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ANTHROPOMETRY AND BODY COMPOSITION OF YOUNG SOCCER PLAYERS

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A – study design, **B** – data collection, **C** – statistical analysis, **D** – interpretation of data, **E** – manuscript preparation, **F** – literature review, **G** – sourcing of funding

ABSTRACT

Background: Body composition and other anthropometric measurements are important factors influencing the overall performance of an athlete. Together with motor coordination, physical fitness, physical, functional, and psychosocial conditions, as well as learned technique and tactics, a player's sports potential and probability of success can be determined.

Aim of the study: Our study aimed to describe anthropometric variables and body composition of young soccer players of various ages.

Material and methods: A cross-sectional study was carried out among 61 young soccer players in the under-15, under-16, and under-19 categories. We used a bioimpedance analyzer to measure the following indicators: body height (BH), body mass (BM), body mass index (BMI), total body water (TBW), muscle mass (MM), fat mass (FM), body fat (BF) percentage, and visceral fat (VF).

Results: The mean findings for the variables among players in the U-15, U-17, and U-19 groups were age (14.79±0.32; 16.07±0.44; 17.43±0.87), BH (175.63±7.36 cm; 179.89±7.49 cm; 180.28±6.42 cm), BM (62.32±8.13 kg; 67.38±8.14 kg; 73.81±8.86 kg), BMI (20.15±1.88 kg/m^2; 20.77±1.58 kg/m^2; 22.68±2.18 kg/m^2), TBW (40.72±5.19 L; 44.13±5.18 L; 47.63±5.58 L), MM (31.18±4.26 kg; 34.06±4.22 kg; 37.11±4.64 kg), FM (6.8±2.68 kg; 7.12±2.48 kg; 8.72±2.72 kg), BF (10.83±3.6%; 10.47±2.83%; 11.79±3.09), and VF (1.83±1.09; 1.89±1.2; 2.61±1.33). Analysis of variance showed statistically significant differences between groups in terms of age, BM, BMI, MM, and TBW. Age had a statistically significant positive correlation with BH, BM, BMI, TBW, MM, and FM.

Conclusions: BM, MM, and TBW increase in the subsequent age groups of soccer players. There was a statistically significant positive correlation between age and BH, BM, BMI, TBW, MM, and FM. The conclusion from this study can help adjust training programs to the individual characteristics of a given player, which will allow for better performance and professional success.

KEYWORDS: body composition, muscle mass, fat mass, young soccer players

Background

Anthropometric variables and body composition are important components of success in sports, including football [1]. Body composition is strongly related to the physical fitness and achievements of a football player [2]. Body composition is one of the factors that when combined with technical/tactical, physical, functional, and psychosocial factors can determine the athlete's athletic potential and the likelihood of success in a given sport [3,4]. However, studies on the influence of anthropometric variables and body composition on soccer performance are not clear-cut, mainly due to the player's position, but also due to the player's individual physique. Nevertheless, monitoring body composition can help players im-

prove their performance and evaluate the results of the administered training plan [5].

In soccer, both body fat and lean body mass should be monitored. An appropriate fat level allows players to move more efficiently during training and matches. Lean mass and muscle mass (excessive or inadequate) can lead to undesirable changes in the body, that can affect performance factors such as speed, strength, power, and risk of injury [6].

Body composition, combined with physical, functional, and psychosocial factors, is one of the factors that can determine athletic potential and the likelihood of success in a given sporting discipline [7]. In the case of soccer players, the level of body fat and lean body mass should be constantly monitored. The right amount of fat is an energy reserve that allows players to maintain efficiency during training and matches. Lean body mass is also important, especially muscle mass. Too much of a training load with too little muscle mass can reduce performance factors such as speed, strength, and power, as well as increase the risk of injury and recovery time after exercise [8].

