

Changes in body water content of elite soccer players during the macrocycle according to function on the field

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Abstract:

Professional soccer players should meet the physical demands and maintain the best possible performance throughout the season. Body mass composition including body water content has a significant impact on athletes' performance. The aim of this study was to evaluate the changes in body hydration of professional soccer players in all periods of the macro-cycle (preparation, starting, and transition periods) taking into account the position on the field. The study was conducted between January 7, 2021, and July 23, 2021. The participants of the study were players of two soccer sports clubs belonging to PKO BP Ekstraklasa 2020/2021. 38 professional soccer players were included in the study. Body mass composition was assessed using a DSM-BIA electrical bioimpedance analyzer (InBody 770, InBody USA, California, USA). Standards recommended by the manufacturer, InBody USA, and WHO were used to determine TBW [L], ICW [L], ECW [L], and ECW/TBW. The obtained data were processed using Statistica v.13.3 software (Stat Soft Polska). A total of 228 body mass composition measurements were taken in 6 different measurements during the spring round of the 2020/2021 PKO BP Ekstraklasa season. Statistically significantly lower values of total body water, intracellular water, and extracellular water were found in midfielders. TBW content increased between 1 and 6 and 5 and 6 measurements ($p<0.01$). ICW content was found to increase between 1 and 2 and 1 and 4 measurements ($p<0.0001$) and ECW content decreased between 2 and 5 measurements ($p<0.001$). Statistically significant differences were found in the water content measurements of players in different positions. Significantly lower values were found for midfielders. The results of the study showed variation in water content in players playing different positions on the field. The study showed changes in the body hydration of soccer players during the macrocycle (preparatory, competitive, and transitional). No changes in body water content suggesting chronic dehydration of athletes were observed in individual periods of the macrocycle.

Key Words: - Hydration, soccer players, macrocycle, athletes, water content

Introduction

Soccer is the most popular sport in the world (Filippella et al., 2020; Pawłowski, 2020). It gathers record numbers of people in stadiums and in front of TV screens (Gardasevic et al., 2019). In 2020, the number of clubs in the Polish Soccer Association (PZPN) was over 6500, and there were 414217 players (Malinowska et al., 2021). As the popularity of the discipline rises, the demands on the players also increase (Bloomfield, Polman, O'Donoghue, 2007).

Athletes need adequate water intake to offset increased sweat losses and maintain water balance (Sawka et al., 2007). The benefits and importance of body water are documented (Judelson et al., 2007). Total body water (TBW) is divided into two main compartments: extracellular water (ECW) and intracellular water (ICW), accounting for approximately 65% and 35% of TBW, respectively (Sawka, Cheuvront, Carter, 2005). The ICW compartment is determined as the difference between the TBW and ECW compartments (Matias et al., 2016). Assessment of the water compartment is extremely important given the relationship between body water, exercise, and performance (Silva et al., 2014; Bull, 2020). In elite judo athletes, it has been documented that

decreased intracellular water results in decreased upper limb muscle strength and maximal grip strength (Silva et al., 2010). Furthermore, in a sample of basketball, handball, and volleyball players, an increase in ICW was associated with improvements in leg strength and jump height (Silva et al., 2014). These findings further support the important role of effective monitoring of the water distribution volumes (TBW, ECW, and ICW) in physical performance (Matias et al., 2016).

An important factor that determines the body mass composition of players during the season is the training macro-cycle, consisting of a preparation period, a competitive period, and a transition period. Each of them is aimed at different sports goals, and therefore they are characterized by different training loads. Consequently, changes in body mass composition occur over each period (Mascherini et al., 2015; Vasileios et al., 2018).

During increased physical activity, the primary mechanism of heat loss from the body is the sweat evaporation through the skin surface (Laitano, Runco, Baker, 2014). This is the main mechanism of internal body temperature control and can lead to sweat-induced dehydration. Impaired physiological function is observed with weight losses of 1%, with 3%–4% losses leading to heat cramps, stroke, and even death (Matias, Júdice et al., 2016). Sweating due to thermoregulation is the main reason for weight loss during intense physical activity, but there are other factors, i.e., loss of water vapor and carbon dioxide with exhaled air (Sawka et al., 2007; Shirreffs et al., 2011). When sweat loss exceeds fluid consumption, dehydration begins and leads to a cascade of events impacting the ratio between extracellular (ECW) and intracellular water (ICW), which influences performance and in some instances can become life-threatening (Matias, Júdice et al., 2016).

