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ORIGINAL

PREDICTION EQUATIONS OF SKINFOLD IN CHILDREN OF PRIMARY SCHOOL

ECUACIONES DE PREDICCIÓN DE PLIEGUES CUTÀNEOS EN ESCOLARES

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Conflict of Interest: None to declare

ABSTRACT

The aim of this paper is to create equations that predict the skinfold measures for school children 6 to 13 years old. Fourteen resulting equations were derived to estimate some measures of skinfold. The equations were validated with random samples of 479 girls and 541 boys in the state of Puebla and 2 other random samples of the state of Veracruz with 155 girls and 146 boys respectively; direct measurements were performed with the methodology and units ISAK (International Society for the Advancement of Kinanthropometry.

KEYWORDS: anthropometry, biomechanics sports, digital technology, skinfold thickness.

RESUMEN

El objetivo de este trabajo es crear ecuaciones que estimen las medidas de los pliegues cutáneos para escolares de 6 a 13 años de edad. Como resultado se obtuvieron catorce ecuaciones que estiman algunos pliegues cutáneos. Las ecuaciones se validaron con muestras aleatorias de 479 niñas y 541 niños del estado de Puebla y otras 2 muestras aleatorias del estado de Veracruz con 155 niñas y 146 niños respectivamente; las mediciones directas se realizaron con la metodología y unidades ISAK (International Society for the Advancement of Kinanthropometry.

PALABRAS CLAVE: Antropometría, Biomecánica deportiva, Tecnología digital, Pliegues cutáneos.

INTRODUCCIÓN

The development of children can help us understand the characteristics of human beings in their various activities, gender, age, short, medium and long term as well as the features that have the generations from different perspectives (Koutedakis, 2009) (Ureña Bonilla, Blanco Romero, & Salas Cabrera, 2015). Thus indicators may be generated for health care when compared with a reference value, setting appropriate cutting points (Flores H., 2006).

Considering that, anthropometric data can be classified into two types: linear distance and circumference; the linear type is defined as the distance between two anatomical landmarks, and that the circumferential type is defined as the length that can be closed around the body part in the appropriate place (Sheng-Fuu, Shih-Che, & Kuo-Yu, 2010), perform these anthropometric measurements, takes time and money by using standard methodologies (Bastos Moreira, 2008) (Wang, Wu, Lin, Yang, & Lu 2007), it is desirable that measurement alternatives exist that are validated.

From this perspective, the aim is to create a set of equations that can estimate the size of triceps skinfold (PTRI), subscapular skinfold (PSUB), biceps skinfold (PBI), Iliac Crest skinfold (PCE), spinal supra skinfold (PSE), thigh frontal skinfold (PMF), leg media skinfold (PPM) for school Children 6 to 13 years old of chronological age, and software to perform digital anthropometry.

MATERIALS AND METHODS

PARTICIPANTS

The study was conducted in the municipality of Puebla of the city of Puebla in México, taking a random sample of urban, public and private primary schools of (eduPortal.com.mx, 2011), random sample of 705 children (Table 1) and 629 children (Table 2) were taken to create multiple regression equations, and these equations were validated with 479 girls (Table 3) and 541 children (Table 4) corresponding to the same samples, direct measurements were made in June 2012 in their schools; likewise, were randomly selected from 13 urban, public and private elementary schools in the state of Veracruz, in the municipality of Veracruz, 146 children (Table 5) and 155 girls (Table 6), to validate the equations with different samples, these direct measurements were made on May 22, 2013 at their schools.

To all the children were measured mass (WT), stature (EST) with traction; skinfolds: triceps (PTRI), subscapular (PSUB), biceps (PBI), Illiac Crest (PCE), Supraspinal (PSE), abdominal, front thigh (PMF), Medial Calf (PPM); circumferences: waist circumference minimum, gluteal circumference, arm relaxed circumference (CBRAZOREL), minimum waist girth (CCINTURAMIN), flexed and outstretched arm girth, girth calf maximum (CPIERNAMAX); breadths: humerus (DHUMER), femur (DFEMUR); according to ISAK (International Society for the Advancement of Kinanthropometry) to have a standard measurement method, and date of birth (AGE) was requested to calculate their chronological age.