Changes in body composition based on age are well recorded in nonathletic adult and adult soccer players and have been correlated with health and athletic performance. But there is little research on body composition, age, and performance of adolescent soccer players. Leão et al. found an increase in lean body mass and a decrease in fat mass with age and training [9], while Manna et al. arrived at the opposite conclusion [10]. As such, further research into body composition changes in adolescent footballers is necessary. In addition, it is necessary to take into account periods sensitive to the development of physical abilities (e.g. puberty, growth spurt) and the appropriate adjustment of training units and proper nutrition.

The variability of anthropometric indices and body composition parameters in this period of adolescence can be used to identify an elite teenage player [11,12]. There are reports that soccer players with increased body dimensions have improved speed, power, and strength, especially during puberty [13]. Conversely, several longitudinal observational studies of teenage soccer players have shown a high consistency in anthropometric measures, sprint speed, lower extremity explosive power, isokinetic strength, and maximum aerobic speed among players [14, 15].

Aim of the study

This study aimed to describe the anthropometric variables and body composition of young soccer players in various age categories.

Material and methods

Study design

A descriptive, comparative cross-sectional study.

Settings

Our study was conducted in March of 2019 among U-15, U-16, and U-19 soccer players belonging to the MKS Mosir Opole in Poland. This study followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for reporting observational studies [16].

Participants

The sample of participants consisted of a total of 61 young soccer players from the MKS Mosir Opole divided into three subsamples. The first subsample of subjects consisted of 24 players in the U-15 group with a mean age of 14.8±2.2, the second subsample consisted of 19 players in the U-17 group with a mean age of 16.1±2.8, and the last subsample of examinees consisted of 18 players in the U-19 group with a mean age of 17.4±4.9. The soccer players were examined during the 2018–2019 season. The inclusion criteria were: (1) male gender, (2) regularly training for football at MKS Mosir Opole in Poland, (3) lack of contraindications to performance of the measurements using bioelectric impedance, (4) signed informed consent/parental or guardian consent in players under 18 years of age. The exclusion criteria included any injuries, contusions, or health problems that might affect the study's results.

Ethical Considerations

The study was approved by the Bioethics Committee of the Opole Medical School, Poland (No. KB/42/NOZ/2019). The study was carried out in accordance with the ethical guidelines of the Declaration of Helsinki and Good Clinical Practice guidelines [17].

Measurement

All measurements were conducted by highly skilled, trained, and experienced physiotherapists and nutritionists. Anthropometric variables included body height (BH, measured while the participant was standing erect against a portable stadiometer without shoes, in 0.1 cm increments), body mass (BM, in 0.1 kg increments), calculated body mass index (BMI; in kg/m^2), and body composition indices (BM, BMI, total body water (TBW), muscle mass (MM), fat mass (FM), body fat (BF) percentage, and visceral fat (VF)), which were measured by bioelectri-

cal impedance analysis using the InBody 120 scale. The scale was used according to the manufacturer's guidelines. Standardized conditions for bioimpedance measurements were maintained. The InBody 120 scale enables athletes to closely monitor their body weight and health condition with all relevant parameters.

Testing took place during the morning hours. Participants were asked not to consume any supplements or pharmacological agents that could influence the measurement results 24 hours prior to body composition measurements. They were also instructed not to eat or drink before the measurements and to maintain good hydration and a normal routine. Furthermore, the athletes did not perform high-intensity physical activity for any significant duration 48 hours before the tests. Players were assessed before training sessions and after urination.

Participants followed the prompts from the device. During the measurements, participants placed their bare feet on the metal plates of the system, firmly grasped the handles, and placed all fingers in standardized places.

The player was then asked to align their heels and forefeet with the electrodes on the measurement scale to ensure the maximum contact area. The player was also asked to align their thumbs, fingers, and palms to maximize the contact area with the electrodes while holding onto the device handles. During the procedure, participants were instructed to extend their elbows and slightly abduct their shoulders to ensure that their arms and legs were not in contact with any other body segments.

Once the proper positioning was achieved, the player was asked to stand still and remain silent while the device completed the body composition measurements, which took 17 seconds on average. The investigators administered and supervised the entire test to ensure that the player maintained proper positioning and did not move.

