South African Journal for Research in Sport, Physical Education and Recreation, 2019, 41(1): 93 - 102.
Suid-Afrikaanse Joernaal vir Navorsing in Sport, Liggaamlike Opvoedkunde en Ontspanning, 2019, 41(1): 93 - 102.
ISBN: 0379-9069

ANTHROPOMETRIC PROFILE AND SERUM 25-HYDROXYVITAMIN D_3 LEVELS IN ELITE SOCCER PLAYERS

Jadwiga PIETRASZEWSKA[1], Anna BURDUKIEWICZ[1], Aleksandra ZAGRODNA[2], Aleksandra STACHOŃ[1], Justyna ANDRZEJEWSKA[1]
[1] *Department of Physical Anthropology, University School of Physical Education, Wrocław, Poland*
[2] *Department of Nutrition, University School of Physical Education, Wrocław, Poland*

ABSTRACT

The objective of the study was to investigate serum vitamin D concentration in a sample of elite soccer players and to analyse the relationship between body composition and anthropometric variables and 25(OH)D_3 status. Research data was collected by measuring 29 Polish Football Premier League players, native to Poland. Anthropometric and biochemical data were collected in December. Mean body height is similar to that of world elite soccer players. Trunk, lower, and upper extremity girths measured indicate a well-developed musculature. Body composition analysis identified a mean fat percentage of 18±3.0%. A high prevalence of vitamin D deficiency was observed in the sample. Mean serum 25(OH)D_3 concentration for the group was 18.3±4.4ng/mL. Significant positive correlations between 25(OH)D_3 and anthropometric variables characterising body musculature and skeletal size may show the indirect impact of vitamin D on the development and function of these respective systems.

Keywords: Soccer players; Anthropometry; Body composition; Vitamin D.

INTRODUCTION

Vitamin D is primarily synthesised in the skin under the influence of solar ultraviolet-B (UVB) radiation. It is an essential factor in normal calcium and phosphorus homeostasis, making it crucial in the maintenance of skeletal and extraskeletal health, the latter of which includes neuromuscular function (Ceglia, 2008; Cannell *et al*., 2009; Hamilton, 2011). Optimal vitamin D concentration also plays a significant and versatile role over a broad spectrum of organ function. Wortsman *et al*. (2000) and Botella-Carretero *et al*. (2007) describe an inverse correlation between the bioavailability of vitamin D and obesity, particularly in individuals with excess visceral fat. As a fat-soluble nutrient, vitamin D is primarily stored in adipose tissue.

It has been hypothesised that subcutaneous fat compartments sequester vitamin D and suppress its conversion into 25-hydroxyvitamin D_3 or 25(OH)D_3, an important hormone precursor, as well as a clinical indicator of vitamin D status (Wortsman *et al*., 2000). This has been hypothesised to be one of the causes of reduced serum 25(OH)D_3 concentrations in obese individuals when compared with healthy controls (Alemzadeh *et al*., 2008; McKinney *et al*., 2008; Caron-Jobin et *al*., 2011). Another important consideration is that 25(OH)D_3 is derived in the liver by the hydroxylation of vitamin D_3 (cholecalciferol). The skin is the major natural source of the vitamin, remaining vitamin D (D_2 and D_3) is ingested as a result of diet. As few foods contain vitamin D, its insufficiency is largely due to reduced dermal synthesis whereby a lack of solar UVB exposure is the root cause.

The majority of studies presenting vitamin D reference levels have involved non-athletes and untrained individuals. For this reason, the normal ranges reported in the literature may not translate to athletes of different disciplines. Furthermore, a high prevalence of vitamin D insufficiency has been reported in athletes. This is despite the fact that this population presents low body fat as a result of a high physical activity level and that many sporting disciplines are executed or practised outdoors.

Pollock *et al.* (2012) demonstrated significant insufficiencies of this vitamin in track and field athletes. According to the authors, the vitamin D insufficiencies in athletes are due to many factors, including most notably, gender, latitude, skin colour or the use of creams with a UV filter. Willis *et al.* (2012) confirm insufficiencies of this vitamin among runners, while also indicating a deterioration of the immune system functions in athletes and physically active persons as a result of this condition.