Table 1. Characteristics of girls to construct the equations, n=705

Variable	Mean (standard deviation)	Median	Minimum – maximum
Mass (Kg)	34,08156 (11,79409)	32,5	11,5-81,5
Stature (cm)	135,2804 (13,02719)	135,6	104,6-177
Skinfold Triceps (mm)	12,38525 (4,411232)	11,75	2,3-30,1
Skinfold Subscapular (mm)	10,52156 (5,236291)	8,75	3,5-37
Skinfold Biceps (mm)	8,356028 (3,884591)	7,5	2,5-26,05
Skinfold Iliac Crest (mm)	15,01695 (7,196236)	13,75	3-39
Skinfold Supraspinal (mm)	11,87035 (6,673433)	10	0,5-38
Skinfold Front thigh (mm)	17,02993 (6,794842)	15,75	5,25-61
Skinfold Medial Calf (mm)	12,45 (5,802209)	11	3,25-41,5
Girth Arm relaxed (cm)	21,45938 (3,566636)	21,2	7-35,25
Girth Waist minimum (cm)	61,77688 (9,596387)	60,8	18-97,55
Girth Calf maximum (cm)	27,69652 (5,253093)	27,25	2,5-93-15
Breadth Humerus (cm)	5,376397 (1,247697)	5,3	3,7-34,25
Breadth Femur (cm)	8,023362 (3,12044)	7,9	4,55-88

Table 2. Characteristics of boys to construct the equations, n=629

Variable	Mean (standard deviation)	Median	Minimum – maximum
Mass (Kg)	40,47751 (11,05549)	39	15-81
Stature (cm)	136,3177 (12,84677)	136	107,95-175-4
Skinfold Triceps (mm)	11,87179 (4,998682)	11	4-32,5
Skinfold Subscapular (mm)	9,704928 (5,744996)	7,25	1-36,5
Skinfold Biceps (mm)	7,640223 (3,960186)	6,5	2-21,5
Skinfold Iliac Crest (mm)	14,24236 (8,438113)	11,75	2-37,75
Skinfold Supraspinal (mm)	11,34603 (7,707051)	8,5	2,5-46
Skinfold Front thigh (mm)	15,01285 (6,431181)	13,75	3-35,5
Skinfold Medial Calf (mm)	11,70715 (6,015475)	10	2,5-35,25
Girth Arm relaxed (cm)	21,31717 (3,720032)	21	6,8-33,45
Girth Waist minimum (cm)	63,64308 (10,87881)	62	5,7-94,35
Girth Calf maximum (cm)	28,01514 (4,116762)	27,775	15-47,7
Breadth Humerus (cm)	5,601308 (0,6493822)	5,55	3,7-9,5
Breadth Femur (cm)	8,416608 (0,8390165)	8,4	5,5-11,05

Table 3 and 4 describe the characteristics of the samples of the state of Puebla, to validate the equations with the same people of the samples that were created equations.

Table 3. Characteristics of girls to validate the equations, n=479

Variable	Mean (standard deviation)	Median	Minimum – maximum
Mass (Kg)	33,53184 (11,62495)	31,4	12,2-80,8
Stature (cm)	134,9477 (13,05043)	134	106,7-174
Skinfold Triceps (mm)	12,36897 (4,427739)	11,5	4-28,25
Skinfold Subscapular (mm)	10,29151 (5,0362)	9	3-30,05
Skinfold Biceps (mm)	8,242034 (4,339225)	7,25	3-55
Skinfold Iliac Crest (mm)	14,65273 (7,000449)	14	3,5-38
Skinfold Supraspinal (mm)	11,40734 (6,436997)	10	2,5-35,5
Skinfold Front thigh (mm)	16,26572 (6,175563)	15	6-42
Skinfold Medial Calf (mm)	12,12275 (5,373995)	11	4-31-5
Girth Arm relaxed (cm)	21,28753 (3,80201)	20,8	4-35
Girth Waist minimum (cm)	61,40818 (9,540226)	60,5	5,5-94
Girth Calf maximum (cm)	27,57715 (4,348333)	27,1	19,25-66-5
Breadth Humerus (cm)	5,52804 (3,244278)	5,3	4,05-54
Breadth Femur (cm)	7,86043 (0,7691566)	7,85	4,8-10,1

Table 4. Characteristics of boys to validate the equations, n=541

Variable	Mean (standard deviation)	Median	Minimum – maximum
Mass (Kg)	33,52802 (11,24576)	30,75	14,9-81
Stature (cm)	134,5654 (12,58272)	133,7	106,8-173,1
Skinfold Triceps (mm)	11,2768 (4,861312)	10	3,5-31-5
Skinfold Subscapular (mm)	9,295833 (5,541476)	7	3-36,05
Skinfold Biceps (mm)	7,560093 (4,117071)	6,5	2-26,1
Skinfold Iliac Crest (mm)	13,47056 (7,990739)	11	3-48
Skinfold Supraspinal (mm)	10,59787 (7,311645)	7,875	2-45,05
Skinfold Front thigh (mm)	14,92657 (6,886113)	13	4-58
Skinfold Medial Calf (mm)	11,27745 (5,877952)	10	3-41
Girth Arm relaxed (cm)	20,89194 (3,611476)	20,175	6,7-35,45
Girth Waist minimum (cm)	62,57157 (10,61484)	60,8	17,7-101,7
Girth Calf maximum (cm)	27,62028 (4,948647)	26,8	15-69,4
Breadth Humerus (cm)	5,650519 (3,504332)	5,425	4-85,7
Breadth Femur (cm)	8,362565 (1,280854)	8,3	5,6-31,1

