apunts EDUCACIÓN FÍSICA Y DEPORTES

ISSUE 149

Published July 1, 2022
https://doi.org/10.5672/apunts.2014-0983.es.(2022/3).149.05

SPORTS TRAINING

OPEN ACCESS

Comparing Body Composition in Young Footballers Categorised by Bio-Banding

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Cite this article

Segueida-Lorca, A., Barrera, J., Valenzuela-Contreras, L., & Herrera-Valenzuela, T., (2022). Comparing Body Composition in Young Footballers Categorized by Bio-Banding. *Apunts Educación Física y Deportes, 149*, 45-52. https://doi.org/10.5672/apunts.2014-0983.es.(2022/3).149.05

Edited by:
© Generalitat de Catalunya Departament de la Presidència Institut Nacional d'Educació Física de Catalunya (INEFC)

ISSN: 2014-0983

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Section:
Sports training

Original language:
Spanish

Received:
September 5, 2021

Accepted:
February 28, 2022

Published:
July 1, 2022

Front cover:
Sports practice in childhood favours the growth and emotional health of children.
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Abstract

Bio-Banding (BB) is a new way of categorising young athletes that considers the variation in maturity stage. To date, differences in body composition as an aspect of performance have not been investigated in young footballers categorised by BB. Therefore, the aim of the present study was to describe and compare the body composition of young football players between BB categories. One hundred and twenty-eight young male players (age: 14.88 ± 1.76 years) from a professional football club in Chile participated in this study. Body composition was assessed with anthropometry and compared with ANOVA and Kruskal-Wallis tests. Significant differences were found between BB categories in body mass (p < .0001); height (p < .0001); muscle mass (p < .0001); bone mass (p < .0001); adipose tissue mass (p < .0001); skeletal muscle mass index (p < .0001) and the sum of 6 skinfolds (p = .0172). The findings of the present study reveal that the process of growth and maturity can be seen in: (i) the greatest increase in height and body mass, (ii) the increase in muscle mass and bone mass, (iii) the smallest increase in adipose tissue mass and SMI, and to a lesser extent, (iv) the evolution of the sum of 6 skinfolds. As a projection of the research, these results can be applied by clubs and coaches as baseline for changes in body size and composition, in order to include BB in the processes of identification, selection and development of talented young athletes.

Keywords: anthropometry, Bio-Band, maturity, youth sport.

Introduction

Football is a discipline that has been extensively studied with the aim of improving player performance, which depends on technical, tactical, physical, physiological, mental (Stølen et al., 2005) and anthropometric factors (Rodríguez et al., 2019), as well as identification and development processes of young footballers (Sarmento et al., 2018).

In the training and development processes of young footballers, the following factors have been considered: physical condition, for example, plyometrics and changes of direction (Beato et al., 2018; Michailidis et al., 2019), speed (Murtagh et al., 2018), psychological (Olmedilla et al., 2019; Scharfen et al., 2019), technical (Rowat et al., 2017), tactical (Machado et al., 2020; Machado et al., 2019), and anthropometric aspects (Lago et al., 2011; Bernal et al., 2020), such as body size (Malina et al., 2017); even chronological age (CA) has been used as an organisational parameter to assess performance in young players (Barrera et al., 2021). However, when organising youth sport categories based on CA or yearly age groupings, a phenomenon of individual differences in the maturation *timing* and *tempo* of those players can be seen when categorised by CA within the same annual cut-off point, and especially those players around the pubertal stages of development, where growth and maturation can significantly affect changes in performance (Lloyd et al., 2014). One example can be the Relative Age Effect (RAE) phenomenon, characterised by a significant overrepresentation of players born early in their year of birth among young athletes (Brustio et al., 2018), which suggests that being relatively older within an annual sporting cut can provide significant achievement advantages compared to those relatively younger (Cobley et al., 2009).

