Acta Biomed 2021; Vol. 92, N. 3: e2021225 DOI: 10.23750/abm.v92i3.10274

Assessment of body weight from percutaneous widths of the bones and joints-Implications in forensic and clinical examinations

Deepika Rani[1], *Kewal Krishan*[1], *Ajay Kumar*[1], *Tanuj Kanchan*[2]

[1]Department of Anthropology (UGC Centre of Advanced Study), Panjab University, Sector-14, Chandigarh, India; [2]Department of Forensic Medicine and Toxicology, All India Institute of Medical Sciences, Jodhpur, India.

Abstract. *Background*: Estimation of age, stature, sex, and ancestry contributes to the establishment of the biological profile of the deceased in forensic examinations. Assessment of the body weight aids in the approximation of the overall body size of the individual which may help in the forensic identification process. In clinical examinations, body weight assessment assumes importance in cases where body weight measurement is a challenging task due to illness and body deformity. *Objective:* The present research was conducted to estimate the body weight from the percutaneous width of the bones and joints with the help of prediction equations. *Methods:* The study was carried out on 344 adults (172 Females and 172 Males) aged between 18 and 25 years from the Himachal Pradesh State of North India. Eleven anthropometric measurements including height vertex, mid-arm circumference, humerus bicondylar width, transverse chest breadth, sagittal chest breadth, bi-iliac breadth, hand breadth, femur bicondylar breadth, ankle breadth, foot breadth, and body weight were taken on each individual. The sex differences were evaluated by using independent student t-test and Mann-Whitney U test and the correlation between the body weight and the anthropometric variables was investigated by using both Karl Pearson's correlation coefficient and Spearman's rank correlation coefficient depending upon the normality of the data. Regression models for the estimation of body weight were calculated. Further, a validation study was carried out to check the accuracy and utility of the derived regression models by calculating the mean absolute percent prediction error (MAPPE). *Results:* Significant sex differences were observed among all the anthropometric variables**.** The transverse chest breadth and mid-arm circumference were strongly correlated with the body weight, whereas, a good correlation was also observed in other measurements except for the ankle breadth. The SEE (Standard error of estimate) of the derived linear regression models was compared, and it was found that multiple linear regression models show better accuracy than simple linear regression models. The MAPPE was found to be less in the case of multiple linear regression models than the linear ones. *Conclusion:* The present investigation concludes that regression models can be used in the estimation of body weight from the percutaneous measurements and joint widths with reasonable accuracy in an Indian population. (www.actabiomedica.it)

Key words: Forensic Anthropology, Anthropometry, Body weight assessment, Clinical and forensic considerations, Mean absolute percent prediction error, percutaneous bone widths.

Introduction

Body weight of an individual is defined as the weight of the body involving skeletal mass, muscle mass, and fat mass. Estimation of the body weight of the deceased from skeletal remains is an important step in the identification process and has been a major concern of forensic anthropologists as well as archeologists (1, 2). Body weight assessment is also a crucial part of drug dose calculation in emergency departments, tidal volumes in ventilated patients, estimation of renal function, and nutritional status. In these kinds of medical setups, body weight measurement is a challenging task due to mobility compromising illnesses, or body deformities (3-7). Earlier, the studies have derived certain prediction equations for the estimation of body weight from skeletal remains and suggested two different approaches i.e. mechanical and morphometric methods for this purpose. "The mechanical method is based on the functional association between a weight-bearing element and a body weight whereas the morphometric method includes the direct reconstruction of body shape and/or size (i.e., body breadth relative to body length) from the preserved elements" (8). The mechanical method is further sub-divided into the articular surface dimension and the diaphyseal breadths (cross-sectional dimensions) (8). In the mechanical method, the breadths were used to predict the body mass which includes mostly the articular surfaces i.e., joints such as femoral head breadth (9-12), knee breadth (10), and pelvic breadth (13) while the bi-iliac breadth and the stature were mostly used in the morphometric method (9, 11, 13, 14). The size of the joint does not change, once the ossification of bone is complete, regardless of the changes in loading due to body mass or activity; this may be one of the reasons that the focus of the researchers shifted to the weight-bearing element which includes joints (15). Femoral head breadth is the most studied element (10) in this regard. Groote and Humphrey (16) also estimated the femoral head diameter, femoral length, and body mass from the first metatarsal bone from a mixed population skeletal sample (16).