Tables 5 and 6 describe the characteristics of the samples of the state of Veracruz, to validate the estimating equations skinfold, using samples of different people and locality.

Table 5. Characteristics of boys of state of Veracruz to validate the equations, n=146

Variable	Mean (standard deviation)	Median	Minimum – maximum
Mass (Kg)	36,83566434(12,6723332)	34	13,1-92,5
Stature (cm)	136,58 (12,6641149)	136	109-169
Skinfold Triceps (mm)	12,199726 (4,82635572)	11	4-26
Skinfold Subscapular (mm)	10,1342466 (6,37072111)	7,75	3-36
Skinfold Biceps (mm)	8,95068493 (4,87834531)	7,75	2,5-28,5
Skinfold Iliac Crest (mm)	13,0373288 (6,84314428)	13	4-36
Skinfold Supraspinal (mm)	10,8684932 (6,86078546)	9	3-38
Skinfold Front thigh (mm)	15,9657534 (6,58420108)	14,5	5-42
Skinfold Medial Calf (mm)	13,9657534 (5,85090119)	12,75	4-33
Girth Arm relaxed (cm)	22,1407534 (4,49833304)	21,35	6,7-36,7
Girth Waist minimum (cm)	64,5821918 (12,9618351)	63,5	8,6-102
Girth Calf maximum (cm)	28,7541096 (4,98330606)	28,1	16-44,3
Breadth Humerus (cm)	6,08275862 (4,62781836)	5,6	4-61
Breadth Femur (cm)	8,65551724 (0,85500791)	8,6	6,3-10,9

Table 6. Characteristics of girls of state of Veracruz to validate the equations, n=146

Variable	Mean (standard deviation)	Median	Minimum – maximum
Mass (Kg)	35,59668874 (12,49581873)	32,9	15,8-73,8
Stature (cm)	135,974342 (13,8005697)	134,85	110-195
Skinfold Triceps (mm)	13,3599342 (4,75722449)	13	2-27
Skinfold Subscapular (mm)	10,8888158 (5,67513679)	9	4-34
Skinfold Biceps (mm)	9,81973684 (3,90281679)	9	4-24
Skinfold Iliac Crest (mm)	14,2703947 (6,39973107)	14	4,5-39
Skinfold Supraspinal (mm)	11,7263158 (5,78934749)	10,25	3-29
Skinfold Front thigh (mm)	17,55322895 (6,23110742)	16	7,7-41
Skinfold Medial Calf (mm)	14,0335526 (5,37181906)	13	6-30
Girth Arm relaxed (cm)	21,9677632 (3,85596943)	21,5	8,3-31,9
Girth Waist minimum (cm)	62,6071053 (10,9749244)	62	6,58-95,4
Girth Calf maximum (cm)	29,7447368 (5,85897635)	28,6	19-52
Breadth Humerus (cm)	5,76032895 (3,74592734)	5,4	4,04-51
Breadth Femur (cm)	8,13440789 (0,86346969)	8,1	4,7-10,5

MATERIAL

The measuring equipment used is the ISAK recommended; Anthropometric Herpenden caliper kit Rosscraft with 10 g/mm2, microlife digital scale, anthropometric drawer Nuevo Leon, metal tape, anthropometer, record sheets measurements squad.

METHODS

Measurement methodology and units of ISAK (International Society for the – advancement of Kinanthropometry) for direct action was used.
The research was adjusted to the Declaration of Helsinki of 2008, why there were children who refused to participate; the chronological age of the children was between 6 and 13 years and the first to sixth grade education.

Validating estimation equations skinfold was performed by calculating the repeatability (B. Mandeville, 2007) and according to the Pearson correlation coefficient for the case to compare estimates with direct measurements to different people and created regression equations used Bland – Altman graphic.