The aim of hydration before, during, and after exercise is to prevent loss of >2% of body weight, which will limit the onset of loss of exercise capacity (Laitano, Runco, Baker, 2014). Rehydration is an important part of the post-exercise recovery process. If athletes observe weight loss, they should aim to completely replenish fluid and electrolyte losses before the next training session or match. In order to rehydrate the body, it is recommended to take ~1.5 L of fluids for every 1 kg of body weight lost during activity (Maughan, 2018).

Bioelectrical impedance methods appear to be an easy to use and fairly inexpensive method for monitoring body composition and hydration in athletes (Kyle et al., 2004). To date, few studies (Matias et al., 2013, Quiterio et al., 2009) have been conducted on this population using commercial impedance measuring devices. Correct assessment of hydration compartments requires the use of lower and simultaneously higher frequencies (Mala et al., 2015).

The **aim** of this study was to evaluate the change in body hydration of professional soccer players during all periods of the macro-cycle (preparation, competitive, and transition periods) considering the position on the field.

Material & methods

Participants. The research was conducted between January 7, 2021, and July 23, 2021. Participating athletes were players of two soccer sports clubs belonging to PKO BP Ekstraklasa 2020/2021 (the highest class of soccer competition in Poland). The study was conducted with the approval of the Bioethics Committee of the Silesian Medical University in Katowice (PCN/0022/KB/68/I/20). Participants in the study were of different nationalities (36 Polish, 6 Slovakian, 3 Spanish, 3 Portuguese, 2 Greek, 2 Slovenian, 1 Czech, 1 Austrian, 1 Danish, 1 Hungarian, 1 Ghanaian, and 1 Gambian). The classification was made in terms of position: striker, midfielder, defender, goalkeeper.

The criterion for inclusion in the study was defined as the professional practice of soccer in the sports clubs included in the study, consent to participate in the study, and no injury requiring long-term treatment that would exclude the player from training and matches in the period of the study, i.e. 7 months. The exclusion criteria for the study included: not speaking Polish or English at a communicative level, exclusion of the player from training and matches for at least consecutive 14 days due to injury, illness, quarantine or isolation related to COVID-19 pandemic, transfer to another sports club during the study period, i.e. January 7, 2021, to July 23, 2021, absence from at least 1 of the 6 measurements for a reason other than the above.

The study included 58 athletes; however, considering the inclusion and exclusion criteria, 228 complete body composition measurements were finally obtained from 38 athletes.

Procedure. Body composition analyses were conducted in 3 periods of the spring round of the PKO BP Ekstraklasa 2020/2021 soccer season (preparation, competitive and transitional period).

Measurements were made:

- 1st measurement - January 7-9, 2021,
- 2nd measurement - February 2-3, 2021,
- 3rd measurement - March 10-13, 2021,
- 4th measurement - April 30, May 02, 2021,
- 5th measurement - June 17-18, 2021,
- 6th measurement - July 23, 2021.

1 measurement was performed before the beginning of the preparatory period, 2 measurement after the end of the preparatory period, 3,4 during the competition period, 5 after the end of the competition period, and 6

measurement after the transition period. Body mass composition was assessed using a DSM-BIA (electrical bioimpedance analyzer) (InBody 770, InBody USA, California, USA).

The DSM-BIA technique employs the assumption that the human body is composed of 5 interconnecting cylinders and takes direct impedance measurements from the various body compartments. A tetrapolar eight-point tactile electrode system is used, which measures the impedance at six different frequencies (1 kHz, 5 kHz, 50 kHz, 250 kHz, 500 kHz, 1000 kHz). The analyzer allows you to obtain a complete body composition in about 60s. The device works with the use of a current of 80 uA (H Ling et al., 2011)

The spectrum of electrical frequencies is used to predict the intracellular water (ICW) and extracellular water (ECW) compartments of the total body water (TBW) in the various body segments. Low-level frequencies rely on the conductive properties of extracellular fluid, whereas, at high-level frequencies, the conductive properties of both ICW and ECW are instrumental. ECW/TBW is a measure of compartmental fluid distribution and shows, as a ratio, how much of total body water is extracellular. Taking tests will establish normal fluid status and help determine any imbalances. As a general guide, check to see that ECW/TBW is below 0.390 (InBody Poland, 2022) The standards recommended by the manufacturer InBody USA were used to TBW [L], ICW [L], ECW [L], and ECW/TBW. The ranges of norms were established according to WHO recommendations based on ideal body weight considering the height and age of the subject.