The accuracy of these measurements is estimated to be 98% compared to DEXA, i.e. a densitometric test. The InBody scale has been extensively tested for its reliability and validity, and reports have shown that these metric traits have been appropriate in various trials, including active people and athletes [18, 19, 20].

Statistical methods

The data obtained during the survey were collated using Microsoft Excel. Statistical analyses were conducted using Statistica version 13.1 (TIBCO Software Inc., USA). The basic description of quantitative variables such as mean (M), median (Me), minimum (Min), maximum (Max), 1st quartile (Q1), 3rd quartile (Q3), standard deviation (SD), and coefficient of variation (CV) was made during the preparation of the results. The distribution of the variables was assessed in terms of normality using the Shapiro-Wilk test. The analysis of variance (ANOVA) and post hoc NIR tests were used to compare quantitative variables. The chi-square test was used to evaluate and compare the correlation between age and body composition. The level of statistical significance for this study was set at a $p\text{-value} < 0.05$.

Results

Participants

A sample of the participants consisting of 61 young soccer players, divided into three subsamples. The first subsample consisted of 24 players (29.4%) under-15, the second subsample consisted of 19 players (31.1%) under-17, and the last subsample consisted of 18 players (29.5%) under-19.

Descriptive data

Descriptive statistics for the age and body composition of the players are presented in Tables 1–3.

Table 1. Characteristics of age, anthropometric variables, and body composition in the U-15 group.

Variables	M	Me	Min	Max	Q1	Q3	SD	CV
Age [years]	14.8	14.8	14.0	15.2	14.6	15.1	0.3	2.2
BH [cm]	175.6	177.5	160	192	172	180.5	7.4	4.2
BM [kg]	62.3	62.1	47.3	75.9	55.6	69.1	8.1	13.1
BMI [kg/m^2]	20.2	19.7	16.4	24.2	19.1	21.4	1.9	9.4
TBW [L]	40.7	41.4	30.9	48.4	37.4	45.4	5.2	12.7
MM [kg]	31.2	31.6	23.1	38.2	28.5	35	4.3	13.7
FM [kg]	6.8	6.2	2.3	13.3	4.8	8.8	2.7	39.5
BF [%]	10.8	9.9	3.5	19.3	8.3	12.9	3.6	33.3
VF [rating]	1.8	1.5	1	5	1	2	1.1	59.5

Notes: BH: body height, BM: body mass, BMI: Body Mass Index, TBW: total body water, MM: muscle mass, MF: fat mass, BF: % of body fat, VF: visceral fat, M: mean, Me: median, Min: minimum, Max: maximum, Q1: 1st quartile, Q3: 3rd quartile, SD: standard deviation, CV: coefficient of variation.

Table 2. Characteristics of age, anthropometric variables, and body composition in the U-17 group

Variables	M	Me	Min	Max	Q1	Q3	SD	CV
Age [years]	16.1	16.1	15.3	16.9	15.9	16.2	0.4	2.8
BH [cm]	179.9	180	167	199	175	183	7.5	4.2
BM [kg]	67.4	66.5	54.5	82.8	61.8	73.3	8.1	12.1
BMI [kg/m^2]	20.8	20.2	18.2	24.7	19.8	22.1	1.6	7.6
TBW [L]	44.1	43.7	35.9	55.9	39.5	47.9	5.2	11.7
MM [kg]	34.1	34	27.4	43.3	30.4	37.2	4.2	12.4
FM [kg]	7.11	6.7	4.3	14.4	5.4	7.8	2.5	34.9
BF [%]	10.5	10.6	6.3	17.4	8.2	11.6	2.8	27
VF [rating]	1.9	2	1	5	1	2	1.2	63.2

Notes: BH: body height, BM: body mass, BMI: Body Mass Index, TBW: total body water, MM: muscle mass, MF: fat mass, BF: % of body fat, VF: visceral fat, M: mean, Me: median, Min: minimum, Max: maximum, Q1: 1st quartile, Q3: 3rd quartile, SD: standard deviation, CV: coefficient of variation.