Constantini *et al.* (2010) demonstrated that athletes practising indoor-type sports had nearly twice the rate of vitamin D insufficiency compared to those practising outdoor sports, who could be more exposed to sunlight. On the other hand, Hamilton *et al.* (2010), who examined athletes from the Middle East, do not confirm the impact of these factors on vitamin D insufficiencies. Cross-sectional studies of footballers indicate latitude-dependent, population diversification of vitamin D levels (Hamilton *et al.*, 2014) and seasonal changes (Morton *et al.*, 2012).

This issue is of particular relevance to athletes as the bioactive metabolites of vitamin D affect skeletal mass, immunity, physical performance and muscle function to a significant degree (Larson-Meyer & Willis, 2010). The discovery of the vitamin D receptor (VDR) in human skeletal muscle cells has also identified the broad roles of vitamin D in the synthesis and function of a number of muscle proteins and highlighted its role in athletic performance (Hamilton, 2010).

PURPOSE OF STUDY

In light of the above considerations, the objective of the present study was to investigate serum $25(OH)D_3$ concentration in a sample of elite soccer players and analyse the relationship between body composition and anthropometric variables and $25(OH)D_3$ status. The additional goal of the study was to present detailed anthropometric characteristics of Polish players in comparison to other football teams in the context of motor activities of footballers.

METHODOLOGY

Ethical approval

The ethical approval for the project was obtained from the Ethical Committee at the University School of Physical Education in Wrocław (Ethical clearance 23.10.12). Their ethical guidelines were followed throughout the study. Participants provided oral and written informed consent prior to testing. The study was carried out within the framework of scientific projects number 69/0203/S/2016 and was financed by the University.

Participants

The study enrolled 29 Polish Football Premier League players native to Poland (latitude 52°; skin synthesis takes place from April to September). The study group was characterised by the following mean parameters of age, 25.6±5.8 years and training experience, 13.5±4.9 years.

Measurements

Anthropometric and biochemical data were collected in December. Measurements were made according to International Standards for Anthropometric Assessment (ISAK) (Norton & Olds 2002). They were supplemented by a few measurements. Considered for measurement were: body height (B-v), sitting height (B-vs), lower extremity length (B-sy), arm span (da3-da3), bi-acromial diameter (a-a), chest diameter (thl-thl), chest depth (xi-ths), bi-iliocristal diameter (ic-ic), shoulder diameter on the deltoid muscles (dl-dl), humerus breadth (cl-cm), femur breadth (epl-epm), shoulder girth, chest girth, waist girth, hip girth, thigh girth, calf girth, and relaxed and flexed biceps girth.

These measures were used to calculate the following anthropometric indexes: lower extremity length (B-sy/B-v), sitting height (B-vs/B-v), bi-acromial diameter (a-a/B-v), bi-iliocristal diameter (ic-ic/B-v), Marty's index (chest girth/B-v), Škerlij's index (thigh girth/B-v), BMI and trunk girth index (chest girth/hip girth). The derived body proportions were classified according to reference values published by Norton and Olds (2002) and Malinowski and Bożiłow (1997).

Skinfold thicknesses at the subscapular, abdominal, supra-iliac, triceps and medial calf sites were also obtained. Body composition was assessed by bioelectrical impedance analysis (BIA) using a BIA-101 Anniversary Sport Edition and the pre-packaged Bodygram 1.3.1 software (Akern, Italy) to discern fat mass (FM), fat-free mass (FFM), and muscle mass (MM).

BIA method has been studied by many scientists and the results of those studies indicate a high consistency of this method with the DXA method, which is regarded as one of the most accurate methods for measuring body composition (Leahy *et al*., 2012).

Somatotype was also classified according to Sheldon's method of somatotype as modified by Heath and Carter. Blood sampling was carried out at 8.00 am after a 12-hour fast and a 24-hour period without training. After blood collection, all blood samples were centrifuged for 10 minutes at 3500 rpm. Serum samples were stored frozen at -70ºC until the analysis. The analysis was performed in a certified laboratory. Serum 25(OH)D_3 levels were measured by electro-chemiluminescence immunoassay using an ECLIA Elecsys analyser (Roche, Switzerland). Intra- and inter-assay coefficients of variation (CV) were 5.6% and 8.0% for 25(OH)D_3, respectively, and limit detection was 4ng/mL (10nmol/l).

Procedure

The athletes were examined in the morning, in a fasted state and, for at least 12 hours prior to the tests, had not engaged in any activities that might disturb the fluid balance in the body (e.g. training), had not consumed alcohol for 48 hours prior to the tests and had not taken any diuretics.

