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ABSTRACT

Anthropometric investigators should be concerned about any significant measurement error of their metric data in order to safeguard the integrity of their scientific investigation. This study aimed to demonstrate the application as well as to evaluate the process of Technical Error of Measurements (TEM), relative Technical Error of Measurements (rTEM) and Coefficient of Reliability (R) for precision estimates in terms of intra-observer error using some hand and foot measurements along with the body height of 349 male young adults (college-going students) who were selected from six different randomly chosen co-educational general degree colleges that belonged to five different subdivisions of North 24 Parganas, West Bengal, India.(Incomplete sentence)

All these colleges were chosen from their respective subdivision-wise list of co-educational general degree colleges following a simple random sampling technique.

Along with the demonstration, the output of the application showed that height was found to have the second lowest TEM (0.06 cm), the lowest rTEM (0.04%), and the highest reliability in terms of R-value (1.00). Besides height, all other measurements showed a minimal margin of technical errors in terms of TEM (0.05–0.07 cm) and rTEM (0.20%–0.70%) as well as higher reliability for their accuracy (R ranges from 0.989–0.999). Overall, it concluded that TEM and other estimates might be some reliable tools for better determining the precision and reliability of the anthropometrist for taking anthropometric measurements.

Keywords: *Anthropometry, Absolute TEM, relative TEM, Coefficient of Reliability, precision estimates, measurement error.*

INTRODUCTION

Forensic Science and investigation include a wide range of specialized domains that are based on the core concepts of different scientific disciplines. One of these important domains is forensic anthropology. From a biological perspective, it often uses anthropometric measurements to draw the conclusion of an investigation. Anthropometry, unlike other methods, can serve the purpose in a very flexible way using very simple, easy, practical, inexpensive, and non-invasive techniques.

The error in the measurement readings may increase even when numerous observers or a single observer may collect a series of repeated measurements. Poor precision of the data may mislead the investigation by giving inaccurate output as well as imperfect correlations with other variables. Therefore, estimation of measurement errors should be an important component of physical measurement-related investigations, which contemporary studies tend to underreport (Arroyo et al., 2010).

These errors in measurements can easily be estimated through the process of Technical Error of Measurements (TEM). A single observer may make intra-observer errors when performing the same measurements on the same participant on multiple occasions, whereas the same measurements taken by two distinct observers on the same participant may generate inter-observer errors. Initially, Mueller and Martorell (1988) and then Frisancho (1990) put emphasis on two distinct estimations to verify the accuracy and reliability of the anthropometric measurements: Technical Error of Measurement (TEM) and Coefficient of Reliability (R). Later, Ulijaszek and Lourie (1994) backed the accuracy of these two methods for detecting errors (Lewis, 1999).

OBJECTIVES

The present study aims to demonstrate the detailed application and evaluation of some well-known estimates to assess the precision and reliability of anthropometric data in terms of intra-observer error using some linear anthropometric measurements (hand and foot dimensions along with body height) obtained from the study population of the North 24 Parganas district of West Bengal, India. More precisely the present study has been conducted-

- To demonstrate the application of three specific estimates such as Technical Error of Measurements (TEM), relative Technical Error of Measurements percentage (rTEM), and Coefficient of reliability (R) to measure intra-observer error and reliability of anthropometric data.
- To verify the reliability of these estimates by applying them, along with Bland-Altman analysis, to empirical data obtained from the male young student population of North 24 Parganas, West Bengal, India.

MATERIAL AND METHODS

Study area and Participants

This cross-sectional study comprised of 349 male young adults (ages 18 to 25) selected from six different randomly chosen co-educational general degree colleges that belonged to five different subdivisions of North 24 Parganas, West Bengal, India. All these colleges were chosen from their respective subdivision-wise list of co-educational general degree colleges following a simple random sampling technique. All the participants (college-going students) were selected through a total enumeration process with their written consent after getting the permission of respective principals and HoDs. Students residing outside the North 24 Parganas district were not included in this study. Additionally, all the participants were confirmed to be free of skeletal or other deformities before being included.

Anthropometric measurements

Each individual's anthropometric measures, including height (vertex to standing platform), hand length (linear distance between the third finger's tip and the middle of a line connecting the forearm's styloid process of the radius and ulna bones), hand breadth (linear distance between the prominence on the lateral aspect of the second metacarpal's head and the prominence on the medial aspect of the fifth metacarpal's head.), foot length, and foot breadth on both sides, were obtained and recorded to the closest 0.1 centimeter (Norton, 2018; Paul et al., 2018, 2020; Rostamzadeh et al., 2021). The vertical height, or stature, was measured using Martin's Anthropometer. For measuring hand length, hand breadth, and foot breadth, Martin's sliding calliper was utilized; and for measuring foot length, a rod compass was used. As recommended by Lohman et al. (1988), all measurements were taken in accordance with standard procedures. All the measurements were obtained twice by the same anthropometrist on two different occasions to estimate the probable intra-observer errors. Measurements on those two different occasions were performed consecutively on the same day.

