Journal of Exercise Physiologyonline

JEPonline

Equations to Predict Body Fat Percentage in Young Chilean Soccer Players

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ABSTRACT

Gómez-Campos R, Urra-Albornoz C, Andruske CL, Almonacid-Fierro A, Pacheco-Carrillo J, Cossio-Bolaños M. Equations to Predict Body Fat Percentage in Young Chilean Soccer Players. **JEPonline** 2017;20(4):96-107. The purpose of this study was to develop equations to predict body fat percentage in young Chilean soccer players. Ninety-four footballers 13.0 to 17.9 yrs of age were studied. The anthropometric variables that were recorded included weight, height, sitting height, and five skinfolds (bicipital, tricipital, subscapular, iliac crest, and abdominal). The reference method used was the dual-energy X-ray absorptiometry. Biological maturity was estimated by age peak height velocity (APHV). Three body fat percentage equations were generated for young soccer players: (a) 7.86 + (0.51*TR) + (0.165*SB) + (0.56*I) - (1.33*APHV); (b) 8.834 + (0.47*TR) + (0.017*SB) + (0.29*I) + (0.27*AB)(1.21*APHV); and (c) 8.677 - (0.008*BI) + (0.502*TR) + (0.051*SB) + (0.24*I) + (0.28*AB) - (1.29*APHV). All three equations displayed similar results when compared with the reference method (P>0.001). The

correlations varied between (R = 0.85 – 0.86). The results indicate that skinfolds along with APHV can help estimate accurately the percentage of body fat in young Chilean soccer players. The results suggest that these equations may be used to predict the percentage of body fat in other young soccer players with similar characteristics.

Key Words: Absorptiometry; Anthropometry; Biological Maturity; Body Fat Percentage Dual-Energy X-Ray; Young Soccer Players

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INTRODUCTION

Body composition can be organized according to a broad model that consists of five levels increasing in complexity (I, atomic; II, molecular; III, cellular; IV, histological; and V, whole body) (0). In fact, in these studies, researchers focus their estimation on the description of body compartments for the entire body. In general two to six body components (22) are examined making it possible to estimate the general health of the athletic as well as the non-athletic populations (0).

Population independent body composition assessment is subject to the use of the indirect method (physicochemical, imaging, and densitometry) and to the double indirect method (total body electrical conductivity, body electrical impedance, near-infrared reactance, and anthropometry). Assessments in professional sports are commonly conducted using practical methods such as skinfolds, bioelectrical impedance (BIA), air displacement plethysmography, and dual-energy X-ray absorptiometry (DXA) (1).

While these methods may vary in precision and level of understanding, they imply counting on highly qualified personnel whose fees may demand high budgets (19). Moreover, to this may be added, the indiscriminate use of regression equations that are non-specific to soccer. According to Faulkner (8), Durnin and Wormersley (5), Boileau (2), and Slaughter (24), these concerns may create bias in the analysis of body composition (given that the equations are more than 27 yrs old and should be updated).

It is also important to point out that no regression equations exist in Chile to predict body fat percentage in young soccer players. To date, even at the international level there are no proposals to create equations that would allow the assessment of body fat percentage in young soccer players. Yet, the use and application of body fat percentage equations are essential in order to optimize sports performance and to verify the effects of training (23). This is especially true when it comes to young soccer players in the middle of development and biological maturity. Even more importantly, no studies exist that have validated equations taking into account biological maturity. Including this factor has the potential to contribute to the marked inter-individual variations in body composition and functional capabilities of young athletes (16).

Consequently, it is commonplace to use non-invasive low cost methods to quickly and precisely analyze the percentage of body fat. In this sense, skinfolds are considered to be the most effective anthropometric variable for predicting body fat percentage in athletes as well as non-athletes (29). The use of skinfolds has even led to derivations of multiple regression

equations in diverse populations (15). Thus, the purpose of this study was to develop equations in order to predict body fat percentage in young Chilean soccer players using the dual-energy X-ray absorptiometry method as the reference.