Statistical analysis

Statistical analyses were performed using Statistica 12.0 (StatSoft, USA). Data were expressed as mean±standard deviation (SD). Spearman's Rank Correlation coefficients were calculated to assess the relationship between the anthropometric variables and serum 25(OH)D_3 level.

RESULTS

Table 1 presents the statistical characteristics of anthropometric variables. The sample presented a normal height-to-weight ratio as evidenced by a BMI.

***Table 1*. ANTHROPOMETRIC CHARACTERISTICS OF EXAMINED SOCCER PLAYERS**

Variables	Mean±SD	Variables	Mean±SD
Body mass (kg)	76.7±8.0	cl-cm (cm)	7.1±0.4
B-v (cm)	183.0±6.0	epl-epm (cm)	10.1±0.5
B-sy (cm)	95.7±3.8	shoulder girth (cm)	116.3±5.7
B-v_s (cm)	95.8±3.1	chest girth (cm)	86.7±4.3
da3-da3 (cm)	184.3±6.4	waist girth (cm)	78.3±5.2
a-a (cm)	42.1±2.1	arm relaxed girth (cm)	29.8±2.6
dl-dl (cm)	46.6±2.3	arm flexed girth (cm)	32.9±2.4
thl-thl (cm)	28.8±1.4	hip girth (cm)	98.1±4.1
xi-ths (cm)	20.2±1.5	thigh girth (cm)	57.9±3.3
ic-ic (cm)	28.5±1.7	Calf girth (cm)	37.4±2.1

(B-v)=body height (B-sy)=lower extremity length (B-vs)=sitting height
(da3-da3)=arm span (a-a)= bi-acromial diameter (dl-dl)=diameter deltoid muscle
(thl-thl)=chest diameter (xi-ths)=chest depth (ic-ic)= bi-iliocristal diameter
(cl-cm)=humerus breadth (epl-epm)=femur breath

As shown in Table 2, the calculated anthropometric indexes indicated an average lower extremity length (B-sy/B-v) and torso in relation to body height (B-vs/B-v). The remaining indexes characterised the sample with average shoulder width (a-a/B-v), narrow hips (ic-ic/B-v), and large thighs (thigh girth/B-v). Trunk girth index (chest girth/hip girth), as a measure of overall body proportion, finds the sample at the extreme end of the male scale and approaching female values. Skinfold thicknesses did not exceed 10mm at any of the measurement sites and indicated evenly distributed subcutaneous fat on the trunk and extremities.

***Table 2*. RESULTS OF ANTHROPOMETRIC INDEXES**

Indexes	Mean±SD	Indexes	Mean±SD
(B-sy/B-v)*100	52.3±1.2	Škerlij's index	31.7±1.7
(B-v_s/B-v)*100	52.4±1.0	Marty's index	47.4±2.4
(a-a/B-v)*100	23.0±1.0	(chest girth/hip girth)*100	88.4±3.4
(ic-ic/B-v)*100	15.6±0.8	BMI	23.0±1.5

Fat percentage revealed that fat constituted a large component of total body mass (Table3). Average somatotype for the participants indicates an endomorphic mesomorph.

Table 3. **BODY COMPOSITION, SKINFOLD THICKNESS MEASUREMENTS AND BODY BUILD COMPONENTS**

Variables	Mean±SD	Variables	Mean±SD
FFM [kg]	62.7±5.9	Triceps skinfold [mm]	4.2±0.9
FFM [%]	81.8±3.0	Supra-iliac skinfold [mm]	7.1±1.9
FM [kg]	14.0±3.1	Abdominal skinfold [mm]	7.0±2.3
FM [%]	18.2±3.0	Calf skinfold [mm]	3.8±0.8
MM [kg]	45.5±4.8	Endomorphy	1.6±0.3
MM [%]	59.4±3.1	Mesomorphy	4.7±1.0
Subscapular skinfold [mm]	8.1±1.1	Ectomorphy	2.9±0.7

(FM)=fat mass (FFM)=fat-free mass (MM)=muscle mass

A high prevalence of vitamin D deficiency was observed in the sample. Mean serum 25(OH)D3 concentration for the group was 18.3±4.4ng/mL. None of the participants met the cut-off for normal values (>30ng/mL), twenty footballers had a deficit of vitamin D (<20ng/mL), whereas nine participants exhibited vitamin D insufficiency (20–30 ng/mL).

