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Validez concurrente de cinco ecuaciones de predicción para evaluar el porcentaje de grasa en un grupo de deportistas con proyección al alto rendimiento de la ciudad de Medellín - Colombia

Validación de ecuaciones de porcentaje de grasa

Concurrent validity of five prediction equations to evaluate fat percentage in a sports group expected to yield high performace from the city of Medellin – Colombia

Ana Lucía López [1], Juan David Vélez [1], Angélica María García [2], Elkin Fernando Arango [1]

[1] INDER Medellín - Team Medellín, Medellín, Colombia

[2] incluir sección institucional, Universidad de Caldas, Manizales, Colombia

Correspondencia:

Ana Lucia López**,** INDER Medellín, Calle 19 # 43 G 80, int. 2314, Medellín, Colombia.

Teléfonos: (034) 5816374 y 3104293944

lopezme.ana@uces.edu.co

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Todos los autores participaron en la planificación y elaboración del proyecto de investigación; diseño y obtención de datos; análisis y presentación de resultados y escritura del manuscrito.

Introduction: In Medellín, Colombia, there are no equations to predict the body composition (BC) of athletes expected to have high performance, making it difficult to make decisions related to training and nutrition plans.

Objective: To calculate the concurrent validity of five prediction equations for fat percentage (FP) within a group of athletes from the city of Medellin, Colombia expected to yield high performance.

Materials and methods: Cross-sectional analysis for diagnostic tests validation with data from a secondary source of athletes under the age of 18 who were part of Team Medellín. The “gold standard” was dual-energy X-ray densitometry (DEXA); the prediction equations analyzed included: Slaughter, Durnin and Rahaman, Lohman, Johnston, and the Five-Component method. The ICC was used to assess the consistency between the methods; moreover, the Bland-Altman plot was used to calculate the average bias and agreement limits of each of the equations.

Results: Participation included 101 athletes (50,5% women), the median age being 14,8 years old (IR 13,0 to 16,0). The concurrent validity was “good/excellent” for the Johnston, Durnin and Rahaman and Five Components equations. The Lohman equation, which overestimated the FP in 12,7 percentage points. All of them showed broad agreement limits.

Conclusions: For the study population, the Durnin and Rahaman, Johnston and Five-Component equations can be used to predict the FP because they yield a “good/excellent” concurrent validity and a low average bias. The equations analyzed have low accuracy, making it difficult to use them to diagnose the individual FP within this population.

Keywords: Body composition; nutritional status; anthropometry; child; adolescent; nutrition assessment; adipose tissue; absorptiometry, photon.

Introducción. En Medellín-Colombia, la falta de ecuaciones de predicción de la composición corporal (CC) para deportistas con proyección al alto rendimiento dificulta la toma de decisiones para el entrenamiento y la nutrición.

Objetivo. Calcular la validez concurrente de cinco ecuaciones de predicción del porcentaje de grasa (PG) en un grupo de deportistas con proyección al alto rendimiento de la ciudad de Medellín- Colombia.

Materiales y métodos. Estudio trasversal de validación de pruebas diagnósticas con datos de fuente secundaria en deportistas menores de 18 años pertenecientes al Team Medellín. La densitometría dual de rayos X (DEXA) fue el "estándar de oro"; las ecuaciones de predicción que se estudiaron fueron: Slaughter, Durnin y Rahaman, Lohman, Johnston, Cinco Componentes. Para evaluar la concordancia entre los métodos, se utilizó CCI; además, se hicieron análisis de Bland y Altman para calcular el sesgo promedio y los límites de acuerdo de cada una de las ecuaciones.

Resultados. Participaron 101 deportistas (mujeres 50,5%) con una mediana de edad de 14,8 años (RI 13,0 a 16,0). La validez concurrente fue "buena/excelente" para las ecuaciones de Johnston, Durnin y Rahaman y Cinco Componentes. La ecuación Lohman sobreestimó el PG en 12,7 puntos porcentuales. Todas mostraron límites de acuerdo amplios.

Conclusiones. Para la población del estudio se pueden utilizar las ecuaciones de Durnin y Rahaman, Johnston y Cinco Componentes para predecir el PG debido a que tienen una validez concurrente "buena/excelente" y un sesgo promedio bajo. Las ecuaciones que se estudiaron tienen una baja precisión, lo que dificulta utilizarlas para el diagnóstico individual del PG en dicha población.

Palabras clave: Composición corporal; estado nutricional; antropometría; niños; adolescentes; evaluación nutricional; tejido adiposo; absorciometría de fotón

Body composition (BC) and the changes it undergoes, play a main role in athletes' performance, particularly in those who are enduring the process of physical development and, therefore, the physical abilities, that directly affect sports performance and the risk of injuries for those who practice the different sports modalities, whether they are resistance, strength, power or speed(1-4). Given the above, it is vital to have evaluation methods that are valid, meaning that they have adequate validity and high reliability (3-5).

In everyday work, professionals who take care for athletes, whether those undergoing training or who are already professionals, use doubly indirect methods to measure BC, such as those that use data derived from measuring skin folds and bioimpedance devices, in order to be implemented later on into prediction formulas that are specific to the population in which it was developed and that may not necessarily be applicable to people who are not part of such groups, as is the case of athletes of the city of Medellin expected to be high performers (1,2,4).

There are no validated methods in Medellin to assess BC in athletes undergoing training, which makes it difficult to get accurate and reliable data that make it possible to improve decision-making related to training and nourishing processes. This causes these people to be at a disadvantage compared to those in developed countries, on the way to becoming high-performing athletes (4,6).