METHODS

Subjects and Design of the Study
The study was a descriptive-comparative. Ninety-four young soccer players were (non-probabilistically) selected from a first division Chilean soccer club at the beginning of the competitive season. The players' ages ranged from 13.0 to 17.9 yrs (15.62 ± 1.45 yrs). The study included 12 goalkeepers, 15 center-backs, 16 wingbacks, 27 midfielders, and 24 forwards for a total of 94 subjects with 4.3 ± 3.1 yrs of experience in soccer.

Anthropometric measurements and the dual-energy X-ray absorptiometry (DXA) method were carried out according to the ethical norms of the Declaration of Helsinki. Additionally, the study was approved by the Ethics Committee at the Universidad Autónoma de Chile.

All parents and/or guardians of the minors were informed regarding the goals and risks of the study. Those responsible for the minors gave their informed consent in writing. The study included young men who were clinically healthy. Excluded from the study were young men who missed the assessment day due to medical excuses, and those with metal implants due to surgery or to a sports associated injury.

The collection of data was conducted in a closed laboratory located at the Universidad Autónoma de Chile. Assessments were carried out Monday to Friday during the mornings of November 2014 between 9:00 and 11:00 A.M. All young men attended the assessment in light clothing (shirt, shorts, and barefoot). Anthropometry was initially conducted followed by DXA scanning.

Procedures
In order to calculate decimal age, registered birth age was used for each subject. Age was calculated by date of birth (day, month, and year) and the date on which anthropometric measurements were taken (day, month, and year).

Body mass (kg) was assessed barefooted on a scale (Tanita, Kewdale, Australia) with a precision of 0.1 kg. Height was measured using a stadiometer (SECA, Hamburg) with a precision of 0.1 cm with the subject's head on the Frankfurt plane. Sitting height was measured with the subject sitting upright on a wooden bench (50 cm long flat box), using a stadiometer (SECA, Hamburg) with a precision of 0.1 cm. Five skinfolds (bicipital, tricipital, subscapular, iliac crest, and abdominal) on the right side of the body were assessed using a Harpenden caliper (Harpenden, England), whose springs exerted a constant pressure of 10 $g \cdot mm^{-2}$.

Anthropometric assessment was conducted using the International Society for the Advancement of Kinanthropometry protocol (13) in order to measure the anthropometric variables. The entire anthropometric assessment process was conducted by an experienced anthropometrist. Intra-observer technical error of measurement in all variables was inferior to 1.8%.

Biological Maturity

Biological maturity was assessed via somatic indicators. The technique proposed by Mirwald et al. (17) was used. Adopting this procedure allowed researchers to calculate peak height velocity (PHV) in a transversal manner. This procedure is based on the interaction of anthropometric variables: weight, height, sitting height, and decimal age. The specified technique allows classification into eight levels (-4, -3, -2, -1, 0, 1, 2, and 3). Zero (0) marks the moment in which PHV is manifested. Lower limb length interaction (LLL) was determined by calculating the difference between sitting height and standing height:

Maturity Offset = - 9.236 + 0.0002708 x Leg Length and Sitting Height interaction - 0.001663 x Age and Leg Length interaction + 0.007216 x Age and sitting Height interaction + 0.02292 x Weight by Height ratio.

DXA Measurement

Prior to the assessment, the subjects were advised that they needed to wear light clothing and remove any metal objects. In order to ensure a standard supine position was adopted during the scans, the subjects' knees and ankles were tied with a Velcro strap while their arms were extended by their sides. Typical duration of the examinations was from 8 to 10 min, depending on the height of the subject. Estimated radiation exposure was 2.2 Sv per examination. Data were collected from the whole body: fat percentage, bone mass, muscle mass, and fat mass. Scans were conducted with the dual-energy X-ray absorptiometry (DXA) (Lunar Prodigy; General Electric, Fairfield, CT). An experienced technician was in charge of the scanning process. Technical error of measurement (TEM) was inferior to 2%. The equipment was calibrated on a daily basis according to the manufacturer's instructions.