In order to try to correct the above, several ways of obtaining a biological age indicator have been suggested. Such as: the *skeletal age,* assessed mainly with radiographs and which refers to the degree of biological maturation according to the development of skeletal tissue (Lloyd et al., 2014), the *sexual maturity,* which refers to the development of secondary sexual characteristics and maturation of the reproductive system (Lloyd & Oliver, 2020), and the *somatic age,* which refers to the degree of growth in overall height or specific body dimensions (Lloyd et al., 2014), one of the most common indicators of which is the prediction of the age of *Peak Height Velocity* - PHV (Malina et al., 2004) along with the use of percentages and predictions of adult height (Lloyd et al., 2014).

In order to use some method of biological categorisation for youth sports, Rogol et al. (2018) presented an alternative method that relates the percentages of height reached at a time of observation to an estimate of adult height in the creation of biological bands. This method, known as Bio-Banding (BB), has been used as a non-invasive indicator of biological maturity. BB has already been applied to young footballers, associated with physical and technical factors (Abbott et al., 2019), perceptions in competition (Bradley et al., 2019), participation experiences (Cumming et al., 2017a) and technical and tactical factors (Romann et al., 2020). However, no record of studies associating this new biological categorisation indicator with another performance factor in youth football such as anthropometry, specifically body composition, exists. Therefore, this research sought to address this aspect and, consequently, its objectives were to describe and compare the body composition of young male footballers between BB categories.

Methodology

Participants

128 male youth football players participated in this study, belonging to a professional football club from the first division in Chile, divided in the following categories: U-12; U-13; U-14; U-15; U-16; U-17 and U-19 (table 1). Players had an average of 5.00 ± 2.16 years of experience and trained 5 times a week. All players signed an informed consent form before starting the study and none of them had any objections during data collection.

Table 1
Descriptive characteristics according to CA.

	U-12 (*N*=20)	U-13 (*N*=10)	U-14 (*N*=26)	U-15 (*N*=18)	U-16 (*N*=22)	U-17 (*N*=18)	U-19 (*N*=14)
Age (years)	12.21 ± 0.26	13.11 ± 0.28	14.23 ± 0.25	14.70 ± 0.29	15.67 ± 0.32	16.73 ± 0.31	17.82 ± 0.24
Body mass (kg)	44.37 ± 7.07	49.33 ± 7.70	57.35 ± 8.47	62.32 ± 9.10	64.92 ± 8.86	66.70 ± 7.58	68.31 ± 7.49
Size (cm)	150.82 ± 7.60	161.34 ± 8.48	164.22 ± 9.55	168.38 ± 6.02	173.04 ± 5.40	172.30 ± 5.05	173.30 ± 4.80

Data presented as Means ± SD

Material

Each participant was assessed for body mass and height using a Detecto (USA) model 2391 scale with a height measuring rod included. It has a capacity of 180 kg and an accuracy of 0.1 kg, and 200 cm with an accuracy of 0.1 cm. Seated height was assessed with the same measuring rod and a wooden bench with dimensions of 30 cm x 40 cm x 50 cm. Body perimeters were measured using a Lufkin anthropometric tape (Executive, W606PM, USA) with a measuring range up to 200 cm and accurate to 0.1 cm. Skinfolds were assessed with a Harpenden skinfold caliper (Baty International, RH15 9LR, England) with a measuring range of 80 mm and an accuracy of 0.2 mm. And Campbell 10 and Campbell 20 bone calipers, with a measuring range of 19 cm and 60 cm, respectively, with an accuracy of 0.1 cm each (Rosscraft. SRL. Argentina), were used for the measurement of small and large body diameters.