STATISTICAL ANALYSIS

In the case of the random number sampling and data analysis were conducted in the language R (R Core Team, 2012) (R Core Team, 2013), the adjustment was verified with the plot (fit) for the case residual. So in the case of the repeatability of the estimating equations skinfold the concordance coefficient Lawrence – Lin (Lawrence & Lin, 1989), the library Agreement was used (Yu & Lin, 2012); multiple regression equations were created with the lm function.

The database is captured in Excel (Microsoft, 2010)

For calculating the accuracy of two methods it was used formula

$$Precision = \sqrt{2} * \frac{(SD_T + SD_E)}{2}$$ (Press & Fisher, 2008)

RESULTS

Girls with the simple described in Table 1, the regression equations of Table 7 were constructed.

Table 7. Regression equations for prediction of skin folds in girls 6-13 years of chronological age of primary education (ISAK measurement units for the parameters of equations).

Equations for girls	R squared adjusted
(1) PTRI= -5,03431-EST(0,05117) +CCINTURAMIN(0,08649) +CBRAZOREL(0,88531)	0,6206
(2) PSUB= -13,59314-EST(0,04737)+ CCINTURAMIN(0,18240) +CBRAZOREL(0,89730)	0,6937
(3) PBI= (-6,30905)+CBRAZOREL(0,79544)-EDAD(0,25009)	0,4507
(4) PCE= -21,96109+CCINTURAMIN(0,21299)+ CBRAZOREL(1,11002)	0,6349
(5) PSE= -22,97773 + CCINTURAMIN(0,23677) + CBRAZOREL(1,04481) – EDAD(0,22883)	0,6762
(6) PMF= - 12,03850+ CCINTURAMIN(0,11188) + CBRAZOREL(1,13412) – EDAD(0,61324)+ CPIERNAMAX(0,10331) + DFEMUR(0,10671)	0,5057
(7) PPM= - 14,34734 + CCINTURAMIN(0,12778) + CBRAZOREL(1,05928) – EDAD(0,39815)	0,5872

Children with sample described in Table 2, the equations of Table 8 were constructed.

Table 8. Regression equations for prediction of skin folds in children aged 6-13 years of chronological age of primary education (ISAK measurement units for parameters of the equations).

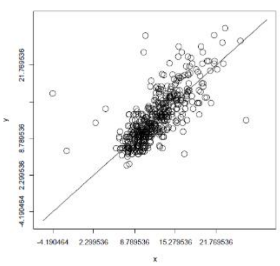
Equations for boys	R squared adjusted
(1) PTRI= -1,85012 - EST(0,11442) +CCINTURAMIN(0,07186) +CBRAZOREL(1,16081)	0,6833
(2) PSUB= -7,90235 - EST(0,12206)+ CCINTURAMIN(0,13823) +CBRAZOREL(1,19386)	0,7056
(3) PBI= -3,85205 - EST(0,04788)+ CBRAZOREL(0,96191) – EDAD(0,25483)	0,581
(4) PCE= -17,04008 – EST(0,13540) + CCINTURAMIN (0,16752)+ CBRAZOREL(1,83990)	0,7087
(5) PSE= -20,60825-EST(0,07050)+CCINTURAMIN(0,16157)+CBRAZOREL(1,59227)-EDAD(0,27270)	0,7378
(6) PMF= - 5,45435 – EST(0,06822) + CCINTURAMIN(0,09429) + CBRAZOREL(1,42063)-EDAD(0,65323)	0,5844
(7) PPM= -10,55279 –EST(0,03679)+ CCINTURAMIN (0,05649) + CBRAZOREL(1,32566) – EDAD(0,46952)	0,6271

Contrasting direct measurements of people of Puebla (Tables 3 and 4) against estimates folds measurements obtained with the predictive equations of the same sample. Tables 9 and 10 are obtained, which verify the reproducibility and reliability estimating equations skinfold.

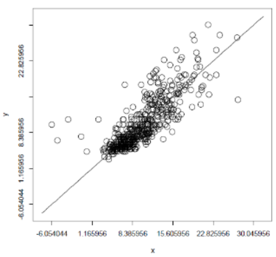
Table 9. Wasted (Direct measurements =y, Equation Forecast=x) Coefficient of Concordance Lawrence – Lin (L.Lin) and Pearson Correlation girls.