Given the situation described, it is crucial to validate the prediction equations most commonly used to assess BC in athletes, such as Slaughter, Lohman, Johnston, Durnin and Rahaman and multicomponent. The purpose of this research is to determine which of the BC prediction equations used for children under the age of 18, best suits athletes training in the city of Medellin, so that the data obtained from these would be more precise and reliable, which would lead to better guided training plans, as well as food interventions that adjust better to the reality of athletes. Therefore, the goal of this study was to clarify the concurrent validity of five BC prediction equations in a group of athletes training in the city of Medellin, Colombia.

Materials and methods

Type of study

A cross-sectional quantitative study was carried out to validate diagnostic tests.

Population, sample and sample design

The population consisted of athletes in the city of Medellin, Colombia with a high-performance forecast; the work was executed with a convenience sample composed of the athletes belonging to Team Medellin (Inder - Mayor's Office of Medellin).

The sample size was not calculated, given that almost all of the athletes part of this sports development program were included, which consists of 116 athletes.

Selection criteria

Athletes who met the following criteria were included: Being part of Team Medellin during the years 2018 and 2019 (first four months), and that both the athlete, as well as his/her advisor (legal representative), gave consent for the existing data to be used in stories of nutritional assessment carried out in the mentioned years.

Those who had health disorders that could alter BC characteristics, such as malignant conditions, thyroid disorders or other endocrine disorders, were excluded; furthermore, those who were 18 years of age or older were also excluded.

Bias control

The work was executed with secondary source data, obtained by three professionals in Nutrition and Dietetics, who had training in anthropometry (ISAK level 2 certification), thus minimizing intra and inter-observer variability. Moreover, calibrated and validated equipment was used to assess BC; all athletes were assessed similarly, following a protocol set for this purpose. Selection criteria was strictly verified.

In addition to the above, the database was subject to debugging and quality control. Extreme values or outliers were sought, which can affect the means of the quantitative variables, and therefore, the results of the parametric statistical tests. Missing data and typing errors were also looked for, which were corrected when necessary; missing data was addressed through multiple imputation, a process that did not need to be carried out.

Instruments and information collection

This study was carried out with secondary source data, taken during the nutritional assessments executed in 2018 and the first four months of 2019.

The information was obtained as follows: Age was calculated using the date of birth; gender was determined according to the primary sexual characteristics; socioeconomic stratum was obtained from the participants' self-report and then it was reclassified as follows: 1). Low, which corresponds to strata 1 and 2; 2). Middle, consisting of those who reside in strata 3 and 4; 3). High, those who resided in strata 4 and 5; the type of sport was classified according to the intensity of resistance, its duration and the predominant metabolic pathway during its practice, as follows: 1). Explosive resistance (maximal intensity and duration close to 6 seconds; use of phosphagens); 2). High-intensity resistance (high intensity without being maximal and duration of >6 seconds and 1 minute; glycolysis); 3). Intense resistance strength (actions greater than 1 minute, mainly using oxidative phosphorylation) (7); weight was defined as the amount of body mass measured in kilograms, which was measured with a SECA 803 brand scale, which has a capacity of 150 kg and an accuracy of 100 gr; height was measured as the length between the lowest part of the heel and the highest part of the skull, with the athlete standing at the end of inhalation, the measurement of which was taken using a Charm HM200P brand stadiometer, which has a range between 14 and 205 cm and an accuracy of 1 mm; body mass index (BMI) was calculated using the Quetelet formula (BMI = weight kg/height m^2); specific sports life time was defined as the time in years that an athlete has been practicing the current specific sport; weekly training time is the amount of time an athlete devotes to training and competing each week; schooling was calculated based on the years of formal education that each athlete acknowledged to have received at the time of the BC assessment.

As a “gold standard” to assess BC, the values obtained using a dual energy x-ray absorptiometry (DEXA) device of the General Electric Lunar Prodigy brand were used, which make it possible to measure the bone mineral mass and soft tissues (lean and fat masses) separately, it is non-invasive and generates low levels of radiation (equivalent to one day or less of solar radiation). It offers information on three components: fat, fat free mass and bone mineral content (1,5,6,8). Test-retest reliability of DEXA devices shows variation coefficients (%VC) to assess fat free mass of the 0,8% (SD 0,4), 2,6% fat mass (SD 1,2) and bone mineral density 1,0% (SD 0,9) (4).

A caliper of the Harpenden brand was used to measure the skin folds, which applies a pressure of 10 gr/mm^2, regardless of the thickness of the fold; its accuracy level is 99%, its precision is 0.2 mm, with a measuring range of 0 to 80 mm.

To assess BC (FP and fat free mass), the following prediction equations were used, which are considered doubly indirect methods (table 1)(8-12).

The proportion of fat mass calculated using the Five-Component Method was converted to FP using the following procedure:

1. The adiposity percentage (%Adip) was calculated using the Five-Component Method.
2. Fat mass was obtained by multiplying each participant's proportion of adiposity by his/her weight.
3. The lipid fraction (LF) of adiposity was obtained using the formula proposed in 1994 by Martin, A. et al (13): LF = 0.327 + (0.0124 x %Adip)
4. Lipid mass of adiposity was calculated by multiplying fat mass by LF.
5. The weight FP was obtained by dividing the lipid mass of the adiposity by the body weight, which was then multiplied by 100.

Assessment description

The anthropometric assessments were carried out in doctor's offices authorized by the Sectional Health Service of Antioquia, during times that ranged between 8 am and 5 pm. Each athlete's assessment took approximately 45 minutes and was done by three nutrition and dietary professionals having a ISAK 2 certification; all of them were accompanied by an adult. The participants wore comfortable clothes that allowed easy access to the anatomical sites required to take measurements, which were marked with a black dermal pencil on the right side of the body; a total of 23 points were marked and it was not required to do so for 6 of them, based on the ISAK protocol. After this, the data of the skin folds (10 points), the perimeters (4 points), the lengths (9 sites) and the diameters (11 points) were taken.