Procedure

The anthropometric assessments were carried out during preseason week in the hours before the respective training sessions of each youth football category. This assessment followed the standards established by *The International Society for the Advancement of Kinanthropometry* (ISAK) (Esparza et al., 2019) and was conducted by a single Level 3 ISAK anthropometrist. From the above standards, three basic measures were assessed: body mass, height and sitting height; six skinfolds: triceps, subscapular, supraspinal, abdominal, thigh and leg; six bone diameters: biacromial, transverse thoracic, anteroposterior thoracic, biliocristal, humerus and femur; seven perimeters: head, relaxed arm, forearm, thorax, waist, upper thigh and leg. With these measurements, body composition was determined using the 5-component fractionation model (Ross & Kerr, 1991) which considers the following tissue types; muscle, adipose, bone, residual and skin expressed both as an absolute (kg) and as a relative (%) value. Similarly, the sum of 6 skinfolds (triceps, subscapular, supraspinal, abdominal, thigh and leg) expressed in mm and the skeletal muscle mass index (SMI) were calculated. The *Peak Height Velocity* (PHV) was estimated to occur at a certain age using the regression equation presented by Mirwald et al. (2002) and adult height was predicted using the model of Sherar et al. (2005). Once the prediction of adult height with its respective actual percentage was established, the study participants were divided into four BB categories (Rogol et al., 2018): < 85.0% (BB1); 85.0 - 89.9% (BB2); 90.0 - 94.4% (BB3) and ≥ 95.0% (BB4) each representing, respectively, prepubertal stage, early puberty, average puberty and late puberty (Cumming et al., 2017b).

Statistical analysis

The following variables were analysed among the BB categories: age (years), body mass (kg), height (cm), muscle mass (kg), adipose tissue mass (kg), bone mass (kg), SMI and sum of 6 skinfolds (mm), and the mean ± standard deviation, 95% confidence interval and medians with 25th and 75th percentile values were presented.

Regarding the statistical analysis, GraphPad Prism Software version 8.0.2 for Windows, GraphPad Software, San Diego, California (USA) were used. The normality of the data was assessed through the Shapiro-Wilk test and the homogeneity of variances was assessed through the Brown-Forsythe test. To check for differences between groups, Tukey's one-way ANOVA test with multiple comparisons was used where there was normality of data, while Dunn's Kruskal-Wallis test with multiple comparisons was used where there was no normality of data. Moreover, effect size was calculated through eta² (η^2) and η_H^2, as appropriate. The minimum level of significance was adjusted to the level of $p < .05$.

Results

Table 2 shows the results of means and standard deviations for the variables of age (years), body mass (kg), residual mass (kg), error (%) between the summed mass of the five separate components and the actual mass recorded on the scale, SMI and PHV age (years), together with the medians and 25th and 75th percentiles for the variables of height (cm), muscle mass (kg), adipose tissue mass (kg), bone mass (kg), skin mass (kg), sum of 6 skinfolds (mm), predicted adult height (cm) and the percentage of actual height (%) relative to predicted adult height for the 128 participants in this study.

Regarding the differences between groups of BB categories, statistically significant differences were found for age ($H = 94.99$; $p < .0001$; $\eta_H^2 = .742$); body mass ($F = 69.79$; $p < .0001$; $\eta^2 = .628$); height ($F = 104.72$; $p < .0001$; $\eta^2 = .717$); muscle mass ($H = 73.31$; $p < .0001$; $\eta_H^2 = .567$); bone mass ($H = 72.81$; $p < .0001$; $\eta_H^2 = .563$); adipose tissue mass ($F = 19.41$; $p < .0001$; $\eta^2 = .320$; SMI ($F = 18.28$; $p < .0001$; $\eta^2 = .307$) and the sum of 6 skinfolds ($H = 10.17$; $p = .0172$; $\eta_H^2 = .058$). (Table 3).

Table 2
Descriptive characteristics of the total sample.

N = 128	Mean ± SD	95% IC
Age (years)	14.88 ± 1.76	14.58; 15.19
Body mass (kg)	59.21 ± 11.42	57.23; 61.19
Size (cm)	167.90 [160.28;173.05]*	164.34; 167.92
Muscle mass (kg)	27.81 [22.72;30.32]*	25.59; 27.73
Adipose tissue mass (kg)	13.89 [12.28;16.40]*	14.02; 15.13
Bone mass (kg)	7.76 [6.74;8.36]*	7.41; 7.87
Skin mass (kg)	3.46 [3.23;3.67]*	3.33; 3.48
Residual mass (kg)	6.93 ± 1.34	6.70; 7.16
Error (%)	0.37 ± 4.10	-0.34; 1.08
Skeletal muscle index	3.47 ± 0.43	3.40; 3.55
Sum of 6 skinfolds (mm) ‖	50.35 [42.60;67.25]*	53.02; 58.98
Age of *Peak Height Velocity* (years)	13.91 ± 0.63	13.81; 14.02
Adult height prediction (cm)	176.30 [173.60;180.00]*	175.96; 177.88
% Current size	96.15 [90.70;98.70]*	92.98; 94.89

‖ triceps, subscapular, supraspinal, abdominal, thigh and leg.
*Data presented as median [p25; p75].