Ethical consideration

Before being conducted, this study got institutional ethical clearance from the competent authority of West Bengal State University (Institutional Ethics Committee for Research on Human participants, West Bengal State University) with approval number WBSU/IEC/30/02, dated October 7, 2021. Along with this, formal consent was obtained from every participant before taking measurements.

Statistical analysis

To determine Intra-observer errors as well as the reliability of the measurements taken during fieldwork, three commonly used precision estimates have been performed: Technical Error of Measurements (TEM), Relative TEM (rTEM), and Coefficient of reliability (R). Among them, TEM is the most common and preliminary estimation, which refers to the square root of measurement error variance (Arroyo et al., 2010). TEM has been calculated for all the measurements with the following equation (Arroyo et al., 2010).

$$\mathrm{TEM} = \sqrt{}(\sum \mathrm{D}\hat{}2\ /2\mathrm{N})$$

Where *D* refers to the deviation between the two values of the same measurements obtained on two occasions from the same participants by the same observer, and *N* refers to the total number of participants. TEM expresses its value in the same unit as the respective measurement.

To transform this absolute TEM into a percentage value, relative TEM (rTEM) had to be calculated. This estimate has been calculated for all the measurements using the following equation (Arroyo et al., 2010).

$$\mathrm{rTEM} = (\mathrm{TEM}/\mathrm{VAV}) * 100$$

Where *VAV (variable* average value) refers to the arithmetic mean of the mean values which have been drawn from both occasions of the same anthropometric measurements obtained by the same anthropometrist from the same participant.

Another estimate to determine the reliability of the data, known as the Coefficient of Reliability (R), has also been performed in this study. This estimate is usually expressed as a proportion and has been calculated using the following equation (Arroyo et al., 2010).

$$\mathrm{R} = 1 - \left(\frac{\mathrm{TEM}^2}{\mathrm{SD}^2}\right)$$

Where SD refers to the standard deviation of the mean values which have been drawn from the two measurements obtained on two separate occasions for the same anthropometric measurements by the same anthropometrist.

Bland-Altman analysis has been performed to analyse the magnitude of the disagreements (bias and agreement) between the two consecutive occasions of the same anthropometric measurements performed on the same participants by the same observer. Bland-Altman plots have also been produced to graphically represent the 95% limits of disagreement as a reference interval between which 95% of the observed differences in intra-observer measurements lie (Bland & Altman, 1986, 1999; Moss et al., 2020).

RESULTS

Besides providing all the detailed descriptions of the above-mentioned methods available for verifying the precision of the metric data, this study also exhibited the outcome of their applications on the several anthropometric measurements obtained from 349 male individuals. The result of this application revealed (Table 1) that all the hand and foot measurements along with height showed minimal error in terms of TEM, just as rTEM revealed very minimal percentages of error for all the measurements. Intra-observer TEMs for all the considered anthropometric measurements were found to lie between 0.05 cm and 0.07 cm, indicating minimal error. LHB (left hand breadth) has exhibited the lowest absolute TEM (0.05 cm), whereas left foot length as well as both foot breadth have shown the highest intra-observer TEM (0.07 cm). The measures of height have also shown as low intra-observer TEM (0.06 cm) as the other measurements have (table 1).

Table 1: Precision estimation for all the anthropometric measurements of the study population (n=349)

Variables	*Ht*	*RFL*	*LFL*	*RFB*	*LFB*	*RHL*	*LHL*	*RHB*	*LHB*
Absolute TEM (cm)	0.06	0.06	0.07	0.07	0.07	0.06	0.06	0.06	0.05
Relative TEM (%)	0.04	0.20	0.28	0.70	0.70	0.33	0.33	0.73	0.61
R Coefficient	1.000	0.999	0.998	0.990	0.989	0.997	0.997	0.989	0.990

Table 2: Bland-Altman analysis for determining intra-observer bias and agreement in the study anthropometric measurements