Skinfold
L-Lin
Pearson
Residuals

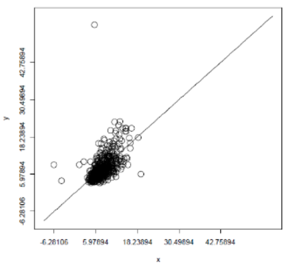
(1) PTRI
L.Lin=0,7206
Pearson=0,7337836



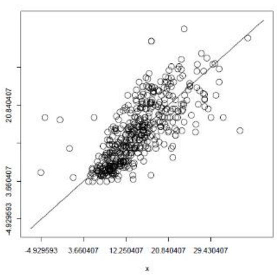
(2) PSUB
L.Lin=0,7993
Pearson=0,8033591



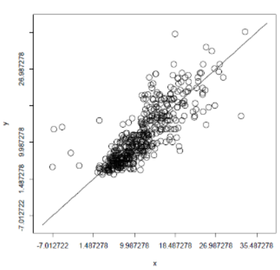
(3) PBI
L.Lin=0,4671
Pearson=0,5117825



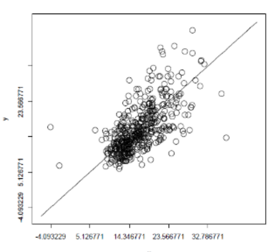
(4) PCE
L.Lin=0,7292
Pearson=0,738086



(5) PSE
L.Lin=0,7997
Pearson=0,8053601



(6) PMF
L.Lin=0,6388
Pearson=0,6536768



(7) PPM
L.Lin=0,7183
Pearson=0,7245369

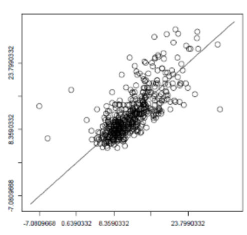
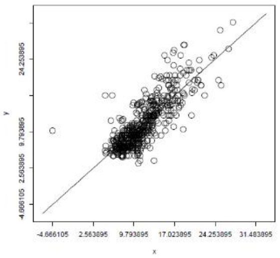


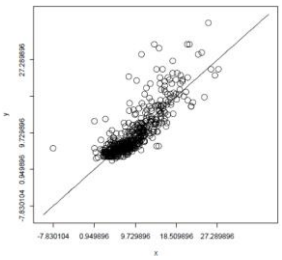
Table 10. Waste (Direct measurements=y, Equation Forecast=x), coefficient of concordance Lawrence – Lin (L.Lin) and Pearson Correlation Coefficient in Boys.