After carrying out the anthropometric assessment, the participants were assessed with the DEXA device, which yielded the values of the total body FP and the fat-free mass. This assessment was executed by three nutrition and dietary professionals, who were trained to run the test for each athlete according to the protocol proposed by the device manufacturer. The equipment was calibrated before starting the assessments, and the hydration status of the athletes was not measured prior to the assessment, although they were given recommendations to hydrate constantly and to not perform strenuous physical activity during the 24 hours prior to the assessment.

Ethical aspects

Parents and athletes were asked to endorse the use of individual data already found in the nutritional histories, obtained by researchers through a written document signed by them.

The Ethics in Human Research Committee of the CES University (Certificate 139) obtained the endorsement on August 16, 2019. The guidelines of the Declaration of Helsinki and Resolution 8430 of 1993 of the Ministry of Health of the Republic of Colombia were taken into account. The privacy of the participants was safeguarded, which was achieved by maintaining the confidentiality of the data provided by each of them, which will only be used for scientific and academic purposes; only the researchers had access to the database and the information of each person was stored without their name and without their identification number (identity card), therefore people external to the research would be unable to know who they belong to. The database was saved using password protection.

Statistic analysis

The Shapiro Wilk test was used to establish the distribution of quantitative variables; those with a normal distribution were summarized with means and standard deviations (SD), while those that did not follow such distribution were summarized using medians and interquartile ranges (IR). Qualitative variables are shown in proportions.

The Intraclass Correlation Coefficient (ICC) was used in order to assess the concurrent validity of each of the prediction formulas; the values <0,40 were assumed to have "poor" concordance, those between 0,41 and 0,75 were considered "moderate" and, those >0,75 were considered "good/excellent".

Likewise, the Bland-Altman plot method was used to analyze the concordance between the measurement methods, which was calculated with the means and SD of the differences between the measurements of FP (DEXA - prediction formulas) of the Lohman, Slaughter, Durnin and Rahaman, Johnston and five-component method equations; measurement biases and limits of agreement (LoA) were obtained.

Statistical analyzes were done using the SPSS software, version 21, with 95% reliability and an alpha error (statistical significance) of less than 5% (p<0,05). The validity of each of the prediction equations was assess according to sex.

Results

Characteristics of the participants

Data was collected during the second semester of 2018 and the first semester of 2019. Participation included 101 athletes, of which 50,5% (n=51) were women; the median age was 14,8 years old (IR 13,0 to 16,0); schooling showed a median of 10,0 years (RI 8,0 to 11,0); average sports life reached 6,5 years (SD 2,2); no statistically significant differences were found when stratifying by sex with these variables. (table 2)

Out of the participants, one in two (51,5%) were part of the middle socioeconomic stratum and one fifth (18,8%) were part of the low stratum. A third (32,7%) practiced power sports and two out of three athletes (60,8%) were involved in high-intensity sports (table 2).

Higher values were found in terms of weight (mean 56,1 kg vs. 50,9 kg) and height (168,3 cm vs. 160,5 cm) in men, while the FP measured with DEXA was higher in women (median 27,3% vs. 19,2%) and with each of the prediction equations, as well as the percentage of adiposity with the Five-Component method (table 2).

Concurrent validity

When analyzing the concurrent validity of the prediction equations of the FP vs. DEXA, it was found that those with "good/excellent" ICCs are those of Johnston (0,833; IC95% 0,290 to 0,935), Durnin and Rahaman (0,912; IC95% 0,867 to 0,941) and Five-Component (0,853; IC95% 0,783 to 0,901); those with "moderate" ICCs were that of Slaughter (0,741; IC95% -0,186 to 0,921) and those with "poor" ICCs were that of Lohman (0,248; IC95% -0,130 to 0,590). The results above showed few changes when the analyzes were carried out according to sex. In the Lohman (all, women and men), Slaughter (all, women and men) and Johnston (women) equations, IC95% were found with negative lower limits and positive upper limits (table 3).

The following was found when the concurrent validity of each of the prediction equations of the FP was assessed versus the value that DEXA yielded using the Bland-Altman plot method:

The Slaughter, Durnin and Rahaman, Johnston and Five-Component prediction equations were compared to DEXA and they showed an underestimation of the FP that oscillated in average values of 0,6 to 5,6 percentage points (PP); the highest error was for the equation proposed by Slaughter and the lowest was for the Five-Component method; Lohman's equation overestimated the FP by 12,7 PP. When discerning by sex, a greater bias was found in women when using the Slaughter equation (6,4 vs. 4,9), Johnston (3,8 vs. 2,7) and Five-Component (1,5 vs. -0,4); likewise, the error was greater in men when using the Lohman (-15,1 vs. -10,4) and Durnin and Rahaman equations (0,9 vs. 0,7) (figures 1 to 5).

Concordance limits were extensive for all the equations studied (Slaughter -0,4 to 11,6; Durnin and Rahaman -5,6 to 7,2; Lohman -22,9 to -2,5; Johnston -3,3 to 9,8; Five-Component -7,98 to 9,1). On the other hand, it can be seen that a low proportion of data from each of the equations is outside the limits of agreement (figures 1 to 5).

Discussion

The main findings of this investigation were that, when comparing each of the prediction equations of the FP with the DEXA, the concurrent validity was “good/excellent” for Durnin and Rahaman, Johnston and Five-Component; “moderate” for Slaughter and “poor” for Lohman, without there being significant changes in these values after stratifying by sex, except for the Lohman equation, the values of which were lower for men, at an average close to 5 PP.

Similarly, with the exception of the Lohman equation that overestimated the athletes’ FP, the others underestimated it in PP averages that varied between 0,6 and 5,6, with extensive concordance limits for all of them.