The measurements were conducted according to a standard protocol as recommended by the device manufacturer. The participants were on an empty stomach, did not consume alcohol or caffeine at least 24 hours before the examination, the measurement was performed at a regular time, after defecation, at least 24 hours after the end of in-tensive physical activity, without shoes and socks, in underwear, with clean and dried feet and hands without applied cream and lotion. Participants had to step on the foot electrodes barefoot and maintain an evenly distributed weight on the measurement platform while holding a pair of electrodes fixed on the display unit. Then, participants extended their arms in front of the chest, maintaining a steady position until measurements were completed. There was a 99% correlation of DSM-BIA (InBody 720) with DXA in middle-aged participants (H Ling et al., 2011).

Statistical analysis. The obtained data were developed using Statistica v.13.3 (Stat Soft Polska) and R v. 4.0.0 package (2020) under the GNU GPL license (The R Foundation for Statistical Computing).

To present quantitative data we calculated mean values and standard deviations - $\bar{X} \pm S$. For qualitative data, percentage notation was used. Compliance with the normal distribution was checked using the Shapiro-Wilk test. The evaluation of the significance of differences between the means in groups due to the position on the field (goalkeeper, defender, midfielder, striker) was made using the ANOVA analysis of variance. For distributions deviating from the normal distribution, their agreement was checked for multiple groups using the Kruskal-Wallis test. For comparisons between groups, appropriate post-hoc tests were performed - Tukey's HSD test for parametric analysis and Dunn's test for non-parametric analysis. Calculations were made for the averaged measurement over the entire period (expressed as the arithmetic mean of the 6 measurements) and for the unit measurements for each moment. For comparative analysis for anthropometric measurements taken at different times, ANOVA of repeated measures or nonparametric Friedman test was performed depending on the conformity of the distributions to the normal distribution. For comparisons between groups, a post-hoc test for the Friedman test was performed. A value of $p < 0.05$ was used as a criterion for statistical significance.

Results

A total of 228 body mass composition measurements were obtained in 6 different measurements during the spring round of the PKO BP Ekstraklasa 2020/2021 season constituting the complete research material. The players were divided into groups according to their function on the field: 5 (13.2%) goalkeepers, 12 (31.6%) defenders, 15 (39.5%) midfielders, and 6 (15.8%) forwards.

Table 1. Characteristics of anthropometric measures of athletes (average values)

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Variable	Age [years] X±S	Height [cm] X±S	Weight [kg] X±S	BMI [kg/m²] X±S	
Total (n=38)	25.89±5.22 26 (21-29)	182.59±5.45 183 (177-186)	79.51±7.16 78.43 (74.17-84.48)	23.82±1.25 23.77 (22.72-24.71)	
Field position	S	25.5±5.89 24,5 (21-28)	182.5±5.32 184.5 (176-185)	79.7±7.55 80.55 (74.17-85.23)	23.96±1.25 24.37 (22.72-24.91)
		24.13±4.69 24 (20-26)	179.63±4.6 177 (176-183)	75.1±6.48 72.88 (71.08-76.07)	23.24±1.24 23.26 (22.23-23.8)
	D	27.5±4.5 28 (26.5-30)	183.88±5.11 183.5 (180.5-187.5)	83.34±5.71 82.62 (78.59-86.91)	24.63±0.85 24.63 (23.96-25.12)
		27.8±7.19 27 (26-28)	188.5±3.5 187 (186-192)	83.35±5.6 81.83 (80.15-86.07)	23.45±1.3 23.65 (22.54-24.61)
	p	0.32	0.01** M vs G**	0.01** M vs D**	0.03* M vs D*

Abbreviations: S=striker; M=midfielder, D=defender; G=goalkeeper; TBW=total body water; ICW=intracellular water; ECW= extracellular water; ECW/TBW= extracellular water index; *= $p < 0.05$; **= $p < 0.01$

Statistically significantly lower values of total body water, intracellular water, and extracellular water were found in midfielders ($p<0.01$; $p<0.05$; $p<0.05$) Information is presented in Table 2.