Skinfold
L-Lin
Pearson
Residuals

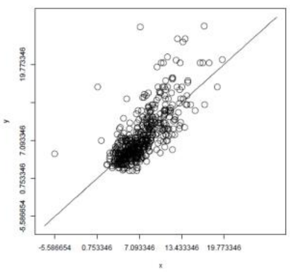
(1) PTRI
L.Lin=0,7979
Pearson=0,8138393



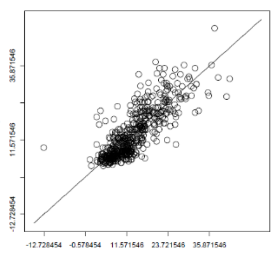
(2) PSUB
L.Lin=0,813
Pearson=0,8252104



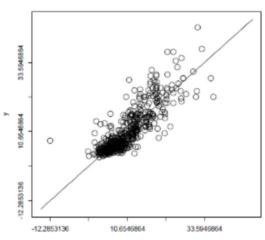
(3) PBI
L.Lin=0,6933
Pearson=0,7330324



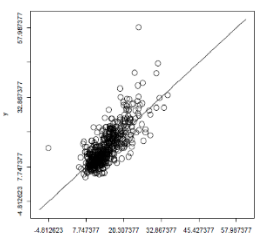
(4) PCE
L.Lin=0,8087
Pearson=0,8146914



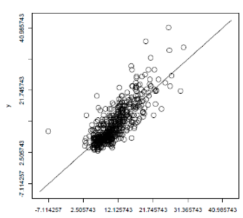
(5) PSE
L.Lin=0,8331
Pearson=0,8404457



(6) PMF
L.Lin=0,7246
Pearson=0,7614115



(7) PPM
L.Lin=0,7804
Pearson=0,8024939

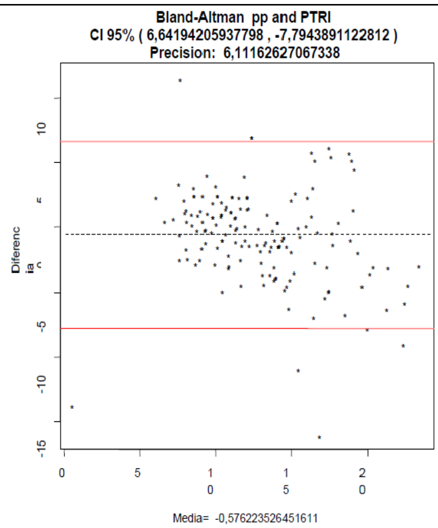


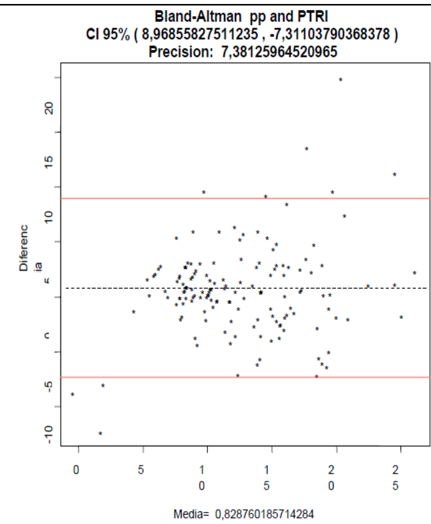
Global data bases of Puebla and Veracruz no adjustment was used in this work are in (Buendía Lozada E. R., 2014).

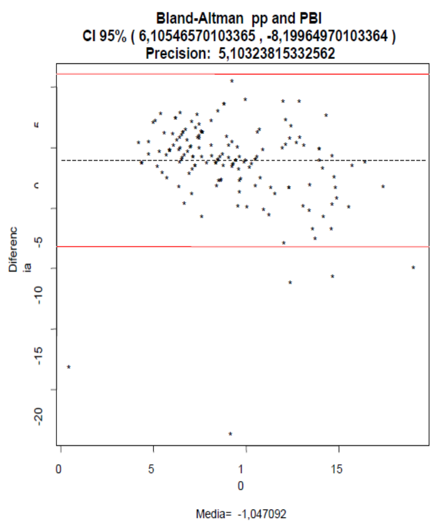
The Bland – Altman graphic Table 11 describe the differences and precision were obtained when using sample data of Tables 5 and 6 with the estimates of the corresponding equations in children of Veracruz.

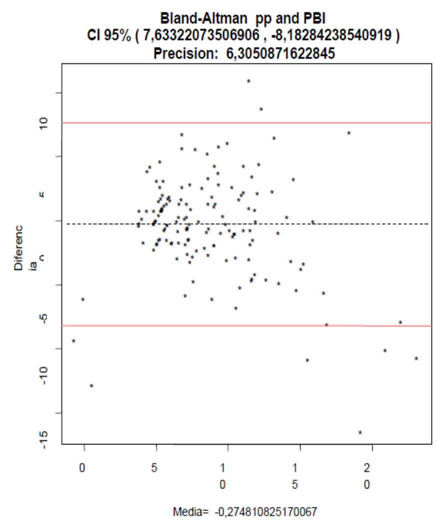
Table 11. Bland – Altman in girls left side and boys right side (Direct measurements = Skinfold corresponding, estimate equation skinfold= pp)