Table 3. Characteristics of age, anthropometric variables, and body composition in the U-19 group

Variables	M	Me	Min	Max	Q1	Q3	SD	CV
Age [years]	17.4	17.7	15.5	19.2	16.9	18	0.9	4.9
HB [cm]	180.3	181	169	191	175	185	6.4	3.6
BM [kg]	73.8	72.4	60.7	89.7	68.2	78.6	8.9	12
BMI [kg/m^2]	22.7	22.8	19.5	27.1	21	24.61	2.2	9.6
TBW [L]	47.6	46.8	36.8	57.2	43.8	52	5.6	11.7
MM [kg]	37.1	36.2	28.2	45.4	33.7	40.9	4.6	12.5
FM [kg]	8.7	8.3	4.9	15.9	7	10.4	2.7	31.2
BF [%]	11.8	11.2	7.2	17.8	9.3	14.2	3.1	26.2
VF [rating]	2.6	2	1	6	2	3	1.3	51.1

Notes: BH: body height, BM: body mass, BMI: Body Mass Index, TBW: total body water, MM: muscle mass, MF: fat mass, BF: % of body fat, VF: visceral fat, M: mean, Me: median, Min: minimum, Max: maximum, Q1: 1st quartile, Q3: 3rd quartile, SD: standard deviation, CV: coefficient of variation.

The mean age of players in groups U-15, U-17, and U-19 group was 14.8 ± 0.3, 16.1 ± 0.4, and 17.3 ±0.9, respectively. In each subsequent age group, there was an increase in BH, BM, BMI, TBW, MM, FM, and VF.

Main results

ANOVA testing revealed differences between groups with respect to age (F=113.7; p<0.001), BM (F=9.7; p<0.001), BMI (F=9.6; p<0.001), MM (F=9.5; p<0.001), TBW (F=8.8; p<0.001), while there were no differences with respect to BH (F=2.9; p=0.066), BF (F=0.8; p=0.443), FM (F=2.9; p=0.057), VF (F=2.5; p=0.090) as shown in Table 4.

The post hoc NIR test confirmed statistically significant differences between all groups of variables such as Age (U-15<U-17, p<0.001; U-15<U-19, p<0.001; U-17<U-19, p<0.001), TBW (U-15<U-17,

Table 4. Analysis of variance (ANOVA) — effects and errors of age, anthropometric variables, and body composition

Variables	SS Effect	df Effect	MS Effect	SS Error	df Error	MS Error	F	p
Age [years]	74.2	2	37.1	19.9	58	0.3	113.7	<0.001
BH [cm]	290.4	2	145.2	2955.0	58	50.9	2.9	0.066
BM [kg]	1357.9	2	678.9	4047.1	58	69.8	9.7	<0.001
BMI [kg/m^2]	68.8	2	34.4	207.2	58	3.6	9.6	<0.001
TBW[L]	494.7	2	247.3	1631.9	58	28.1	8.8	<0.001
MM [kg]	362.9	2	181.5	1104.8	58	19.1	9.5	<0.001
FM [kg]	41.5	2	20.8	402.1	58	6.9	2.9	0.058
BF [%]	17.2	2	8.6	604.7	58	10.4	0.8	0.443
VF [rating]	7.2	2	3.6	83.4	58	1.4	2.5	0.091

Notes: BH: body height, BM: body mass, BMI: Body Mass Index, TBW: total body water, MM: muscle mass, MF: fat mass, BF: % of body fat, VF: visceral fat, SS: sum of squares; df: degree of freedom; MS: mean square; F: the value of the F statistic, p: p-value.

p<0.05; U-15<U-19, p<0.001; U-17<U-19, p<0.05), and MM (U-15<U-17, p<0.05; U-15<U-19, p<0.001; U-17<U-19, p<0.05). Statistically significant differences were found in BM (U-15<U-19, p<0.001; U-17<U-19, p<0.05), and BMI (U-15<U-19, p<0.001; U-17<U-19, p<0.01). These results are shown in Table 5.