Validity of the slaughter equation

In the group of athletes under the age of 18 who participated in this study, the Slaughter equation showed an ICC of 0,741 (IC95% -0,186 to 0,921), a figure that had few variations when discerning by sex. These results are not comparable to those published in other studies, given that the Pearson or Spearman correlation coefficients were used in those as a statistic to assess the concurrent validity of this equation and DEXA (14,15).

On the other hand, the average bias reached 5,6 PP with limits of agreement between -0,4 and 11,6, a value that was higher than the one reported in two spanish studies; one of them included 98 soccer players of both sexes, whose average age was 13,4 (SD 0.6), in which the bias was 3,3 PP (limits of agreement -2,9 to 9,5)(16) and the other was carried out with 88 swimmers of both sexes whose average age was 14,3 (SD 1,84), with a bias of 4,1 PP (limits of agreement -2,2 to 10,4) (17). These results match those presented by Garcia, N. et al. in a group of Chilean soccer players (average age 19,9; SD 1,3), whose average bias was lower (-1,3 PP) and the limits of agreement were narrower (-6,1 to 3,5) (15).

There are reports in which the validity of the Slaughter equation was assessed by comparing it to DEXA, in Latin American (Colombia and Chile), Spanish and African non-athletes under the age of 18, in which the results of concordance with the Bland-Altman method are consistent with those found in this research, meaning that they underestimate the FP with extensive limits of agreement (17,18). The previous findings resemble those reported in a sample of swimmers in Spain (17).

Validity of the Durnin and Rahaman equation

This equation showed a “good/excellent” concurrent validity, a rating that was maintained when assessing the results according to sex; these values are difficult to compare to other studies, because they calculated the correlation and not the concordance (17).

In a study conducted with swimmers under the age of 18 in which the Durnin and Rahaman equation was compared to DEXA, the results found were an average bias of -0,46 PP, a figure that was lower than the one from this research, in which the bias was 0,8 PP in men and 0,7 PP in women (17); moreover, values were close to those reported by Rodríguez, G. et al. in 2005, using a sample of non-athletic adolescents (men -1,34; women 0,0); despite the above, the limits of agreement were extensive in all three studies (17,18).

Validity of the Lohman equation

The equation proposed by Lohman was the only one that showed a "poor" concurrent validity in this research, men having a poorer performance. Furthermore, when compared to DEXA, it overestimated the FP at high average percentage points (women -10,4; men -15,1; all -12,7), with rather extensive limits of agreement.

No research was found comparing the Lohman equation to DEXA to estimate FP in people under 18, or in athletes, so it was not possible to compare the results obtained in the current study.

Validity of the Johnston equation

The Johnston equation had a "good/excellent" concurrent validity (ICC 0,833; IC95% 0,290 to 0,935), which was reduced to "moderate" when carrying out the analysis stratified by sex (ICC women: 0,736 - men: 0,732). No studies that assessed the results of this equation with the ICC were found; some used the Pearson correlation coefficient, which assesses the relationship between the variables, without taking the concordance among data into account.

On the other hand, in a previously described Spanish research, which was conducted with soccer players under the age of 18, an average bias of this equation of 2,3 PP (limits of agreement -2,9 to 7,6) was found, while in this study, this error was greater, with a value of 3,3 PP (limits of agreement -3,3 to 9,8) (16). Similarly, in a research that was carried out in Spain with men and women whose average age was 15,3 (SD 1,3), the average bias found was 2,4 PP in women and -1,1 in men, values that are lower than those found in the current study (women 3,8; men 2,7); it should be emphasized that the limits of agreement were extensive in both works (18).

Validity of the five-component equation

The results that this method yielded, which assess adiposity, were converted to FP using a formula that takes into account the lipid fraction of each participant, which led to finding a “good/excellent” concurrent validity, a result that was maintained when the finding was disaggregated according to sex (13). When using the Bland-Altman method, the average bias was 0,6 PP, which over-estimated the FP at 0,4 PP in men and underestimated it at 1,5 PP in women.

No studies that implemented the same procedure performed in this research were found, nor any that used the ICC or the Bland-Altman analysis as statistical tests to calculate concurrent validity (concordance), average bias and limits of agreement, so it was not possible to discuss the results that were obtained.

Currently, DEXA is under consideration as a “gold standard” to assess BC in humans, because it is an indirect method that has biases with respect to the only known direct method all on its own, which is the dissection of corpses. On the other hand, the manufacturers of DEXA devices have not standardized this technology and there are even differences in the estimation of BC with different models of the same brand and the software they use, which makes it difficult to have consistent results, a situation that hinders the “in vivo” estimate of BC of people (19,20).

In addition to the above, it is known that the BC prediction equations are specific to the population in which they were developed (20,21). None of the equations included in this study were developed with a Colombian population, nor with athletes expected to be high-performers, which may explain part of the lack of accuracy of the results they all yielded and the high average bias when compared to DEXA, when it comes to the equation proposed by Slaughter, Lohman and, to a lesser extent, Johnston.

On the other hand, some equations use the prediction of body density (BD) as an initial step and then, they use such value to calculate the FP, which can lead to bias due to the assumptions about the BD they assume (lean mass 1,1 g/cm^3; fat mass 0,9 g/cm^3) without taking individual variation in the proportions and densities of human body tissues into account. In that same sense, when the skin folds are used to predict the FP, it is assumed that there is a constant compressibility of the skin and subcutaneous fat and that the thickness of the skin is not variable; it has been known for several years that the thickness of the skin varies within a population, which is associated with characteristics such as age and sex, which modifies the compressibility of said tissue and leads to measurement errors. In addition to the above, the relative distribution of body fat is not constant between the population and the proportion of internal fat vs. external fat is not fixed, which can increase the error of the measurements and, therefore, those to predict BC (22).