Anthropometric Measurements (n=349)	Bias (t-value) (95% CI)	Lower Limits of Agreement (95% CI)	Upper Limits of Agreement (95% CI)	Linear regression coefficient P-value
Height	-0.0020 (-0.46) (-0.0107 – 0.0066)	-0.1630 (-0.1778 – -0.1482)	0.1590 (0.1442 – 0.1738)	0.917
Right Foot Length	0.0009 (0.20) (-0.0074 – 0.0091)	-0.1530 (-0.1673 – -0.1390)	0.1550 (0.1408 – 0.1691)	0.226
Left Foot Length	0.0083 (1.55) (-0.0022 – 0.0188)	-0.1879 (-0.2059 – -0.1698)	0.2045 (0.1865 – 0.2225)	0.044
Right Foot Breadth	0.0092 (1.80) (-0.0009 – 0.0192)	-0.1779 (-0.1950 – -0.1607)	0.1963 (0.1790 – 0.2134)	0.006**
Left Foot Breadth	0.0086 (1.60) (-0.0020 – 0.0192)	-0.1884 (-0.2065 – -0.1703)	0.2056 (0.1875 – 0.2237)	0.975
Right Hand Length	-0.0020 (-0.46) (-0.0105 – 0.0065)	-0.1610 (-0.1756 – -0.1464)	0.1569 (0.1423 – 0.1716)	0.106
Left Hand Length	0.0003 (0.07) (-0.0080 – 0.0086)	-0.1540 (-0.1687 – -0.1403)	0.1550 (0.1408 – 0.1693)	0.179
Right Hand Breadth	0.0060 (1.41) (-0.0024 – 0.0144)	-0.1504 (-0.1648 – -0.1361)	0.1625 (0.1481 – 0.1768)	0.272
Left Hand Breadth	-0.0080 (-1.96) (-0.0161 – 0.0000)	-0.1580 (-0.1718 – -0.1440)	0.1419 (0.1282 – 0.1560)	0.220

*Significant, P<0.05; **Significant, P<0.01

Bland-Altman analysis (table 2) shows that right foot breadth measurement (RFB) has the maximum intra-observer bias of 0.0092 cm (95% CI: −0.0009, 0.0192 cm) with significant disagreement (−0.1779 cm (95% CI: −0.1950, −0.1607 cm) to 0.1963 cm (95% CI: 0.1790, 0.2134 cm); linear regression coefficient P value <0.01) and left foot length (LFL) has the minimum intra-observer bias of 0.0003 cm (95% CI: −0.0080, 0.0086 cm) with significant intra-observer agreement. It is significantly exhibited in this study that all the study anthropometric measurements have an intra-observer bias of <±0.01 cm, which is very minimal to be considered. Bland–Altman 95% limits of agreement for two different intra-observer measurements of height having the lowest rTEM (0.04%) and the highest R Coefficient (1.000) have been found as from −0.1630 cm (95% CI: −0.1778, −0.1482 cm) to 0.1590 cm (95% CI: 0.1442, 0.1738 cm) with bias of −0.0020 cm (95% CI: −0.0107, 0.0066 cm), whereas, for right hand breadth (RHB), which has the highest rTEM (0.73%) and the lowest R Coefficient (0.989), Bland-Altman 95% limits of agreement for two distinct intra-observer measurements have been found as from −0.1504 cm (95% CI: −0.1648, −0.1361 cm) to 0.1625 cm (95% CI: 0.1481, 0.1768 cm) with bias of 0.0060 cm (95% CI: −0.0024, 0.0144 cm). Therefore, 5% of height measurement pairs show a disagreement of more than ∼0.15 cm, and 5% of right hand breadth pairs have a difference of more than ∼0.15 cm. (Figure 1).