Other analyses

There was a statistically significant positive correlation between Age and BH (r=0.3; p<0.05), BM (r=0.5; p<0.001), BMI (r=0.5; p<0.001), TBW (r=0.5; p<0.001), MM (r=0.5; p<0.001), and FM (r=0.3; p<0.05) as shown in Table 6.

Table 5. Post hoc NIR test in age, anthropometric variables, and body composition

Variables	Group	M	U-15	U-17	U-19
Age [years]	U-15	14.8		U-15<U-17***	U-15<U-19***
	U-17	16.1	U-15<U-17***		U-17<U-19***
	U-19	17.4	U-15<U-19***	U-17<U-19***	
BM [kg]	U-15	62.3		n.s	U-15<U-19***
	U-17	67.4	n.s		U-17<U-19*
	U-19	73.8	U-15<U-19***	U-17<U-19*	
BMI [kg/m^2]	U-15	20.2		n.s	U-15<U-19***
	U-17	20.8	n.s		U-17<U-19**
	U-19	22.7	U-15<U-19***	U-17<U-19**	
TBW [L]	U-15	40.7		U-15<U-17*	U-15<U-19***
	U-17	44.1	U-15<U-17*		U-17<U-19*
	U-19	47.6	U-15<U-19***	U-17<U-19*	
MM [kg]	U-15	31.2		U-15<U-17*	U-15<U-19***
	U-17	34.1	U-15<U-17*		U-17<U-19*
	U-19	37.1	U-15<U-19***	U-17<U-19*	

Notes: BM: body mass, BMI: Body Mass Index, TBW: total body water, MM: muscle mass, M: mean, significant differences are marked: *p<0.05, **p<0.01, ***p<0.001, n.s.: nonsignificant differences between compared pairs.

Table 6. Spearman's Rank correlation between age, anthropometric variables, and body composition

Variable		BH [cm]	BM [kg]	BMI [kg/m2]	TBW [L]	MM [kg]	FM [kg]	BF [%]	VF [ratio]
Age [years]	r	0.260	0.510	0.490	0.490	0.520	0.280	0.10	0.24
	p	0.040	<0.001	<0.001	<0.001	<0.001	0.030	n.s.	n.s.

Notes: BH: body height, BM: body mass, BMI: Body Mass Index, TBW: total body water, MM: muscle mass, FM: fat mass, BF: body fat, VF: visceral fat, r: value of coefficient r, p: p-value, n.s.: nonsignificant differences.

Discussion

Key results

The study aimed to analyze the differences in anthropometric variables and body composition in young soccer players from three different age groups. The players in the U-19 group were heavier and had a higher BMI compared to the U-15 and U-17 players. The mean BMI of each group was within the normal range. Differences in TBW and MM were also significant. The youngest group (U-15) had the lowest TBW and lowest MM. The oldest group (U-19) had the highest TBW and MM.

Interpretation

The higher BMI in U-19 players may be associated with a greater MM. The older age and longer training periods of U-19 players likely result in an increase in MM and a greater body weight and BMI. Other authors have also found differences in body weight, BMI, and body composition parameters in young players of different ages. A study conducted in the Czech Republic showed that the age of the footballer has a significant impact on the MM of the lower limbs. Researchers observed an increase in the percentage of MM with age [21]. Research by Spehnjak et al. evaluated Serbian footballers of different ages and found players in the U-15 group were the lightest and had the lowest BMI, MM, and TBW compared to players from the U-17 and U-19 groups. There were no significant differences between the U-17, U-19, and senior groups [22]. In studies by Bernal-Orozco et al., the youngest age category of footballers also had the lowest values in body weight and MM [7].