Table 2. Water content in players' bodies taking into account their position on the field (average values)

Variable	TBW [L] X±S	ICW [L] X±S	ECW [L] X±S	[ECW/TBW] X±S
Total (n=38)	52.17±4.24 52.53 (49.52-55.2)	33.09±2.7 33.2 (31.62-35.02)	19.01±1.62 18.88 (17.75-20.2)	0.36±0 0.37 (0.36-0.37)
Field position	S 52.26±4.65 53.18 (49.13-55.98)	33.32±3.07 33.75 (31.73-35.97)	18.89±1.59 19.31 (17.45-19.95)	0.36±0.01 0.36 (0.36-0.37)
	M 49.64±4.25 49.52 (46.33-51.42)	31.49±2.56 31.62 (29.35-32.22)	18.11±1.66 17.75 (16.92-18.93)	0.36±0 0.37 (0.36-0.37)
	D 54.39±3.04 53.25 (52.72-57.21)	34.48±2.11 33.93 (33.07-36.18)	19.78±1.32 19.32 (18.68-20.83)	0.36±0.01 0.36 (0.36-0.37)
	G 54.35±2.5 55.2 (52.78-56.28)	34.3±1.82 35.02 (33.2-35.53)	19.97±0.88 20.23 (19.55-20.7)	0.37±0 0.37 (0.37-0.37)
	0.008** M vs D*	0.01* M vs D*	0.01* M vs D*	0.43

Abbreviations: S=striker; M=midfielder; D=defender; G=goalkeeper; TBW=total body water; ICW=intracellular water; ECW= extracellular water; ECW/TBW= extracellular water index; *= $p<0.05$; **= $p<0.01$

There was no statistically significant variation in athlete hydration in measures 1-6 (Figure 1).

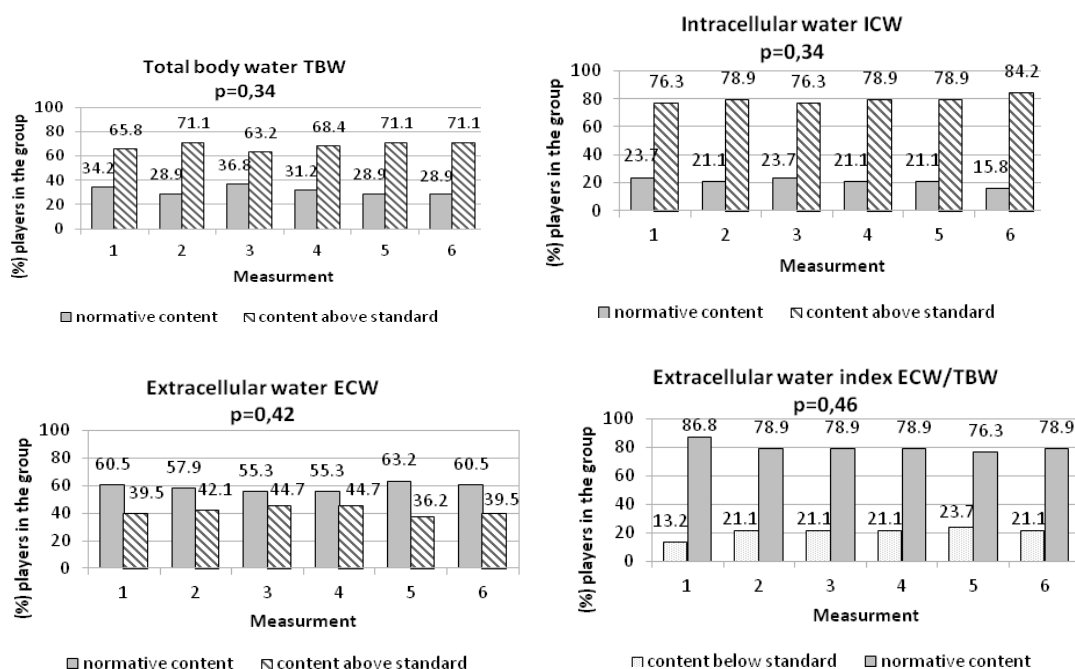


Fig. 1. Body water content of athletes including standards (measurement 1-6).