Table 3
Groups based on the percentage reached of predicted adult height at the time of observation.

	BB1 <85% (*N*=13) Mean ± SD	(95% IC)	BB2 85 - 89.9% (*N*=18) Mean ± SD	(95% IC)	BB3 90 - 94.9% (*N*=25) Mean ± SD	(95% IC)	BB4 ≥95% (*N*=72) Mean ± SD	(95% IC)	Size effect (η^2)
Age (years) &	12.23[11.99;12.39]	(11.99;12.30)	12.91[12.44;13.47]	(12.66;13.30)	14.33[14.03;14.41]*	(13.99;14.38)	16.00[15.07;17.01]*^#	(15.83;17.26)	.742¥
Body mass (kg)	41.18 ± 4.35	(38.81;43.54)	47.97 ± 6.70*	(44.87;51.06)	56.12 ± 5.66*^	(53.91;58.34)	66.35 ± 7.88*^#	(64.53;74.22)	.628
Size (cm)	146.58 ± 4.09	(144.36;148.81)	156.81 ± 6.21*	(153.74;161.85)	164.16 ± 5.38*^	(162.06;166.27)	172.68 ± 5.67*^#	(171.37;178.35)	.717
Muscle mass (kg) &	16.05[15.19;17.67]	(15.54;17.35)	19.58[17.93;20.34]	(18.46;22.14)	25.45[24.19;28.00]*	(24.50;27.19)	29.70[27.85;32.69]*^#	(29.44;34.43)	.567¥
Adipose tissue mass (kg)	11.69 ± 1.97	(10.62;12.76)	12.55 ± 2.22	(11.53;13.57)	13.03 ± 1.81	(12.32;13.73)	16.14 ± 3.10*^#	(15.42;19.24)	.320
Bone mass (kg) &	5.60[5.05;5.81]	(5.05;5.83)	6.52[6.24;7.09]	(6.29;7.05)	7.14[6.88;7.78]*	(6.95;7.48)	8.21[7.79;8.94]*^#	(8.21;9.36)	.563¥
Skeletal muscle index	3.06 ± 0.37	(2.86;3.25)	3.04 ± 0.43	(2.84;3.24)	3.59 ± 0.41*^	(3.43;3.75)	3.61 ± 0.33*^	(3.54;3.94)	.307
S. 6 Skinfolds (mm) ‖ &	61.20[48.90;77.30]	(54.17;72.55)	47.00[42.68;67.80]	(46.43;61.01)	45.40[38.90;57.00]*	(42.29;52.57)	54.95[43.23;68.63]	(54.08;76.12)	.058¥

‖ Sum of triceps, subscapular, supraspinal, abdominal, thigh and leg skinfolds
* Statistically significant difference of BB1
^ Statistically significant difference of BB2
# Statistically significant difference of BB3
& Data presented as median [p25;p75]
¥ η_H^2

Discussion

According to the objectives, and to our knowledge, this is the first study describing and comparing body composition in young male football players according to the 5-component fractionation model categorised through a non-invasive biological indicator such as BB.

With regard to the results observed in the CA within each BB category, significant differences can be seen between BB3 and BB1; and between BB4 and BB1, BB2 and BB3. However, when statistically significant differences are observed between one category of BB and the next, the difference is only apparent between BB3 and BB4 ($\Delta = 13.46\%$; $p < .0001$). Comparatively, these categories could resemble chronological categories in Argentinean youth football players in age groups 14 (14.5 ± 0.2 years) and 16 (16.5 ± 0.2 years), respectively (Holway et al., 2011).