Large variation was found in the associations between 25(OH)D_3 levels and the anthropometric variables (Table 4). Significantly high correlations were observed between 25(OH)D_3 and body height, trunk girths, extremity girths, total body mass, fat-free mass and muscle mass. No statistically significant correlations were found between 25(OH)D_3 levels and skinfold thickness.

Table 4. **SPEARMAN'S RANK CORRELATION COEFFICIENT FOR ANTHROPOMETRIC VARIABLES AND SERUM 25(OH)D_3 LEVEL**

Variables	Spearman's coefficients	Variables	Spearman's coefficients	Variables	Spearman's coefficients
B-v	0.42*	epl-epm	0.32	FM	0.23
B-sy	0.19	Shoulder girth	0.33	Triceps skinfold	-0.02
B-v_s	0.40*	Chest girth	0.42*	Subscapular skinfold	0.16
da3-da3	0.12	Waist girth	0.44*	Supra-iliac skinfold	0.10
a-a	0.08	Arm girth	0.22	Abdominal skinfold	0.15
dl-dl	0.28	Hip girth	0.37*	Calf skinfold	-0.28
thl-thl	0.09	Thigh girth	0.36	Endomorphy	-0.00
xi-ths	0.67*	Calf girth	0.28	Mesomorphy	0.08
ic-ic	0.06	FFM	0.45*	Ectomorphy	-0.06
cl-cm	0.18	MM	0.39*	Body mass	0.47*

*Statistically significant correlations (p≤0.05)

DISCUSSION

The anthropometric characteristics of the sample are representative of soccer players (Reilly & Doran, 2003; Gil *et al*., 2010; Hazir, 2010). Mean body height (183±6cm) is similar to that of world elite soccer players and exceeds the population mean for Polish males (178.5±6.6cm) (Kułaga *et al*., 2010). Norton and Olds (2002) determined that the mean body height of soccer players (178.6±6.4cm) is very similar to the general population and that soccer players share similar within-group differences with the untrained population. This explains the significant overlap observed in the distribution of body height in both groups. Reilly and Doran (2003) provided a summary of mean body height among worldwide professional and elite soccer teams. Depending on the playing level and nationality, senior-level players ranged from 173.4±0.6cm (Hong Kong) to 181.1±4.8cm (Norway). Hazir (2010) presented a slightly wider range for the mean body height of soccer players, from 173.4±4.6 to 182.8±6.0 cm. The BMI of the current sample is also similar to the values reported by the above authors.

When considering body girths, the measured trunk, lower and upper extremity girths indicate a well-developed musculature. The recorded values are also congruent to the datasets reported by researchers on other soccer teams (Matković *et al*., 2003; Gil *et al*., 2010; Hazir, 2010). One item of interest in the present sample is the high Škerlij's index, indicating sizable thighs in relation to body height. This may suggest strongly developed lower extremity muscles and the ability to generate significant power. In addition, this muscle group is an important functional determinant of soccer-related skills, such as jumping, kicking and quick change of pace or direction.

The lower extremities, in connection with a well-developed trunk, are also a major contributing factor to maintaining balance on the field, as well as improved ball handling (Reilly & Doran, 2003). A well-developed upper body in itself plays a significant role in numerous soccer skills (for example running). Arm and trunk musculature act to maintain balance and counterbalance the rotation of the body when the pelvis rotates (Howe & Hanchard, 2003). In turn, the gluteal muscles are important during abduction and rotating movements at the hip joints and also when extending the hips (Howe & Hanchard, 2003).

Analysis of the remaining body proportions showed a number of similarities with the values provided in the literature (Norton & Olds, 2002). It has been suggested that a moderately-sized trunk and lower extremities in relation to body height, benefit performance in a variety of motor tasks. Howe and Hanchard (2003) believe that the proper development of individual body segments may aid body positioning during soccer actions involving the ball. Body composition analysis identified a mean fat percentage of 18±3.0%.

While the physical demands of soccer are known to be predominantly met by the aerobic energy system (Kemi *et al*., 2003; Stolen *et al*., 2005; Popovic *et al*., 2013), an optimal amount of body fat is undoubtedly necessary to maintain performance in the endurance efforts typical of soccer. This may explain the slightly higher fat content exhibited by soccer players compared with athletes involved in sports with a large anaerobic component. The somatotype characteristics of the present sample are also in line with those reported in the literature, in which numerous authors have confirmed a large mesomorph component in soccer players, although certain variation is present dependent on playing position (Gil *et al*., 2007; Gil *et al*., 2010; Hazir, 2010).