Strengths and limitations.

The strengths in this research included the use of DEXA as a “gold standard,” a method that yields good accuracy and reliability to assess BC in children under the age of 18; robust statistical tests (ICC and the Bland-Altman plots) were used to calculate the concordance and accuracy of the values yielded by each of the prediction equations studied; a correction formula that takes into account the lipid fraction to change it to FP was applied to the data obtained with the Five-Component method, which assesses body fat, therefore it would be possible to compare them to the figures given by DEXA better.

On the other hand, there were some limitations, such as having worked with secondary source data, a situation that could possibly introduce information bias in the final results; furthermore, anthropometric assessments and densitometries were not performed on the same day, which could lead to changes in the BC during that period, altering the true concurrent validity of the prediction equations included in the study.

By using DEXA as a “gold standard” to evaluate the FP in athletes of both sexes under the age of 18 of the city of Medellin, Colombia, expected to have high athletic performance, the prediction equations of Durnin and Rahaman, Johnston and Five-Component have a “good/excellent” Concurrent Validity; it was “moderate” for the Slaugther equation and “poor” for the Lohman equation.

The equations that were studied when compared to DEXA underestimate the FP (average bias in PP: Five-Component 0,6; Durnin and Rahaman 0,8; Johnston 3,3; Slaughter 5,6), except Lohman, who overestimated it (average bias -12,7 PP). The accuracy of the equations that were included in the research was low, which is reflected in the extensive limits of agreement found for each of them.

The results of this study have several practical implications. The first has to do with the recommendation of the Five-Component method (with the conversion of adiposity to FP) and the Durnin and Rahaman equation to predict the FP in sports groups of both sexes from the city of Medellin, Colombia, under the age of 18, with high-performance expectations, because they showed lower average biases when compared to the results yielded by DEXA and have a “good/excellent” concurrent validity.

On the other hand, none of the equations studied have an acceptable accuracy, a situation that became evident in the extensive limits of agreement found in all of them, which makes it difficult to apply the data yielded to athletes individually, meaning that there are great limitations in these equations' individual clinical application due to the inaccuracy of the values of the FP that they yield, which can lead to errors in decision-making in terms of the athletes' training and nourishing plans, in order to optimize their health and sports performance.

No research was found in the search carried out to validate the prediction equations of the BC compared to DEXA in athletes under the age of 18, which were executed in Colombia, works that are scarce in the world, therefore, it has been proposed to develop specific equations for the population of athletes in the national, regional and local spheres of the country, differentiated by sport discipline, age and sex, if possible, which would allow a better approach to the knowledge of the BC of Colombian athletes and to adjust the training and nourishing plans based on these findings.

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Conflict of interest

Researchers report having no conflicts of interest.

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Table 1. Equations for the prediction of the fat percentage (FP) and adiposity within the population under the age of 18.

Equation	Variables	Population
Slaughter:[8]	• *Folds:* Tricipital and calf.	These date back to 1988; it is recommend for them to be used for children between the ages of 8 and 17; they were built using a sample of 59 people (30 boys and 29 girls), both African-American and Caucasian, from the states of Illinois and Arizona in the United States of America (USA).
Durnin and Ramahan:[9]	• *Folds:* Triceps, biceps, subscapular and suprailiac.	These were developed in 1967 to get the body density (BD) and then calculate the FP using the SIRI equation. The sample consisted of English people (Great Britain), as follows: 38 girls participated in the formula for girls, ranging between the ages of 13,2 and 16,4; 48 boys participated in the formula for boys, ranging between the ages of 12,7 and 15,7.
Lohman:[10]	• *Age,* • *Sex,* • *Body weight* (kg), • *Folds:* Triceps and suprailiac.	This equation was obtained using a sample of 39 boys and 59 girls, all of American Indian origin, from Arizona, USA.
Johnston:[11]	• *Folds:* Triceps, biceps, subscapular and suprailiac.	Equations created in 1988 to calculate BC, and then obtain the FP using the SIRI equation. The sample consisted of 168 girls and 140 boys from Canada, the ages ranging from 8 to 14.
Five-Component Method:[12]	• *Body weight (kg),* • *Height (cm),* • *Height while sitting (cm),* • *Perimeters:* Head, relaxed arm, forearm, thigh, calf, rib cage, waist. • *Diameters:* Biacromial, Biiliocrestal, humerus, femur, anteroposterior and transverse of the rib cage. • *Folds:* Triceps, subscapular, supraspinal, abdominal, thigh, calf.	The five-component method was proposed in 1982 and included one sample of 1669 people of both sexes, university students, school students and athletes, the ages ranging between 6 and 77. This method had an excellent correlation with the dissection of corpses, the value being 0,987.

Table 2. Socio-demographic and anthropometric characteristics of participants (n = 101)