Statistically significant variations were found between measurements 1-6 in the study group. TBW content increased between 1 and 6, 5 and 6 measurements ($p<0.01$). There was an increase in ICW content between 1 and 2, 1 and 4 measurements ($p<0.0001$) and a decrease in ECW content between 2 and 5 measurements ($p<0.001$). There were statistically significant differences in water content measurements of players in different positions. Significantly lower values concerned midfielders ($p<0.05$) (Table 3).

Table 3. Characteristics of body water content in players taking into account the position on the field (measurement 1-6).

Variable	Measurement	Total N=38 X±S	p	S N=6 X±S	p	M N=15 X±S	p	D N=12 X±S	p	G N=5 X±S	p	p
TBW [L]	1	51.92±4.2	0.008** 1 vs 6* 5 vs 6*	52.22±4.64	0.1	49.53±4.21	0.28	53.95±3.35	0.37	53.84±2.15	0.3	0.03* M vs D*
	2	52.27±4.2		52.42±4.86		49.75±4.22		54.53±2.76		54.22±2.47		0.009** M vs D*
	3	52.2±4.12		52.3±4.6		49.79±4.18		54.27±2.97		54.32±2.14		0.01* M vs D*
	4	52.25±4.3		52.23±4.59		49.73±4.33		54.34±3.1		54.8±2.85		0.009** M vs D*

	5	51.92± 4.35		52.02± 4.54		49.35± 4.26		54.08±3. 39		54.34± 2.83		0.008** M vs D*
	6	52.49± 4.65		52.35± 4.77		49.69± 4.47		55.19±3. 62		54.6±2 .9		0.005 Mvs D**
ICW [L]	1	32.94± 2.67	0*** 1 vs 2*	33.28± 3.07	0.35	31.43± 2.6	0.17	34.23±2. 16	0.02* 1 vs 2*	33.96± 1.6	0.35	0.03* M vs D*
	2	33.19± 2.7	1 vs 4*	33.42± 3.19		31.6±2. 59		34.64±2. 01		34.18± 1.81		0.02* M vs D*
	3	33.14± 2.66		33.38± 3.06		31.59± 2.56		34.52±2. 08		34.24± 1.67		0.01* M vs D*
	4	33.18± 2.77		33.3±3. 07		31.52± 2.63		34.6±2.0 9		34.58± 2.05		0.01* M vs D*
	5	32.97± 2.74		33.18± 2.93		31.31± 2.57		34.38±2. 17		34.32± 2.04		0.008** M vs D*
	6	33.15± 2.77		33.37± 3.13		31.51± 2.58		34.53±2. 23		34.52± 1.93		0.01 M vs D*
	1	18.96± 1.58	0.0003*** 2 vs 5*	18.95± 1.58	0.21	18.1±1. 64	0.49	19.69±1. 32	0.33	19.8±0 .7	0.91	0.02* M vs D*
	2	19.07± 1.61		18.98± 1.7		18.16± 1.64		19.9±1.1 8		19.94± 0.89		0.008** M vs D*
	3	19.06± 1.59		18.93± 1.55		18.16± 1.63		19.8±1.2 4		20.1±0 .9		0.006** M vs D* M vs G*
	4	19.05± 1.65		18.9±1. 54		18.17± 1.71		19.8±1.3 5		20.08± 1.04		0.01* M vs D* M vs G*
	5	18.9±1. 69		18.75± 1.6		17.99± 1.74		19.69±1. 43		19.92± 0.96		0.01* M vs D*
	6	18.99± 1.71		18.85± 1.6		18.07± 1.72		19.79±1. 52		20±0.8 9		0.03* M vs D*
[ECW/ TBW]	1	0.37±0. 01	0.17	0.36±0. 01	0.9	0.37±0. 01	0.13	0.37±0.0 1	0.19	0.37±0 1	0.87	0.46
	2	0.36±0. 01		0.36±0. 01		0.36±0. 01		0.36±0.0 1		0.37±0 1		0.42
	3	0.36±0. 01		0.36±0. 01		0.36±0. 01		0.36±0.0 1		0.37±0 .01		0.58
	4	0.36±0. 01		0.36±0. 01		0.36±0 01		0.36±0.0 1		0.37±0 1		0.48
	5	0.36±0. 01		0.36±0. 01		0.36±0. 01		0.36±0.0 1		0.37±0 1		0.46
	6	0.36±0 01		0.36±0 01		0.36±0. 01		0.36±0 01		0.37±0 01		0.34

Abbreviations: S=striker; M=midfielder, D=defender; G=goalkeeper; TBW=total body water; ICW=intracellular water; ECW= extracellular water; ECW/TBW= extracellular water index; *=p<0.05; **=p<0.01; ***=p<0.001

Discussion

Performing physical loadings causes diverse morphological and functional changes in the athlete's body. The changes involve body mass composition, which includes water content (Campa et al., 2021).

