

Players with the lowest percentage of body fat often have a better performance. Because body fat is a direct reflection of the intensity of training [21, 32], the BC of soccer players is likely to change during the course of the competitive season as a result of training, competition, and diet [21]. In general, the results showed that the size and body composition in the soccer elite players of Czech Republic are similar in relation to international studies. As to the playing positions, there were no significant differences, except that the soccer players who serve as midfielders are those who have only low values of BF with relation to the other playing positions and they are lower and lighter with regard to the goalkeepers [1].

Sutton *et al.* [5] found differences in BC that were evident between goalkeepers and outfield players, but not between outfield playing positions. No differences were found on the basis of international status. The non-Caucasian players demonstrated significantly lower percent body fat (9.2 +/- 2.0%) than the Caucasian players (10.7 +/- 1.8%).

Similar changes in BF and %BF and FFM was found by Milanese *et al.* [33]. Their results in Italy professional soccer players showed that whole-body FM and %FM significantly ($p < 0.001$) decrease at mid-season (-11.9%; -1.3%, respectively) and end-season (-8.3%; -0.8%, respectively) whereas fat-free soft tissue mass (FFSTM) significantly ($p < 0.001$) increase at mid-season (+1.3%) and end-season (+1.5%). It was concluded that professional soccer players undergo changes in their FM, FFSTM, and mineral mass across the season with some regional variations, irrespective of the playing position. Changes are mostly positive at mid-season, possibly due to difference in training between the first and second phase of the season.

The BF contents in this study were similar to those previously reported in data of similarly aged soccer players [26]. Sutton *et al.* [5] presented in non-Caucasian players significantly lower %BF (9.2 +/- 2.0%) than in the Caucasian players (10.7 +/- 1.8%). The percent of BF values that were presented by Silvestre *et al.* [26] (defenders 10.6+2.1%, midfielders 10.2+1.8%, forwards 9.9+2.0%) were broadly similar to the values reported by Davis *et al.* [9] (defenders 10.7+2.0%, midfielders 10.6+2.1%, forwards 10.0+1.8%) and Arnason *et al.* [37] (defenders 10.6+3.6%, midfielders 10.7+4.2%, forwards 9.6+5.1%); all of these results conform to the 10% average body fat for competitive male soccer players reported by Rico-Sanz [34]. The similarities in findings, in spite of different methods of assessment, testify to the homogeneity of elite outfield soccer players [17].

The significant seasonal increase in body mass might be reasoned as being detrimental to competitive performance; however, 60% of the increase in body mass may be explained by a gain in lean tissue [12]. Presumably, increases in lean tissue primarily resulted from gains in muscle tissue, suggesting that an athlete's strength also would improve [26]. Lean tissue significantly increased in the trunk and the legs. This may have happened due to a conditioning program that can be characterized as total conditioning, with the continuous development of aerobic capacity, power, speed, and speed endurance designed to maintain and improve physical performance with associated benefits in body composition [4, 6, 8, 11].

Body composition is a key consideration in the physical make-up of professional soccer players. The aims of the present study were to determine whether the BC of professional soccer players varied during the training year. One aim of BC assessment is to differentiate and quantify different body compartments. In professional soccer players, assessments are used alongside fitness measurements to determine physical preparedness for competition and to monitor the effects of training and dietary interventions on body composition status. Excess fat mass acts as a dead weight in activities in which the body is lifted repeatedly against gravity [4]. This excess weight has a deleterious effect upon general locomotion and soccer-specific actions such as jumping to contest aerial possession of the ball. The fat-free compartment, which includes lean muscle mass and bone mineral mass, is important for the production of speed, strength and power, and for injury prevention [13, 17, 32].

Differences in BCM exist among athletes of different sports, and among athletes within the same sport who compete at different performance levels [38].

The physical performance is caused by actual state of functional variables and muscle state. Both these groups of predispositions are strongly depending on a quality of imposed training load, mainly on the level of exercise intensity. The decisive is in majority of movement and/or sports activities the volume of strength and speed training [17, 23, 35, 36, 38]. This could be confirmed by data from different sport events that are presented in Table 2.

The lowest values of relationship ECM/BCM were found in athletes with higher part of speed and/or strength activities ice hockey players. Oppositely the highest values and the

lowest actual predisposition for physical exercise were found in non-trained subjects of the same age [21].

The data in female athletes of similar training state are slightly lower than in male. This could be explained by a higher muscle mass in males than in females and a better predisposition for highly intensive exercise in males what is following from higher percentage of FT fibers in their muscles [8, 18].

The cause of significantly higher changes in BC than in functional variables connected with peak oxygen uptake could be found in the structure and orientation of imposed training and in the selectivity of followed variables on the used training stimulus [8]. We may conclude that the parameters that may characterize the BC better reflect the changes in the quality and quantity of the imposed training load and/or training state than the maximal functional variables in highly trained subjects. Thus the BC is an important determinant of functional and training state in highly trained subjects that cannot be overlooked. Variations in the ECM/BCM index were due to accretion of BCM, which was associated with quality of imposed training load and with an increase of ICW [22, 23].

A maximal oxygen uptake of 60 ml.kg⁻¹.min⁻¹ seems to be adequate even at high levels of the game in adults, though there are commentators on the game who believe that a figure of 65 ml.kg⁻¹.min⁻¹ in adult soccer players is necessary [4, 6, 11]. Soccer player's values 60 ml.kg⁻¹.min⁻¹ are about 10 ml.kg⁻¹.min⁻¹ above the mean values that were collected in the general population of the same age, but are in turn at least 15 ml.kg⁻¹.min⁻¹ below those obtained in true endurance athletes, for example, long-distance runners and cross-country skiers [8, 18]. Soccer players, therefore, seem to have good but not outstanding aerobic capacity.

The dilemma for the coach and player is to determine how to accomplish improvements in fitness through an organized fitness program without sacrificing the ability to perform well in game after game or neglecting the skills which gave soccer play its unique character [4]. This is very important especially in very young soccer players which must firstly improve the basic motor abilities. It is likely that an increase in fitness will be able to be capitalized on only if there is an increase in the player's skill and game sense, and the reverse may apply also [6, 16].

Any change in these variables can only result from basic alterations in the quality and, in particular, the quantity of training of top soccer players. These changes are most unlikely to occur during a single year. This means that the maximal oxygen uptake can be changed during training in trained athletes only with great difficulty and it has little practical use for evaluating influence of the training stimulus on the course of adaptation to this level of exercise [4, 7, 9, 39]. Attention should be directed to how the necessary properties and prerequisites of running performance can best be developed during the whole training year.

It may be concluded that BC is important for elite soccer players, but that homogeneity between players at top professional level results in little variation between individuals. The variation during the season could significantly be higher than in inter-individual differences.

CONCLUSION

We can conclude that in trained soccer players the BC evaluation could be used for evaluation of qualitative and quantitative alterations in the imposed training load. Body cell mass, measured using the whole body multi-frequency bioimpedance method, represents an innovative, simple approach to assess BC.

The present study demonstrates that it is very important to analyze BC in soccer players, not only with the aim to evaluate the variation of weight in a quantitative and qualitative way, but also with the purpose of imposed training assessment. Although these results must be considered not yet conclusive, they could be the important information for coaches, especially during the selection of young soccer players.

Changes in BC were similar for all playing positions. It may be concluded that professional soccer players undergo changes in their FM, FFM, BCM, ECM and ECM/BCM across the season with some regional variations, irrespective of the playing position. Changes are mostly positive at mid-season, possibly due to difference in training between the first and second phase of the season.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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