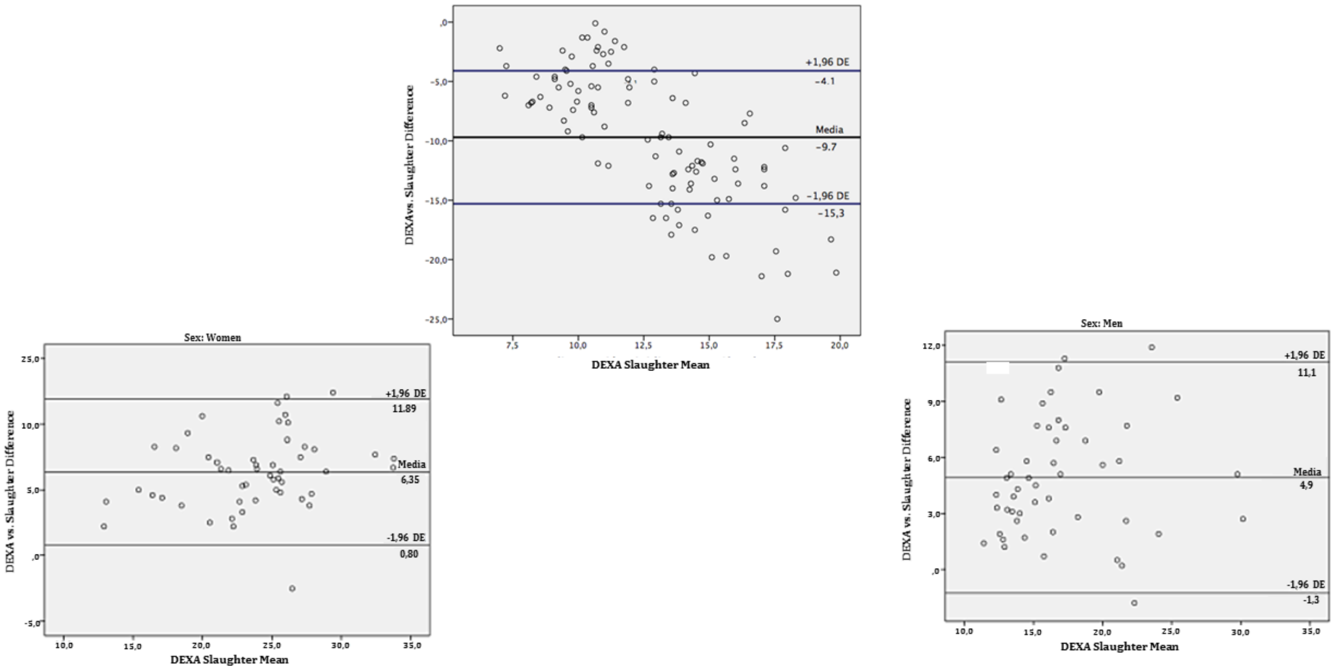
Variables	Women	Men	All
Proportion of participants	51 (50,5%)	50 (49,5%)	101 (100%)
Age (years)**	14,8 (13,0 to 16,0)	14,9 (13,0 to 16,0)	14,8 (13,0 to 16,0)
Schooling (years)**	10,0 (8,0 to 11,0)	9,5 (8,0 to 11,0)	10,0 (8,0 to 11,0)
Socio-economic stratum:			
Low	8 (15,6%)	11 (22,0%)	18,8%
Medium	28 (54,9%)	24 (48,0%)	51,5%
High	14 (27,4%)	15 (30,0%)	28,7%
Sports Life (years)*	6,2 (2,2)	6,7 (2,2)	6,5 (2,2)
Type of sport:			
Resistance	17 (33,0%)	16 (32,0%)	33 (32,7%)
High-Intensity	31 (60,8%)	32 (64%)	63 (62,4%)
Long-Duration	1 (2,0%)	0 (0,0%)	1 (1,0%)
Other	2 (3,9%)	2 (4,0%)	4 (4,0%)
Weight (kg)*	50,9 (8,6)	56,1 (13,8)	53,5 (11,7)
Height (cm)**	160,5 (153,1 to 164,6)	168,3 (151,8 to 173,6)	162,0 (152,5 to 169,8)
BMI (kg/m^2)*	20,1 (2,3)	20,5 (2,5)	20,3 (2,4)
%fat (DEXA)**	27,3 (24,2 to 30,6)	19,2 (15,2 to 22,2)	23,0 (17,7 to 28,2)
%fat (Slaughter)**	20,7 (18,0 to 23,2)	12,9 (11,6 to 16,9)	17,5 (12,5 to 21,7)
%fat (Durnin and Rahaman)**	26,8 (24,6 to 29,3)	17,7 (15,4 to 20,2)	22,1 (17,4 to 27,1)
%fat (Johnston)**	23,7 (21,5 to 26,2)	15,8 (13,4 to 18,5)	19,8 (15,5 to 24,6)
%fat (Lohman)**	37,9 (34,9 to 39,6)	34,2 (31,6 to 37,4)	35,9 (32,8 to 38,9)
%adiposity (Five-Component)**	34,3 (29,7 to 37,8)	27,4 (25,4 to 30,9)	30,5 (26,9 to 35,4)

*Values provided in means and standard deviations;
**Values provided in averages and interquartile ranges;
BMI = body mass index; DEXA = dual energy x-ray absorptiometry