Here, the author found the U-15 group was heavier and had a higher BMI, MM, and TBW compared to the U-15 group in the study by Spehnjak et al. The differences in results for the U-15 group may be because the Serbian footballers in the U-15 group were younger (mean age 13.7±1.9) compared to the Polish U-15 players (mean age 14.8±0.3) [22]. In turn, players in the U-15 group from our research were taller and had a greater body weight and lower fat content compared to 14-year-old Portuguese soccer players [23].

In a study by Konarski et al., select and non-select U-15 male soccer players differed significantly in terms of estimated maturity, body size, muscle mass, body proportion, and functional tests. MM differed significantly ($p<0.05$) and was larger in the select players compared to the non-select players (45.5 vs. 40.9). Both select and non-select players had a much higher MM compared to the U-15 soccer players from our research. The soccer players from our research also had a lower FM than players from the research by Konarski et al. (select and non-select, 14.8% vs. 15.6%, respectively) [24].

The U-17 and U-19 results obtained in our study were similar to the results obtained in these age groups in the Serbian research [22]. Here, the authors found no significant differences between groups regarding the percentage of adipose tissue and VF. However, other researchers have observed different results. In the study by Spehnjak et al., differences in BF were significant. The U-15 group had a significantly higher percentage of BF compared to the U-17 and U-19 groups [22]. A study of young Greek soccer players showed no differences between age groups regarding BF, but a weak significant negative correlation between BF and age was found [25]. In Mexican soccer players, the youngest age group had the highest percentage of BF [7].

Age was a significant factor in most of the parameters on the build and body composition of young footballers. The authors' own research showed positive significant correlations between age and height, body weight, BMI, MM, TBW, and FM. There were no significant correlations between age and BF or VF. However, the relationship between age and BF percentage may not be clear. The overall increase in body weight with age and a greater gain in lean mass could have resulted in a lower relative proportion of BF mass as the absolute amount of BF as measured in kilograms increased with age in our football groups. Milson et al. came to a similar conclusion [11]. An interesting result is the fact that the examined players had similar BF in all groups.

The growth and maturity characteristics of youth male soccer players are well documented. Given the popularity of soccer throughout the world, there is considerable interest in the growth and maturation of young players [26, 27, 28, 29].

Strengths

The strength of our study was the use of standardized methods to assess body composition. In addition, this study broadens the knowledge on the body composition characteristics of young footballers in particular age categories.

Limitations

Our study also has several limitations. This study was conducted only within one club. It is possible that conducting the test at different clubs with lower or higher levels would have produced different results. In addition, we did not divide the players according to their playing position due to the relatively small number of participants. Therefore, the generalization of this data is limited.

In subsequent studies, the anthropometric data and body composition of players should be taken and observed longitudinally, taking into account variables such as the timing of puberty (allowing the determination of the peak velocity of growth). Research should also be carried out to include functional testing and comparisons based on anthropometric features. The other limitation is the lack of information on the number of games and duration of play in each game for the individual players and the lack of information on the injury of a player during the course of a season. It is worth considering these variables in future research.

Recommendations

Anthropometric variables and body composition provide objective and specific information that allows professionals in the medical, nutritional, physical, and technical industries to develop strategies to improve individual player performance through exercise and diet plans that optimize body composition. In particular, this information can assist with nutritional assessments and the subsequent monitoring of the athlete's nutrition from an early age to adulthood and in the setting of body composition goals. In addition, this data can be useful for strength and conditioning practitioners in designing effective and specific training programs according to the most suitable anthropometric and body composition profile of each player.

CONCLUSIONS

Overall, the U-19 division obtained higher anthropometric and body composition values compared

to all other age divisions, with the youngest group having the lowest values for most variables. Soccer players in subsequent age groups had increased body weight, MM, and TBW. Soccer players had statistically significant differences with regard to body composition except in FM, BF, and VF. There were statistically significant positive correlations between age and the body composition component BH, BM, BMI, TBW, MM, and FM. Future research should include the relative age effect on anthropometry, body composition, and biological maturation in young Polish soccer players.

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