According to published reference values of serum 25(OH)D_3 levels (Holick, 2007), our participants can be classified as having vitamin D deficiency. Congruent to our findings, Hamilton *et al*. (2014) analysed soccer players from 12 clubs playing in the Qatar premier Stars

League football division to find $25(OH)D_3$ concentrations below 30ng/mL, although this was influenced by the player's country of origin. Morton *et al*. (2012) also reported insufficient $25(OH)D_3$ in English Premier League players albeit in winter, with increased levels found during summer months. Similar fluctuations were described by Kopeć *et al*. (2013) in Polish soccer players. This is naturally the effect of seasonal changes resulting in modulated exposure to UVB radiation, making vitamin D synthesis subject to various external factors that include latitude, time of day, skin colour and choice of clothing.

The players in this study originate from a geographical location where maximal vitamin D synthesis occurs from April to September between 10:00 and 15:00 in which 18% of the skin is exposed (forearms and lower extremities) and without the use of sunscreen (Charzewska *et al*., 2010; Krzyścin *et al*., 2011). Upon finding low $25(OH)D_3$ levels in a large sample of track and field athletes, Pollock *et al*., (2012) concluded that vitamin D deficiency may directly affect athletic performance via increased susceptibility to bone fractures and perturbed physiological response in muscle function, immunity and post-exercise inflammation. There is also evidence that insufficient vitamin D levels may affect motor performance, such as in a study on 99 post-menarche young females that presented a positive relationship between serum $25(OH)D_3$ level and jump height, running speed and muscle power (Ward *et al*., 2009).

As previously noted, the literature shows numerous works on the relationship between vitamin D levels and body composition, particularly body fat content, although based on untrained populations. This may confound findings on athletes, as this group presents generally low levels of fat regardless of certain intra- and inter-group differences (due to the specificity of the sport). Hence the search for existing relationships between vitamin D level with other anthropometrical variables, may show significant promise in this regard. Research on this subject has indicated that low $25(OH)D_3$ is related to both reduced total body mass and fat-free mass in soccer players (Hamilton *et al*., 2014). However, this group showed no association of $25(OH)D_3$ level with body height, BMI or fat mass.

While the relationship between vitamin D and fat mass was unsubstantiated in the present study, the findings showed significant correlations with body height, trunk girths, extremity girths, total body mass and muscle mass. These results lead to the suggestion that high vitamin D status is associated with increased muscle mass and skeletal solidity in soccer players. This seems understandable due to the role of vitamin D in regulating the synthesis and function of muscle proteins (Hamilton, 2010). This is, obviously, not the only factor that determines the structure and metabolism of muscles and bones. However, the pleiotropic effect of this vitamin should also be taken into account in the context of preventing sport injuries and muscle regeneration.

CONCLUSIONS AND PRACTICAL APPLICATION

Despite the small size of the group, significant positive correlations were recorded between $25(OH)D_3$ and the anthropometric variables characterising body musculature and skeletal size. It may show the indirect impact of vitamin D on the development and function of these respective systems. In view of the differential response of dermal vitamin D synthesis to numerous independent variables, the continuous monitoring of $25(OH)D_3$ appears to be justified particularly given the negative health consequences of vitamin D deficiency. Such monitoring could suggest individual modification in diet and vitamin D supplementation depending on the season and exposure to sunlight.

A diagnosis of vitamin D insufficiencies in footballers' bodies should prompt coaches to arrange for winter training camps in countries located at lower latitudes to achieve the targeted concentration of 25(OH)D_3 in the blood serum, which should contribute to the improvement of athletes' effort capacities.

Acknowledgement

This work was supported under the Scientific Project of the University School of Physical Education in Wrocław.

REFERENCES

ALEMZADEH, R.; KICHLER, J.; BABAR, G. & CALHOUN, M. (2008). Hypovitaminosis D in obese children and adolescents: Relationship with adiposity, insulin sensitivity, ethnicity, and season. *Metabolism*, 57(2): 183-191.