Table 3. Concurrent validity of the body fat percentage prediction equations

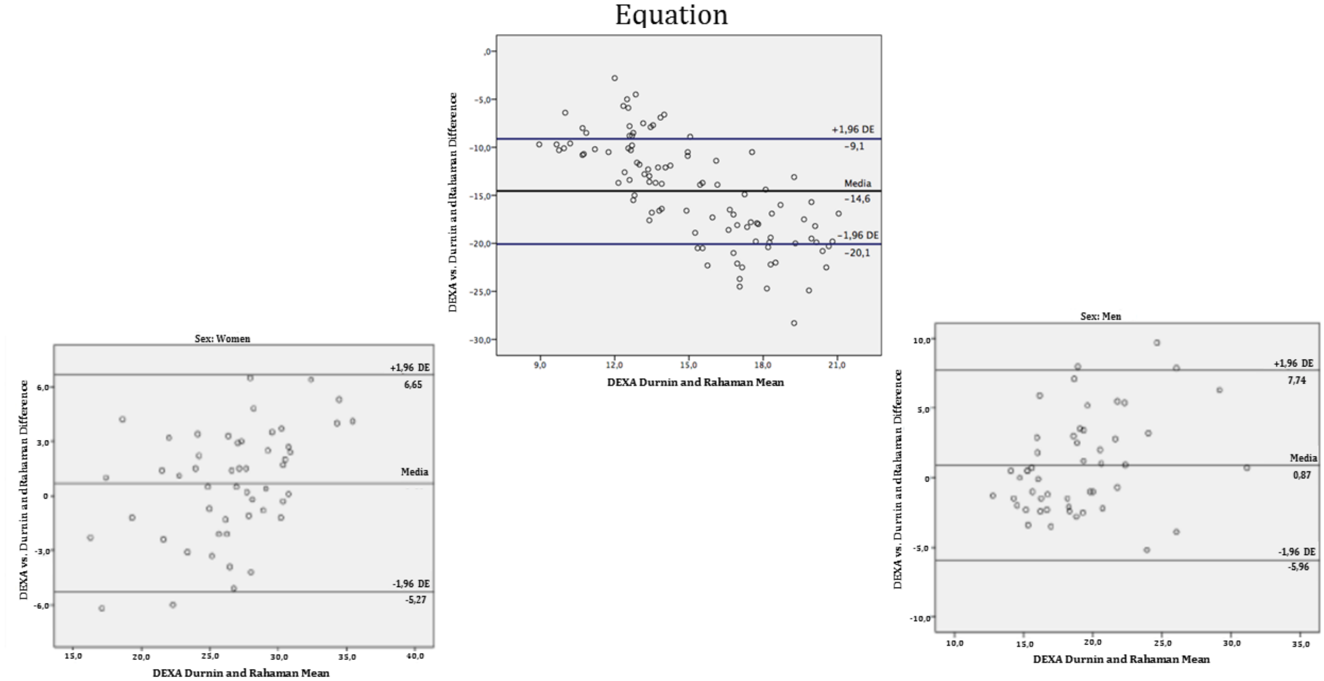
"Gold Standard"	Prediction Equation	Sample	ICC	CI95%
DEXA	Slaughter	Women	0,618	-0,161 to 0,880
		Men	0,666	-0,216 to 0,888
		All	0,741	-0,186 to 0,921
	Durnin and Ramahan	Women	0,874	0,779 to 0,928
		Men	0,795	0,640 to 0,884
		All	0,912	0,867 to 0,941
	Lohman	Women	0,341	-0,094 to 0,715
		Men	0,082	-0,081 to 0,298
		All	0,248	-0,130 to 0,590
	Johnston	Women	0,736	-0,111 to 0,908
		Men	0,732	0,285 to 0,878
		All	0,833	0,290 to 0,935
	Five-Component (%fat)	Women	0,770	0,593 to 0,870
		Men	0,800	0,648 to 0,887
		All	0,853	0,783 to 0,901

DEXA = dual energy x-ray absorptiometry; ICC = intraclass correlation coefficient; CI95% = 95% confidence interval



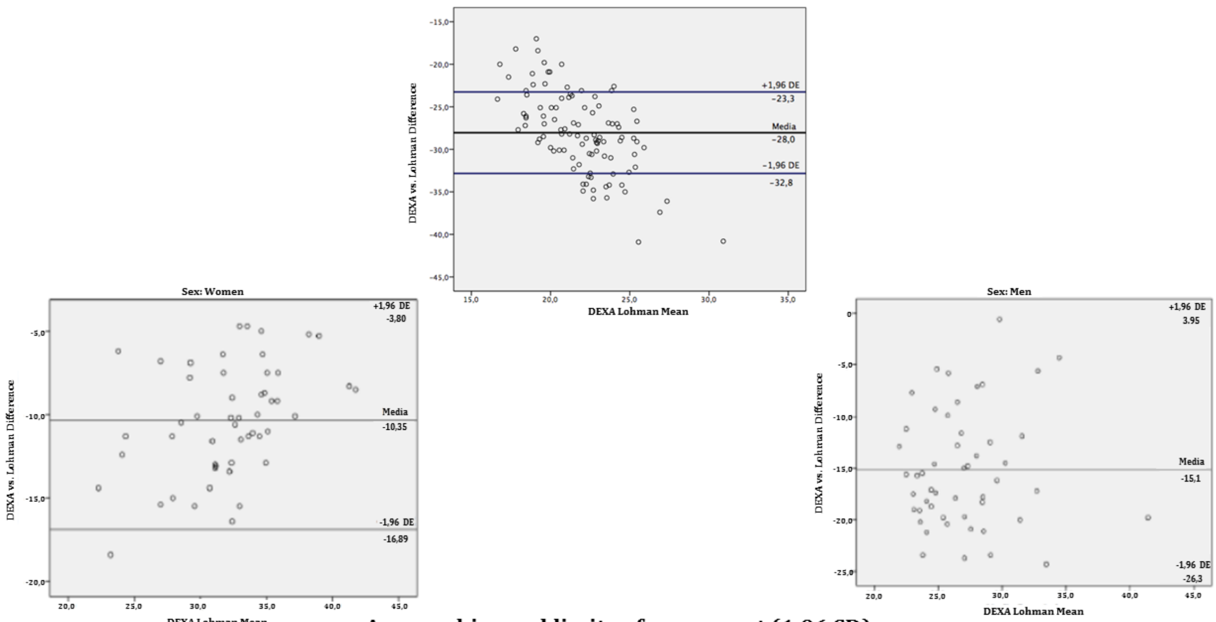
Average bias and limits of agreement (1.96 SD)

Figure 1. Bland and Altman Graphs – Fat Percentage Concordance Analysis: DEXA vs. Slaughter Equation