In terms of body mass and height, significant differences between adjacent categories can be observed between BB1 and BB2; BB2 and BB3 and between BB3 and BB4. The results of the two anthropometric variables are similar to those presented by Di Credico et al. (2020), where youth players from Italy were grouped into 3 biological categories (*Pre-PHV*; *Circa-PHV* and *Post-PHV*) and where statistically significant differences were observed between Pre-PHV and Circa-PHV and between Circa-PHV and Post-PHV, except for body mass between Circa-PHV and Post-PHV groups. Similarly, these authors report that these two anthropometric variables and their associations with the years of the *Peak Height Velocity* (YPHV) have significant correlations of $r = .76$ for body mass and $r = .92$ for height. Furthermore, Figueiredo et al. (2009) indicate for these anthropometric variables a similar behaviour to the one reported in the present study, a significant increase in body mass and height in young Portuguese players, aged 11 and 12 years, and 13 and 14 years, divided into three categories by degrees of maturity (*Late*, *On Time* and *Early*). And, with regard to the differences in the height and body mass of the players in the present study between groups by CA, only one significant difference is observed ($\Delta = 6.98\%$; $p = .0033$) in height among the U-12 players (150.82 ± 7.60 cm) and U-13 (161.34 ± 8.48 cm).

Body composition in terms of muscle mass and bone mass variables show significant differences only between adjacent categories BB3 and BB4 (on time puberty and late puberty, respectively). Muscle mass shows a higher value in late puberty, with a median of 29.70 kg (p25 = 27.85 kg; p75 = 32.69 kg), with respect to on time puberty, with a median of 25.45 kg (p25 = 24.19 kg; p75 = 28.00 kg), and bone mass shows a higher value in late puberty, with a median of 8.21 kg (p25 = 7.79 kg; p75 = 8.94 kg), with respect to on time puberty, with a median of 7.14 kg (p25 = 6.88 kg; p75 = 7.78 kg). This is a fact that can be largely associated with the process of puberty, which is characterised by changes in body size, composition and function in response to testosterone, and which results in linear growth and muscle mass development in males (Rowland, 2005) and is reflected, in this case, by a greater percentage increase in body mass between BB3 and BB4 ($\Delta = 18.22\%$) than between BB2 and BB3 ($\Delta = 16.99\%$) and between BB1 and BB2 ($\Delta = 16.49\%$). However, the increase in kilograms of muscle mass is continuous between one category and the subsequent one, as shown by a group of studies in youth football players categorised by CA (Bernal et al., 2020; Hidalgo et al., 2015; Holway et al., 2011; Jorquera et al., 2012); nevertheless, and although the kilograms of bone mass also show a continuous increase between one category and the subsequent one in the present study, it is not consistent with the pattern in the studies already cited, probably due to the difference in the higher average CA of the youth categories compared to the smaller categories in the present study.

Adipose tissue mass, as another variable of body composition, shows a continuous increase between categories. However, no significant differences are observed between BB1 and BB2, nor between BB2 and BB3. It is only possible to observe significant differences between adjacent categories in BB3-BB4 (mean 13.03 kg vs 16.14 kg, respectively, $p < .0001$). This situation can also be associated with the significant increase in height and body mass among these same categories, a condition that is not possible to observe with the analysis of the evolution of the sum of skinfolds as another indicator of body adiposity, which will be mentioned later. Hidalgo et al. (2015) obtain similar results to those presented here, as the researchers find a continuous increase in adipose tissue between the four chronological categories, from 14.2 ± 0.54 to 17.0 ± 1.16 kg. On the other hand, Bernal et al. (2020) report a constant average value of 15.5 kg of adipose tissue mass among the chronological categories of 4th division (15.7 ± 0.4 years), 3rd division (16.7 ± 0.3 years) and U-17 (17.5 ± 0.5 years). Lastly, Holway et al. (2011) report a higher variability of adiposity among CA categories (14 = 15.8 ± 2.8 kg; 15 = 16.4 ± 3.2 kg; 16 = 15.0 ± 3.2 kg, and 17 = 15.7 ± 2.8 kg).