BOTELLA-CARRETERO, J.I.; ALVAREZ-BLASCO, F.; VILLAFRUELA, J.J.; BALSA, J.A.; VÁZQUEZ, C. & ESCOBAR-MORREALE, H.F. (2007). Vitamin D deficiency is associated with the metabolic syndrome in morbid obesity. *Clinical Nutrition*, 26(5): 573-580.

CANNELL, J.J.; HOLLIS, B.W.; SORENSON, M.B.; TAFT, T.N. & ANDERSON, J.B. (2009). Athletic performance and vitamin D. *Medicine and Science in Sports and Exercise*, 41(5): 1102-1110.

CARON-JOBIN, M.; MORISSET, A.S.; TREMBLAY, A.; HUOT, C.; LÉGARÉ, D. & TCHERNOF, A. (2011). Elevated serum 25(OH)D concentrations, vitamin D, and calcium intakes are associated with reduced adipocyte size in women. *Obesity*, 19(7): 1335-1341.

CEGLIA, L. (2008). Vitamin D and skeletal muscle tissue and function. *Molecular Aspects of Medicine*, 29(6): 407-414.

CHARZEWSKA, J.; CHLEBNA-SOKÓŁ, D.; CHYBICKA, A.; CZECH-KOWALSKA, J.; DOBRZAŃSKA, A.; HELWICH, E.; IMIELA, J.R.; KARCZMAREWICZ, E.; KSIAZYK, J.B.; LEWIŃSKI, A.; LORENC, R.S.; LUKAS, W.; ŁUKASZKIEWICZ, J.; MARCINOWSKA-SUCHOWIERSKA, E.; MILANOWSKI, A.; MILEWICZ, A.; PŁUDOWSKI, P.; PRONICKA, E.; RADOWICKI, S.; RYZKO, J.; SOCHA, J.; SZCZAPA, J. & WEKER, H. (2010). Prophylaxis of vitamin D deficiency: Polish Recommendations 2009. *Polish Journal of Endocrinology*, 61(2): 228-232.

CONSTANTINI, N.W.; ARIELI, R.; CHODICK, G. & DUBNOV-RAZ, G. (2010). High prevalence of vitamin D insufficiency in athletes and dancers. *Clinical Journal of Sport Medicine*, 20(5): 368-371.

GIL, S.M.; GIL, J.; RUIZ, F.; IRAZUSTA, A. & IRAZUSTA, J. (2007). Physiological and anthropometric characteristics of young soccer players according to their playing position: Relevance for the selection process. *Journal of Strength and Conditioning Research*, 21(2): 438-445.

GIL, S.M.; GIL, J.; RUIZ, F.; IRAZUSTA, A.; & IRAZUSTA, J. (2010). Anthropometrical characteristics and somatotype of young soccer players and their comparison with general population. *Biology of Sport*, 27(1): 17-24.

HAMILTON, B. (2010). Vitamin D and human skeletal muscle. *Scandinavian Journal of Medicine and Science in Sports*, 20(2): 182-190.

HAMILTON, B. (2011). Vitamin D and athletic performance: The potential role of muscle. *Asian Journal of Sports Medicine*, 2(4): 211-219.

HAMILTON, B.; GRANTHAM, J.; RACINAIS, S. & CHALABI, H. (2010). Vitamin D deficiency is endemic in Middle Eastern sportsmen. *Public Health Nutrition*, 13(10): 1528-1534.

HAMILTON, B.; WHITELEY, R.; FAROOQ, A. & CHALABI, H. (2014). Vitamin D concentration in 342 professional football players and association with lower limb isokinetic function. *Journal of Science and Medicine in Sport*, 17(1): 139-143.

HAZIR, T. (2010). Physical characteristics and somatotype of soccer players according to playing level and position. *Journal of Human Kinetics*, 26(October): 83-95.

HOLICK, M.F. (2007). Vitamin D deficiency. *New England Journal of Medicine,* 357(3): 266-281.

HOWE, T. & HANCHARD, N. (2003). Functional anatomy. In T. Reilly & A.M. Williams (Eds.), *Science and soccer* (Part 1: Biology and soccer, pp. 9-20). London and New York: Routledge, Taylor & Francis Group.

KEMI, O.J.; HOFF, J.; ENGEN, L.C. & WISLOFF, U. (2003). Soccer specific testing of maximal oxygen uptake. *Journal of Sports Medicine and Physical Fitness,* 43(2): 139-144.