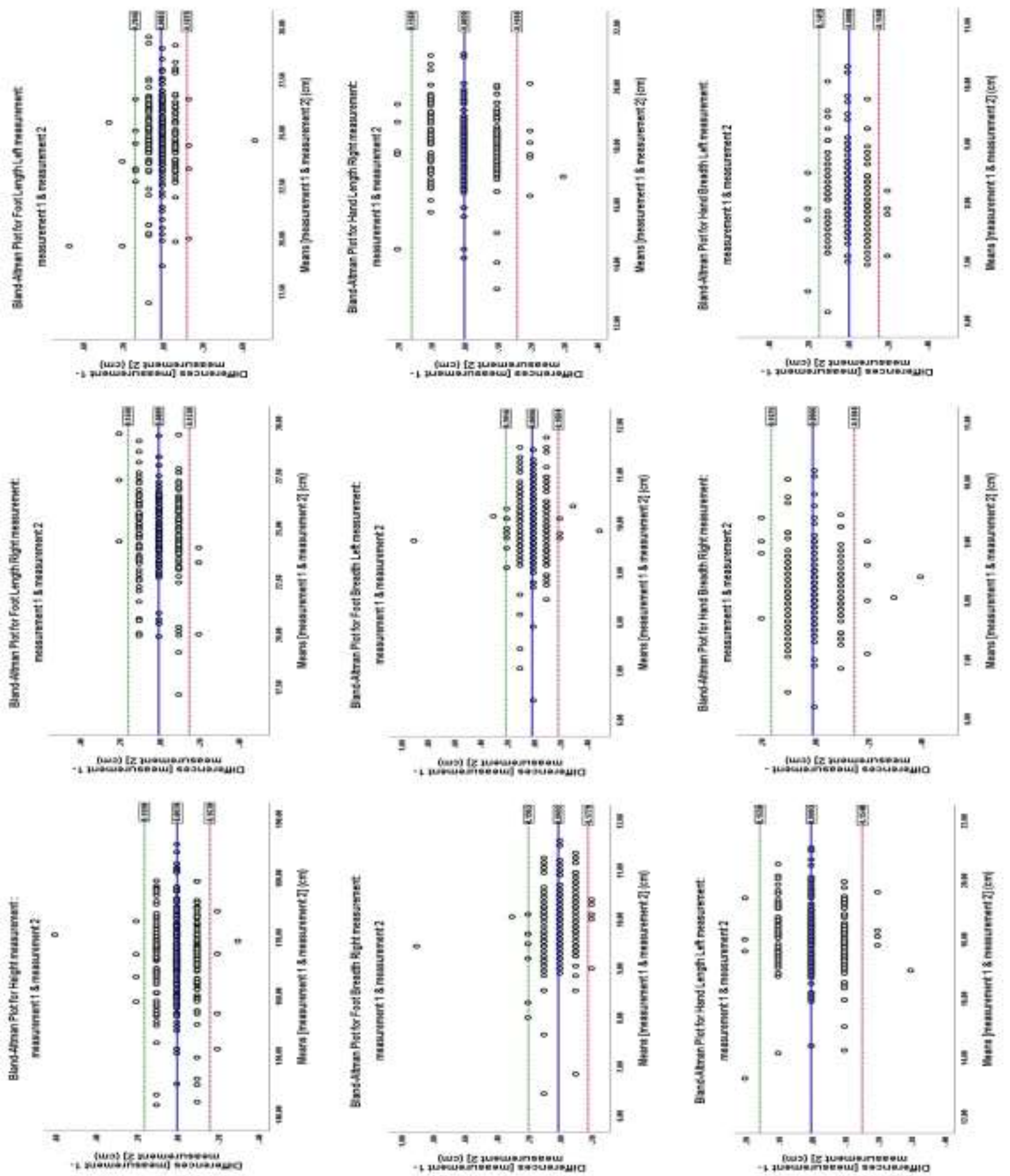

Figure 1: Bland-Altman plot for analysing bias and agreement in between intra-observer measurements of Height, Foot Length Right, Foot Length Left, Foot Breadth Right, Foot Breadth Left, Hand Length Right, Hand Length Left, Hand Breadth Right, and Hand Breadth Left (from Left to Right)

DISCUSSION

All the considered methods, described and applied through this study, for estimating the precision of the anthropometric data at the intra-observer level, were successful in making it understand its' whole procedures to conduct, as well as its implications and reliability, by estimating measurement error and reliability of the anthropometric data obtained from the study population. As with all other relevant studies, this study also found lesser measurement errors as well as greater reliability for its anthropometric data. In a publication, Arroyo et al. (2010) found less than 2.2 rTEM for skinfold measurement and less than 0.6 for circumference measurement, both of which were within the acceptance range. Jamaiyah et al. (2010) also found in their study a very minimal TEM value for intra-observer measurements (absolute differences were 0.1 kg for weight measurement and 0.3 cm for length). Unlike other studies, Perini et al. (2005) found some of the skinfold measurements which were outside the acceptable range for relative TEM, although most of the skinfold measurements appeared within the acceptable range of rTEM for intra-observer TEM. Geeta et al. (2009) also found reliability for all the measurements, such as height, weight, and waist circumference. The WHO multicenter growth reference study group found the coefficient of reliability to be above 95% for all the measurements except skinfold measurements, whose R-value was found to be less than 93%. This study also supports the others' findings. Conkle et al. (2017) exhibited a lesser TEM for some of the measurements than the present study; the TEM was exhibited for height as 0.40, as 0.28 for hip circumference, and as 0.25 for MUAC.

Conclusions

This study described all the methods of estimating the precision of anthropometric data in terms of intra-observer error of measurements. Then it concluded after applying them to empirical data that all the above-mentioned methods of precision estimation could function as intended and could always serve as the most effective tools for validating physical measurement-related data for scientific exposure.