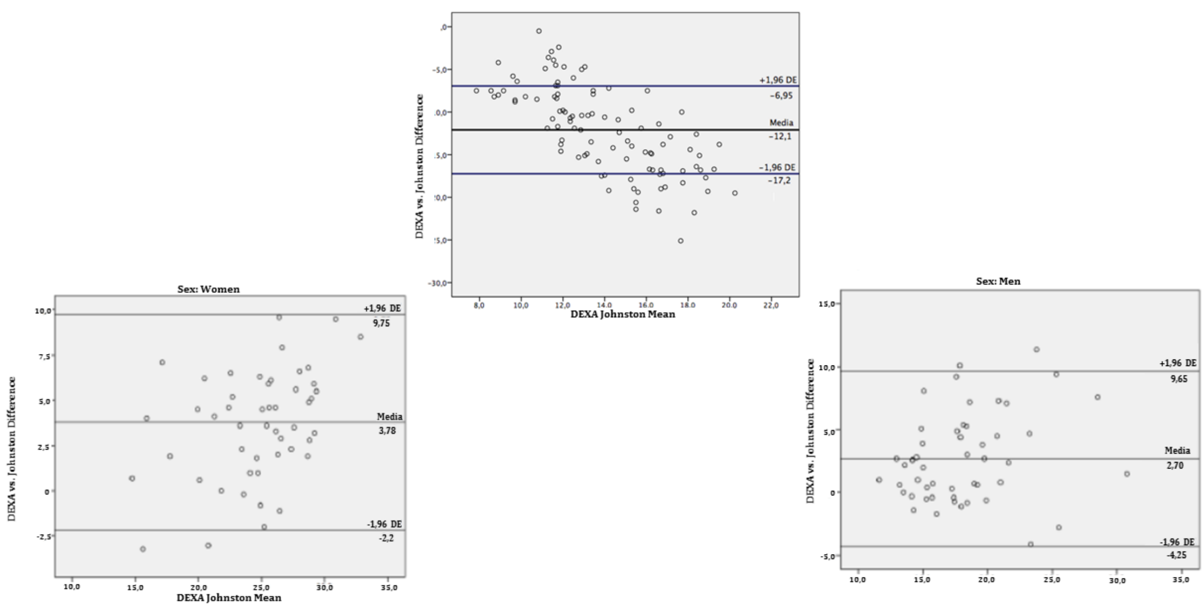
Average bias and limits of agreement (1.96 SD)

Figure 2. Bland and Altman Graphs – Fat Percentage Concordance Analysis: DEXA vs. Durnin and Rahaman Equation



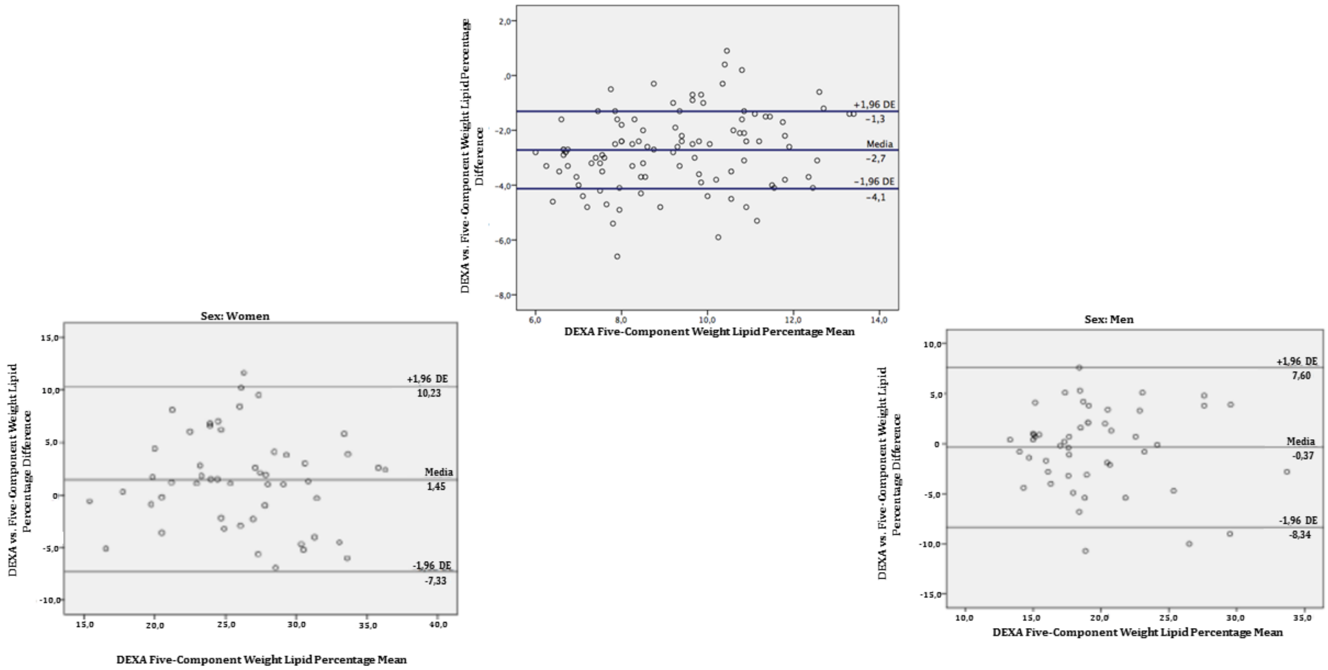
Average bias and limits of agreement (1.96 SD)

Figure 3. Bland and Altman Graphs – Fat Percentage Concordance Analysis: DEXA vs. Lohman Equation



Average bias and limits of agreement (1.96 SD)

Figure 4. Bland and Altman Graphs – Fat Percentage Concordance Analysis: DEXA vs. Johnston Equation



Average bias and limits of agreement (1.96 SD)

Figure 5. Bland and Altman Graphs – Fat Percentage Concordance Analysis: DEXA vs. Five-Component Equation