KRZYŚCIN, J.W.; JAROSŁAWSKI, J. & SOBOLEWSKI, P.S. (2011). A mathematical model for seasonal variability of vitamin D due to solar radiation. *Journal of Photochemistry and Photobiology B: Biology*, 105(1): 106-112.

KULAGA, Z.; LITWIN, M.; TKACZYK, M.; RÓŻDŻYŃSKA, A.; BARWICKA, K.; GRAJDA, A.; ŚWIĄDER, A.; GURZKOWSKA, B.; NAPIERALSKA, E. & PAN, H. (2010). The height-, weight-, and BMI-for-age of Polish school-aged children and adolescents relative to international and local growth references. *BioMed Central Public Health,* 10(March):109. Doi:10.1186/1471-2458-10-109.

LARSON-MEYER, D.E. & WILLIS, K.S. (2010). Vitamin D and athletes. *Current Sports Medicine Reports,* 9(4): 220-226.

LEAHY S.; O'NEILL C.; SOHUN R. & JAKEMAN P. (2012). A comparison of dual energy X-ray absorptiometry and bioelectrical impedance analysis to measure total and segmental body composition in healthy young adults. *European Journal of Applied Physiology,*112(2): 589-595.

MALINOWSKI, A. & BOŻIŁOW, W. (1997). *Basics of anthropometry: Methods, techniques, standards* [in Polish]. Warszawa-Łódź, Poland: PWN.

MATKOVIĆ, B.R.; MIŠGOJ-DURAKOVIĆ, M.; MATKOVIĆ, B.; JANKOVIĆ, S.; RUŽIĆ, L.; LEKO, G. & KONDRIČ M. (2003). Morphological differences of elite Croatian soccer players according to the team position. *Collegium Antropologicum,* 27(Suppl.1): 167-174.

MCKINNEY, K.; BREITKOPF, C.R. & BERENSON, A.B. (2008). Association of race, body fat and season with vitamin D status among young women: A cross-sectional study. *Clinical Endocrinology*, 69(4): 535-541.

MORTON, J.; IQBAL, Z.; DRUST, B.; BURGESS, D.; CLOSE, G.L. & BRUKNER, P.D. (2012). Seasonal variation in Vitamin D status in professional soccer players of the English Premier League. *Applied Physiology Nutrition and Metabolism,* 37(4): 798-802. doi: 10.1139/h2012-037.

NORTON, K. & OLDS T. (2002). *Anthropometrica*. Sydney, Australia: UNSW Press.

POLLOCK, N.; DIJKSTRA, P.; CHAKRAVERTY, R. & HAMILTON, B. (2012). Low 25(OH) vitamin D concentrations in international UK track and field athletes. *South African Journal of Sports Medicine,* 24(2): 55-59.

POPOVIC, S.; AKPINAR, S.; JAKSIC, D.; MATIC, R. & BJELICA, D. (2013). Comparative study of anthropometric measurement and body composition between elite soccer and basketball players. *International Journal of Morphology,* 31(2): 461-467.

REILLY, T. & DORAN, D. (2003). Fitness assessment. In T. Reilly & A.M. Williams (Eds.), *Science and soccer* (Part 1: Biology and soccer, pp. 21-46). London and New York: Routledge, Taylor & Francis Group.

STOLEN, T.; CHAMARI, K.; CASTAGNA, C. & WISLOFF, U. (2005). Physiology of soccer: An update. *Sports Medicine,* 35(6): 501-536.

WARD, K.; DAS, G.; BERRY, J.; ROBERTS, S.; RAWER, R.; ADAMS, .J & MUGHAL, Z. (2009). Vitamin D status and muscle function in postmenarchal adolescent girls. *Journal of Clinical Endocrinology and Metabolism*, 94(2): 559-563.

WILLIS, K.S.; SMITH, D.T.; BROUGHTON, K.S. & LARSON-MEYER, D.E. (2012). Vitamin D status and biomarkers of inflammation in runners. *Open Access Journal of Sports Medicine*, 3(April): 35-42.

WORTSMAN, J.; MATSUOKA, L.Y.; CHEN, T.C.; LU, Z. & HOLICK, M.F. (2000). Decreased bioavailability of vitamin D in obesity. *American Journal of Clinical Nutrition*, 72(3): 690-693.

Corresponding author: Dr. Jadwiga Pietraszewska; **Email:** jadwiga.pietraszewska@awf.wroc.pl.

(*Subject editor: Prof. Hanlie Moss*)