Statistics Analysis

All variables showed a satisfactory pattern after verification with the Kolomogorov-Smirnov normality test. The data were analyzed through descriptive statistics of arithmetic mean, standard deviation, range, and coefficient of variation (CV). Relationships between variables were verified by using the Pearson product-moment correlation coefficient. Three regression models for predicting fat percentage in young soccer players were developed. The procedure consisted of carrying out a multiple regression analysis in steps. The objective was to identify the best combination of predictive variables of body fat percentage. Factor variance inflation perfomed by R^2, SEE, and collinearity was used to analyze the three equations. All three equations displayed similar results when compared with the reference method (P>0.001). The correlations varied between (R = 0.85 – 0.86). The results indicate that skinfolds along with APHV can help estimate accurately the percentage of body fat in young Chilean soccer players. The entire statistical analysis was carried out using SPSS 18.0, Sigma Esta 8.0 and Excel forms. A probability of P<0.001 was adopted in all cases.

RESULTS

Table 1 depicts the anthropometric variables: chronological age, biological age, and body composition of young soccer players based on their playing position. Forwards and Mid-fielders presented less adipose tissue in the subscapular and abdominal region compared to Goalkeepers. No differences occurred between chronological and biological age, weight,

height, sitting height, bicipital, tricipital, and iliac crest skinfolds among playing positions as well as in body composition (fat percentage, fat mass, muscle mass, and bone mass) P>0.001.

Table 1. General Characteristics of Anthropometric Variables and Body Composition of the Young Soccer Players.

Variables	Goalkeeper (n = 12) X	±SD	Center-Back (n = 15) X	±SD	Forward (n = 24) X	±SD	Midfielder (n = 27) X	±SD	Wingback (n = 16) X	±SD	Total (n = 94) X	±SD	F	P
Chronological Age (yrs)	15.2	1.35	15.55	1.51	15.63	1.52	15.87	1.27	15.56	1.7	15.62	1.45	0.465	0.761
Biological Age (APHV)	0.63	1.36	0.77	1.16	0.71	1.25	0.69	1.06	0.54	1.44	0.68	1/21	0.079	0.367
Weight (kg)	66.56	11.02	63.39	6.21	60.84	8.95	62.19	7.71	60.29	11.31	62.27	9.00	1.088	0.218
Height (cm)	172.2	9.53	170.3	4.8	167.6	6.68	167.8	7.29	166.7	6.99	168.5	7.15	1.471	0.989
Sitting Height (cm)	90.13	5.50	89.52	4.07	89.21	4.67	88.16	4.67	88.02	5.34	88.95	4.79	0.698	0.596
Skinfolds (mm)														
Bicipital	4.78	1.31	7.23	10.23	3.98	1.04	4.47	1.09	4.23	0.94	4.78	4.23	1.616	0.177
Tricipital	8.33	4.1	9.4	2.01	7.74	1.64	8.79	2.44	8.29	1.66	8.47	2.38	1.299	0.277
Subscapular	9.13	2.37	7.54	1.77	6.93	1.84a	7.44	1.27a	7.76	1.9	7.59	1.85	3.210	0.016
Iliac Crest	10.62	4.89	10.44	3.57	8.8	3.23	8.86	2.13	9.14	3.05	9.37	3.26	1.222	0.307
Abdominal	15.15	7.95	11.95	3.42	9.72	4.17a	9.76	3.03a	10.04	3.63a	10.83	4.65	4.114	0.004
Body Composition														
Fat Percentage (%)	19.4	5.9	18.22	2.83	16.52	2.26	18.06	4	17.11	3.16	17.7	3.68	1.541	0.197
Fat Mass (kg)	12.31	3.98	11.13	2.15	9.66	1.98	14.05	17.15	9.88	2.64	11.53	9.50	0.852	0.496
Muscle Mass (kg)	51.15	9.7	49.9	5.05	48.85	7.27	48.89	6.59	48.02	9.02	49.18	7.36	0.361	0.836
Bone Mass (kg)	2.84	0.55	2.66	0.36	2.64	0.43	2.68	0.40	4.35	7.16	2.97	2.97	1.060	0.381