The SMI shows the kg ratio of muscle mass per kg of bone mass, and in this study, only a significant difference can be observed between BB2 adjacent categories (3.04 ± 0.43) and BB3 (3.59 ± 0.41), but not between BB1 and BB2, and between BB3 and BB4. Furthermore, Bernal et al. (2020) report values of 4.0 ± 0.4 for the 4th division (15.7 ± 0.4 years), 4.0 ± 0.3 for the 3rd division (16.7 ± 0.3 years), and 4.1 ± 4.0 for U-17 (17.5 ± 0.5 years).

Lastly, the sum of skinfolds shows an opposite behaviour to adipose tissue mass, as a continuous decrease in total mm is observed in the sum, especially in BB1, BB2 and BB3 categories, a situation that can be found in other studies with a sum of 6 skinfolds (Bernal et al., 2020; Jorquera et al., 2012), while adipose tissue mass shows a continuous increase in kilograms from one category to the next. This condition can be explained, in part, by the Geometrical Similarity theory (Jaric et al., 2005), which indicates that mass-volumes increase with the height cubed; in other words, mass-volumes are understood three-dimensionally, an aspect considered in the determination of adipose tissue mass, muscle mass and bone mass in the 5-component fractionation model (Ross & Kerr, 1991), but not considered in the sum of skinfolds (understood linearly and without considering height). However, Figueiredo et al. (2009) analyse the behaviour of the sum of 4 skinfolds between 2 age groups divided into 3 biological categories. As a result, authors indicate a significant difference only in the youngest age group (11 - 12 years; $p < .01$; $\eta 2 = .13$), while in the older age group (13 - 14 years) no significant difference is found between biological groups. Lastly, in the comparison by Di Credico et al. (2020) on the millimetres of the triceps and subscapular skinfolds in three pubertal stages, significant differences are only observed in the triceps skinfold ($p = .042$) and not in the subscapular skinfold ($p = .143$). Furthermore, the same authors state that, in the associations of these skinfolds with the YPHV, non-significant correlations of $r = -.28$ (weak) for the triceps skinfold and of $r = -.03$ (negligible) for the subscapular skinfold are presented.

As it can be expected, maturity degree significantly affected the size and body composition of youth football players, especially between on time puberty and late puberty in the variables of body mass, height, muscle mass, adipose tissue mass and bone mass, while between early and on time puberty these differences are reduced to the variables of body mass, height and SMI, and between prepubertal and early puberty, only to body mass and height. On the other hand, the statistical analysis showed that the categorisation by BB allows the explanation of the variances of height in 71.7%, body mass in 62.8%, muscle mass in 56.7%, bone mass in 56.3%, adipose tissue mass in 32.0%, SMI in 30.7% and the sum of 6 skinfolds in 5.8%.

The present study also has its limitations and strengths which should be acknowledged. Firstly, this study used a cross-sectional design which does not allow the establishing of cause-and-effect relationships. Secondly, other performance variables or playing positions are not considered. However, this study is the first to describe and compare the body composition of youth football players categorised by BB, using the 5-component fractionation model.

Conclusions

The findings of the study show that, in youth football players categorised by BB, the growth and maturity process can be seen in the following aspects, in order of relevance: (i) the greatest increase in height and body mass, (ii) the increase in muscle mass and bone mass, (iii) the smallest increase in adipose tissue mass and SMI, and, to a much lesser extent, (iv) the evolution of the sum of 6 skinfolds. Based on these data, it is suggested to continue with research that associates this type of categorisation with other aspects of performance in young footballers.

Furthermore, as a projection, the results can be applied by clubs and coaches who need to include BB as a complement to the categorisation by CA, in the processes of identification, selection and development of young talents. Similarly, these data can be useful to select, for their control and follow-up, the variables of body composition, understood as an aspect of performance, that best represent the process of growth and maturity in young football players. The final aim is to develop strategies to optimise body composition.

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Conflict of interest: No conflict of interest was reported by the authors.