The total body water content of the entire study group increased during the transition period. Intracellular water content increased during the preparation period in the whole study group and in defenders. During the preparatory period, there are a lot of training sessions that are aimed at modifying the body mass composition which results in an increase in muscle mass. Muscle mass content is closely related to ICW content. The content of extracellular water in the whole studied group increased during the competitive period, this increase was caused by an intensive period including many matches and training sessions.

The study by de Caldas Honorato et al. evaluated the body water content of professional soccer players before during and after the preparation period. TBW [L] content increased between measurements and was 53.5±8.4, 57.0±7.2, and 57.5±7.0, respectively. The intracellular water content also increased, being 31.9±5.2 L in the first measurement, 34.0±4.5 L in the next measurement, and 34.5±4.2 L in the last measurement, while the extracellular water content before the preparation period was 21.5±3.3 L, 22.9±2.9 L in the middle of the period and 23.0±2.8L at the end. The results obtained are in agreement with the authors' study (Honorato, 2022).

The study by Mascherini et al. evaluated body mass composition before and after 50 days of soccer training. The players significantly increased TBW from 47.34±5.01 L to 47.82±4.72 L. The study showed an increase in ICW from 29.02±3.33 L to 29.19±2.94 L and ECW from 18.33±2.0 L to 18.62 ± 2.0 L (Mascherini, Petri, Galanti, 2015).

Alvero Cruz et al. analyzed 53 male soccer players; the subjects underwent a 6-week training period. There was a significant increase in total body water (35.5 ± 5.2 vs. 36.7 ± 4.9 L; p < 0.001), intracellular water (14.2 ± 1.8 vs. 14.8 ± 1.6 L; p < 0.001) and extracellular water (21.5 ± 3.6 vs. 22.0 ± 3.4 L; p < 0.001) in the

body of the soccer players studied. In contrast, no changes were observed in ECW/TBW ratios (0.4 ± 0.02 vs. 0.4 ± 0.02 ; $p > 0.05$). Our results confirm the described observations (Alvero Cruz, 2017).

An increase in TBW and water distribution was observed in the elite soccer players included in the study, indicating an increase in the lean body mass compartment. Future studies should explain the physiological significance of this adaptation disorder. Further research on this issue is needed to assess its impact on physical performance.

Strengths and limitations

Strengths of the study include the fact that despite the popularity of soccer, there are still few scientific studies analyzing hydration changes over the entire training macrocycle. Typically, hydration during a specific period is assessed or single measurements are analyzed. Furthermore, in many reports, the study group consists of amateur or semi-professional soccer players whose training intensity and frequency, match demands, and daily physical activity differ from elite players. The study reported here analyzed the outcomes of professional soccer players playing in Poland's top division.

One of the limitations of the study is the size of the study group. However, it is important to highlight the fact that multiple exclusion criteria were defined and one of them was a 14-day exclusion from training related to quarantine or isolation due to COVID-19, which were common in the 2020/2021 soccer season. A limitation of the study is the lack of representativeness for other sports. Such a sample is worth considering and such a study is planned by the authors.

Conclusions

A professional soccer player should meet the physical demands and maintain the best possible performance throughout the season. Body mass composition including body water content has a significant impact on athletes' performance. The aim of this study was to evaluate the changes in body hydration of professional soccer players in all periods of the macro-cycle (preparation, starting and transition periods) taking into account the position on the field. The study was conducted between January 7, 2021 and July 23, 2021. The participants of the study were players of two soccer sports clubs belonging to PKO BP Ekstraklasa 2020/2021. 38 professional soccer players were included in the study. Body mass composition was assessed using a DSM-BIA electrical bioimpedance analyzer (InBody 770, InBody USA, California, USA). Standards recommended by the manufacturer, InBody USA, and WHO were used to determine TBW [L], ICW [L], ECW [L], and ECW/TBW. The obtained data were processed using Statistica v.13.3 software (Stat Soft Polska).

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Conflicts of interest - The authors declare no conflict of interest.

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