APHV = Age Peak Height Velocity; **SD** = Standard Deviation; **a** = Significant Difference in Relation to Goalkeepers; **b** = Significant Difference in Relation to Center-Backs

Table 2 illustrates the regression equations developed for the young soccer players. All three equations presented an explanatory power between 72% and 75%. SEE varied from 1.86 to

1.95. The factor inflation values (FIV) for predictor variables was inferior to 4.50. In all cases, probability was less than 0.0001. Additionally, Figure 1 depicts the connection of observed residuals and predictor values obtained by the three new equations.

Table 2. Regression Equations for Body Fat Percentage Based on Skinfolds.

|	Equations	FIV	R	R^2	SEE	P
1	7.86+(0.51*TR)+(0.165*SB)+(0.56*I)-(1.33*APHV)	--	0.85	0.72	1.95	0.000
	Tricipital	1.59				
	Subscapular	1.76				
	Iliac Crest	1.76				
	APHV	1.44				
2	8.834+(0.47*TR)+(0.017*SB)+(0.29*I)+(0.27*AB)-(1.21*APHV)	--	0.87	0.75	1.86	0.000
	Tricipital	1.62				
	Subscapular	1.99				
	Iliac Crest	3.85				
	Abdominal	4.16				
	APHV	1.51				
3	(0.008*BI)+(0.502*TR)+(0.051*SB)+(0.24*I)+(0.28*AB)-(1.29*APHV)	--	0.86	0.74	1.95	0.000
	Bicipital	1.09				
	Tricipital	1.68				
	Subscapular	1.85				
	Iliac Crest	4.50				
	Abdominal	4.39				
	APHV	1.39				