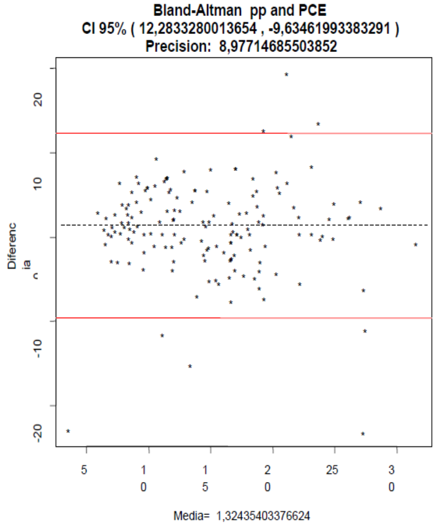
Girls	Boys

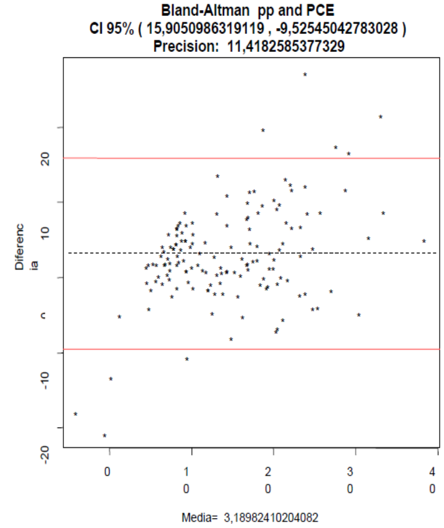


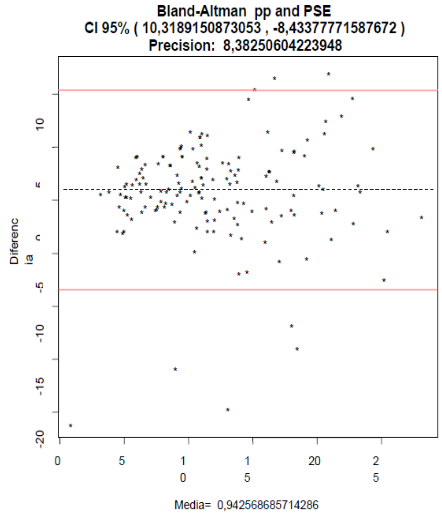


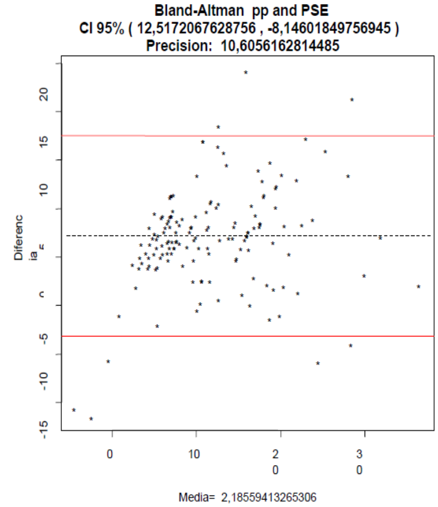


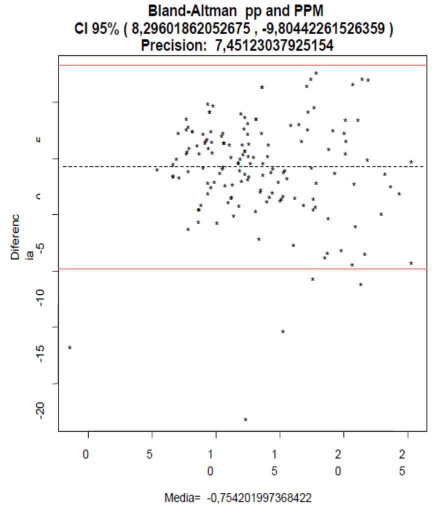


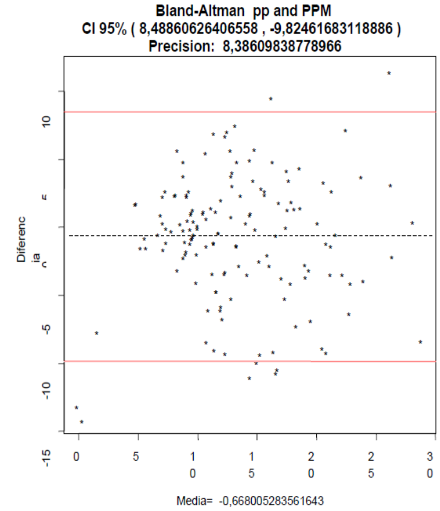

Bland-Altman pp and PCE
CI 95% (12,2833280013654 , -9,63461993383291)
Precision: 8,97714685503852
Diferenc ia
Media= 1,32435403376624