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REFERENCES

Arroyo M, Freire M, Ansotegui L, Rocandio AM. 2010. Intraobserver error associated with anthropometric measurements made by dietitians. *Nutricion Hospitalaria* 25(6):1053–1056. doi:10.3305/nh.2010.25.6.4854.

Bland JM, Altman DG. 1986. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet North Am Ed 327(8476):307–10.

Bland JM, Altman DG. 1999. Measuring agreement in method comparison studies. Stat Methods Med Res 8(2):135–60.

Conkle J, Ramakrishnan U, Flores-Ayala R, Suchdev PS, Martorell R. 2017. Improving the quality of child anthropometry: Manual anthropometry in the Body Imaging for Nutritional Assessment Study (BINA). *PLoS ONE* 12(12). doi: 10.1371/journal.pone.0189332.

Frisancho AR. 1990. *Anthropometric Standards for Assessment of Growth and Nutritional Status*. Ann Arbor (Mich): University of Michigan Press.

Geeta A, Jamaiyah H, Safiza MN, Khor GL, Kee CC, Ahmad AZ, Suzana S, Rahmah R, Faudzi A. 2009. Reliability, technical error of measurements and validity of instruments for nutritional status assessment of adults in Malaysia. Singapore medical journal 50(10):1013-1018.

Jamaiyah H, Geeta A, Safiza MN, Khor GL, Wong NF, Kee CC, Rahmah R, Ahmad AZ, Suzana S, Chen WS, Rajaah M, Adam B. 2010. Reliability, Technical Error of Measurements and Validity of Length and Weight Measurements for Children Under Two Years Old in Malaysia. The Medical journal of Malaysia 65:131-137.

Lewis SJ. 1999. Quantifying measurement error. In Anderson S. editors. *Current and recent research in osteoarchaeology 2: Proceedings of the 4th, 5th and 6th meetings of the Osteoarchaeological Research Group.* Oxford: Oxbow Books. p 54-55.

Lohman TG, Roche AF, Martorell R. 1988. *Anthropometric Standardization Reference Manual*. Chicago: Human Kinetics Books.

Moss C, Kuche D, Bekele TH, Salasibew M, Ayana G, Abera A, Eshetu S, Dangour AD, Allen E. 2020. Precision of Measurements Performed by a Cadre of Anthropometrists Trained for a Large Household Nutrition Survey in Ethiopia. Current Developments in Nutrition 4: 139.

Mueller WH, Martorell R. 1988. Reliability and accuracy of measurement. In Lohman TG, Roche AF, Martorell R, editors. *Anthropometric Standardisation Reference Manual.* Chicago: Human KineticsBooks Champaign, Illinois. p 83-86.

Norton K. 2018. Standards for Anthropometry Assessment. In Kinanthropometry and Exercise Physiology. Taylor and Francis Group. p.68-137. doi: 10.4324/9781315385662-4.

Paul P, Biswas S, Mukhopadhyay A. 2020. Estimation of Stature from Foot Anthropometry: A cross-sectional study among Bengali speaking Hindu Population of West Bengal. *Journal of Life Sciences* 12(1-2):20-27. doi: 10.31901/24566306.2020/12.1-2.242.

Paul P, Biswas S, Mukhopadhyay A, Bhadra M. 2018. Relationship of hand anthropometry and stature: an empirical cross sectional study among Bengali speaking Hindu population of West Bengal, India. *Genus Homo* 2:20-30.

Perini TA, Oliveira GL de, Ornellas J dos S, Oliveira FP de. 2005. Technical error of measurement in anthropometry. Revista Brasileira de Medicina do Esporte 11(1):81-85.

Rostamzadeh S, Saremi M, Vosoughi S, Bradtmiller B, Janani L, Farshad AA, Taheri F. 2021. Analysis of hand-forearm anthropometric components in assessing handgrip and pinch strengths of school-aged children and adolescents: A partial least squares (PLS) approach. BMC Pediatrics 21. https://doi.org/10.1186/s12887-020-02468-0

Ulijaszek SJ, Lourie J A. 1994. Intra- and inter-observer error in anthropometric measurement. In Ulijaszek SJ, Mascie-Taylor CGN, editors. *Anthropometry: The Individual and the Population.* Cambridge: Cambridge University Press. p 30-55.

WHO Multicentre Growth Reference Study Group. 2006. Reliability of anthropometric measurements in the WHO Multicentre Growth Reference Study. *Acta Paediatrica (Oslo, Norway: 1992).* Supplement 450: p 38-46. doi: 10.1080/08035320500494464.