BI= Bicipital; TR = Tricipital; SB = Subscapular; I = Iliac Crest; AB = Abdominal; APHV = Age from Peak Height Velocity; R = Correlation Coefficient; R^2 = Coefficient of Determination; SEE = Standard Error of Estimate; P<0.0001
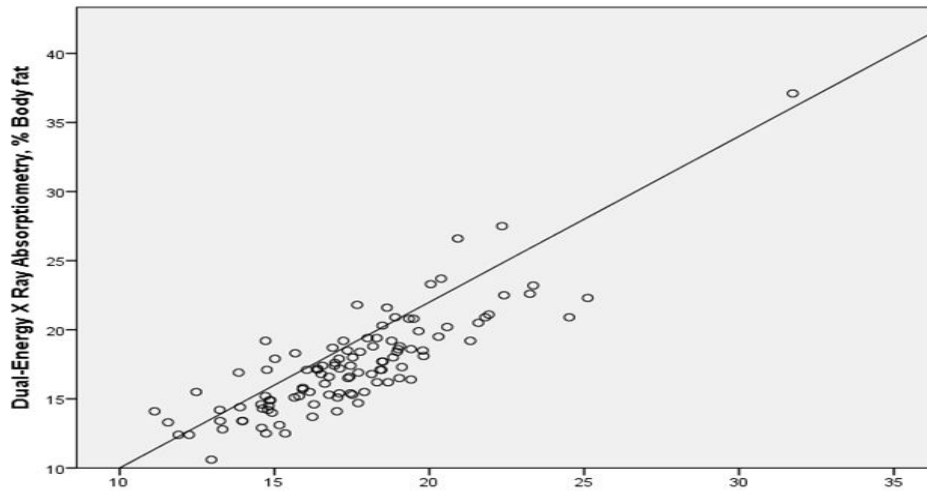
Equation 1: 7.86+(0.51*TR)+(0.165*SB)+(0.56*I)-(1.33*APHV)
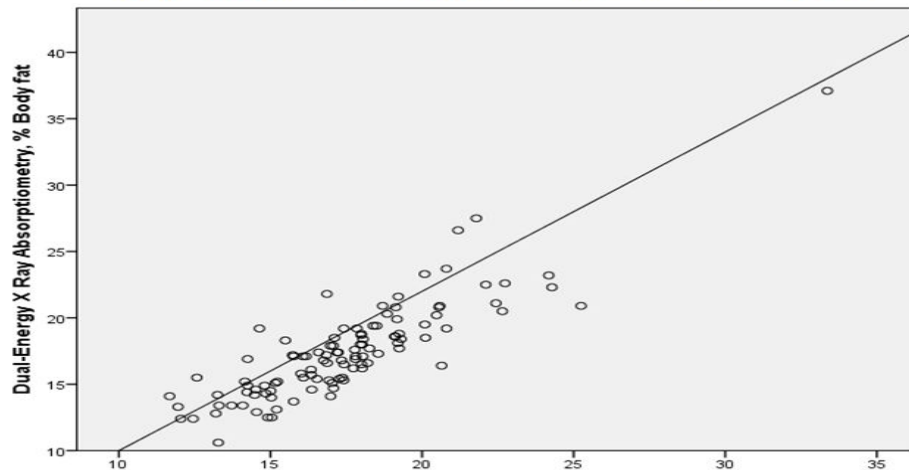
Equation 2: 8.834+(0.47*TR)+(0.017*SB)+(0.29*I)+(0.27*AB)-(1.33*APHV)
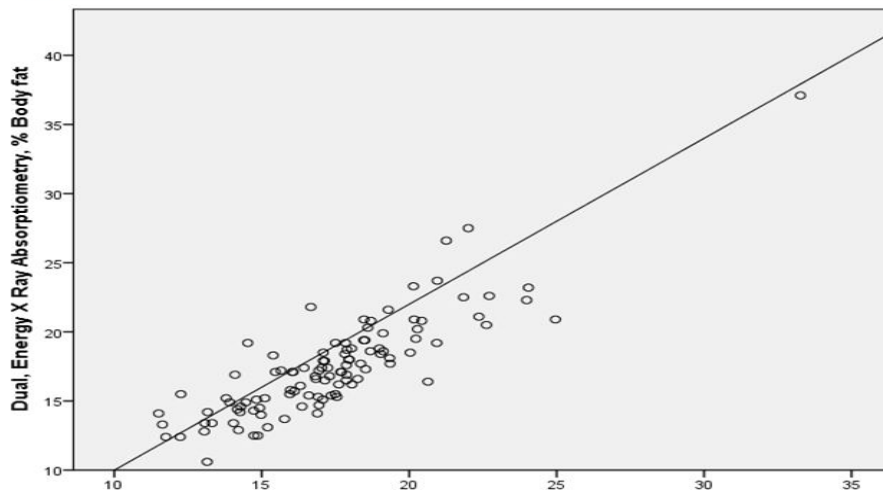
Equation 3: 8.677-(0.008*BI)+(0.502*TR)+(0.051*SB)+(0.24*I)+(0.28*AB)-(1.29*APHV)

Figure 1. Scatter Plot of Observed Values in Reference Method (DXA) and Predicted Values for the Three Regression Equations.

The comparisons of body fat percentage in the three new equations and the reference method (DXA) are shown in Table 3. No differences occurred in statistical significance in any of the cases (P>0.001). Average values and ±SD of F% were similar to the reference method (DXA). Percentages of coefficient of variation of the three generated equations depicted a strong positive correlation with the method of reference method (DXA).

Table 3. Comparison of Body Fat Percentage (F%) Estimated with DXA and Skinfold Regression Equations.

	N	Mean	±SD	Range	Minimum	Maximum	CV	r	*t*-test	P
BF% (Reference)	94	17.44	3.62	26.50	10.60	37.1	20.80			
Equation 1	94	17.45	3.09	20.61	11.13	31.74	17.70	0.85*	0.0204	0.904
Equation 2	94	17.37	3.00	20.56	11.87	32.42	17.27	0.86*	0.1444	0.885
Equation 3	94	16.98	3.13	21.43	11.18	32.61	18.43	0.86*	0.9319	0.353

BF% = Body Fat Percentage; **1** = DXA Estimate; **SD** = Standard Deviation; **r** = Pearson Correlation Coefficient; **CV** = Coefficient of Variation; ***** = Strong Positive Correlation P<0.001).