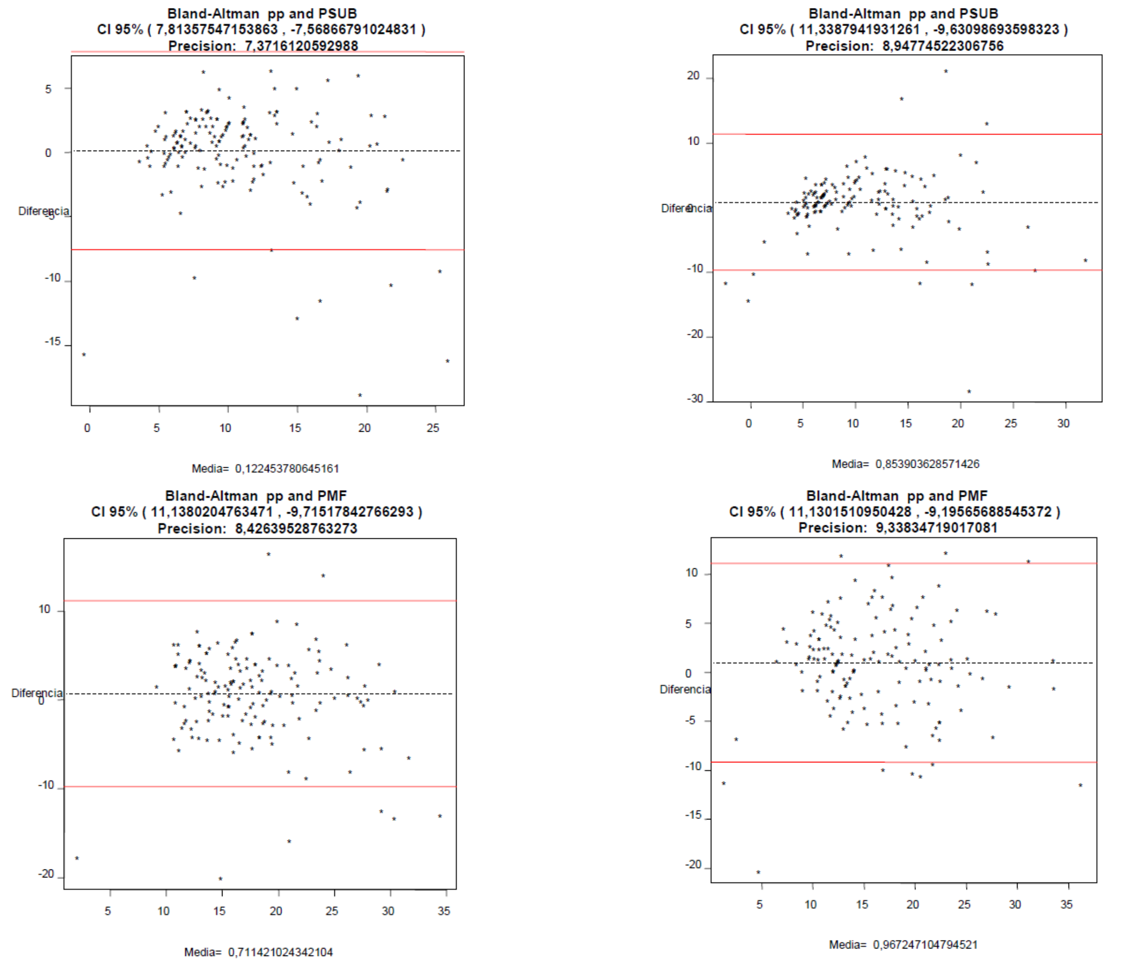

Bland-Altman pp and PCE
CI 95% (15,9050986319119 , -9,52545042783028)
Precision: 11,4182585377329
Diferenc ia
Media= 3,18982410204082


Bland-Altman pp and PSE
CI 95% (10,3189150873053 , -8,43377771587672)
Precision: 8,38250604223948
Diferenc ia
Media= 0,942568685714286


Bland-Altman pp and PSE
CI 95% (12,5172067628756 , -8,14601849756945)
Precision: 10,6056162814485
Diferenc ia
Media= 2,18559413265306


Bland-Altman pp and PPM
CI 95% (8,29601862052675 , -9,80442261526359)
Precision: 7,45123037925154
Diferenc ia
Media= -0,754201997368422


Bland-Altman pp and PPM
CI 95% (8,48860626406558 , -9,82461683118886)
Precision: 8,38609838778966
Diferenc ia
Media= -0,668005283561643



DISCUSSION AND CONCLUSIONS

The equations of tables 7 and 8 are validated in order to estimate measures of skinfolds: triceps (PTRI), subscapular (PSUB), biceps (PBI), with the lowest level of confidence, iliac crest (PCE), supraspinale (PSE), front thigh (PMF), medial calf (PPM); for girls and school children 6 – 13 years of chronological age in the municipalities of Puebla and Veracruz, give the possibility to extend its use in physical education, thus expanding alternative measurement, as suggested (Bastos Moreira, 2008) (Wang, Wu, Lin, Yang, & Lu, 2007).

To increase portability of measuring instruments according to (Kohlschutter & Herout, 2012), it was designed and created an application computing, which uses perpendicular photograph the body segments to capture or approximate the parameters of the equations for estimating skinfold tables 7 and 8; to calibrate the measurements, use a reference object of known size, the software adjusts the extent to photograph an actual measurement by rule of tree; calculates the linear

Euclidean distance to the diameters and lengths and circumferences with an elliptical perimeter model (MathsFun, 2013). In the case of boys the data, high waist circumference, arm circumference relaxed, and for girls are needed: minimum waist girth, relaxed arm circumference, leg circumference and maximum diameter of the femur; that can be calculated by checking with the mouse pointer in the points defining extreme measure of body segments in the corresponding medial part, and children need to capture their chronological age, height and weight; avoiding this software be invasive to people as described (Herianto, probandari, & Darmawan, 2010). Ad computer application described above is available in (ER Lozada Buendia, 2014), which has the same potential problems referred by (Kohlschütter & Herout, 2012) and more research needs to improve.

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