DISCUSSION

The results from this study confirmed that skinfolds and biological maturity (determined by age peak height velocity, APHV) were the best predictors of body fat percentage in young soccer players. To our knowledge, and as far as we are aware, this is the first body fat percentage study where biological maturity was controlled in young soccer players between the ages of 13.0 to 17.9 yrs. All three new equations generated are widely acceptable since the reference method (criterion) used to validate each one was the dual-energy X-ray absorptiometry (DXA).

In fact, the aforementioned technique has become one of the most widely accepted methods for assessing body composition in children and adolescent athletes (2,27) as well as non-athletes (7,26). Its use and application is relevant as it provides exact estimations while validating other methods like the hydrostatic weighing (14).

The results of the three regression equations developed in the present study are similar to other research studies with similar goals (20,21,30). In all three equations, variance inflation factors (VIF) showed inferior ranges when compared to the normal values (>0.10 and <10.0 respectively) according to descriptions by Slinker and Glantz (25). Furthermore, several studies emphasize that the precision of regression coefficients can be identified using R^2 (4,9), SEE (25), and statistical significance analysis (31). Ultimately, the equations generated fulfil the four previously mentioned requirements that guarantee robustness. Additionally, skinfolds as simple anthropometric segment measurements are reliable good predictors of soft tissue in *in vivo* (12).

This study offers important contributions by using upper limb skinfolds (bicipital and tricipital) and the central region of the body (subscapular, liac crest, and abdominal). In addition. the

control of the variable of maturity by using a non-invasive technique (APHV) offers another contribution to predicting body fat percentage. Moreover, for team sports participation, categories are based primarily on chronological age groups (9). This represents different paces of biological maturity in young soccer players. The equations developed can contribute to the fields of orientation, specifically in connection with practice and training where the main goal is to enhance skill and mastery (6) in young soccer players.

Regarding cross-validation, no differences were found between the criterion method (DXA) and the three equations developed. The results confirm the efficacy of the new equations. This guarantees a high internal validity (R=0.85 – 0.86) despite the third equation showing a small non-significant variation to the criterion method (DXA). Despite the equations being of use to the young soccer players studied, it is necessary for future researchers to direct their efforts into externally validate the equations. It is also suggested to include other body segments, like body circumferences for the arm, torso, and legs. Moreover, it is necessary to control for the consumption of optimal energy from young athletes of this sports modality since training, competitive demands (3), and training stages, in general, may affect body composition in young soccer players.

Although this study shows strengths, like the large sample size, few observed technical errors of measurement (TEM) in the anthropometric variables during DXA scanning, and the observed efficacy and firmness in the equations, it is necessary to emphasize certain limitations. For example, the study was carried out on a transversal sample of young Chilean soccer players ranging in ages from 13.0 to 17.9 yrs. Consequently, the use and application of the equations is limited to this specific population of young athletes. In addition, the use of the technique to assess biological maturity (APHV) was proposed and validated for Belgian youths. As a result, this may introduce a slight bias into the analysis in the results of body fat percentage. Nevertheless, it is also true that the use of other techniques to assess biological maturity in young athletes may be rejected by parents, sports organizations, and ethics committees (16). Because of this, the technique proposed by Mirdwal et al. (17) becomes attractive and serves as a means of classification and stratification of work groups in order to homogenize children and adolescents in sports-related situations (11).

CONCLUSIONS

Results from this study indicate that bicipital, tricipital, subscapular, iliac crest, and abdominal skinfolds, and APHV can help in the precise estimation of body fat percentage in young Chilean soccer players. Results suggest that since this is a non-invasive, easy to use, and low cost field method, the three proposed equations may be applied to groups with similar characteristics. Calculations can be carried out using the link: http://www.reidebihu.net/

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