The estimation of body mass or body weight is not only applicable in archeological and forensic context but are also widely used in the medical scenario. In a medical scenario, there are various therapeutic mediations which are based on body weight (3, 4, 17). In the case of critically ill patients and obese patients, where direct measurement of body weight is practically impossible (18, 19) due to immobility, illness, or body deformity (3, 17), the assessment of body weight through indirect method is a major concern. In such situations, body weight is measured to track the nutritional status, clinical conditions, drug dosages, renal functioning, tidal volumes in ventilated patients, thrombosis in stroke patients, degenerative joint diseases, and cardiovascular diseases (3-7, 17, 20, 21). In the pediatric emergency department, body weight is mostly estimated with the help of various methods such as Broselow tape, Cattermole formula, etc. (22-26). Out of these methods, Broselow tape is the best estimator of body weight (25). However, in children older than 6 years, the Cattermole formula is a better option than Broselow tape (26). The Cattermole formula is calculated based on mid-arm circumference (26). Efforts have been made to estimate the body mass from anthropometric measurements by using computed tomography (27) and dual-energy x-ray absorptiometry (DXA) scans (15). The femoral head, neck, proximal shaft diameters (15), mid-arm circumference (17), knee breadth (28), stature, and bi-iliac breadth (29) were used for the body mass assessment. The femur, bi-iliac breadth, and knee breadth are the weight-bearing elements of the body, whereas, mid-upper arm circumference is a marker of undernutrition (30).

The objective of the present research is to estimate body weight from the percutaneous width of the bones and joints with the help of prediction equations so that the relationship between body weight and the percutaneous width of the bones and joints can be drawn. The study may be useful in the circumstances where the bone and joint widths are available for forensic casework as well as in the archaeological and palaeoanthropological context.

Material and Methods

A cross-sectional sample of 344 adults (172 Females and 172 Males) with an age range from 18 to 25 years (with mean age 19.06±1.19 years) was collected from the Shimla Town of the Himachal Pradesh State in North India. The investigation was part of a large study conducted for the Master's degree dissertation in the Department of Anthropology, Panjab University, Chandigarh, India (31, 32). Informed consent was obtained from the participants before initiating the data collection for the study. The purpose and the details of the study were explained to every participant. The physically handicapped participants or those with any physical disability related to the extremities were excluded from the study.

Eleven anthropometric measurements along with the general demographic data were collected from the study participants. The measurements comprised of height vertex, mid-arm circumference, humerus bicondylar width, transverse chest breadth, sagittal chest breadth, bi-iliac breadth, hand breadth, femur bicondylar breadth, ankle breadth, foot breadth, and body weight. The anatomical landmarks involved and the techniques for obtaining the anthropometric measurements were followed by Singh and Bhasin (33) and Weiner and Lourie (34) (Table 1). All the measurements were taken by two trained physical anthropologists under the supervision of an experienced physical and forensic anthropologist.

Table 1. Table showing the details of the anthropometric measurements used in the present study

Measurements	Landmarks involved	Definition	Instrument used	Technique followed
Height vertex	Vertex	It measures the straight distance from the vertex to the floor.	Anthropometric rod	Singh and Bhasin (33)
Mid Arm Circumference	Acromion, Radiale	It measures the maximum circumference of the upper arm taken at the midpoint of upper arm length.	Steel tape	Wenier and Lourie (34)
Humerus Bicondylar breadth	Lateral epicondyle and Medial epicondyle	It measures the straight distance taken across the two epicondyles of the humerus when the elbow is bent to a right angle.	Sliding Caliper	Weiner and Lourie (34)
Transverse Chest Breadth	Mesosternale	It measures the most laterally places points of the ribs at the height of the mesosternale.	The first segment of Anthropometer or Rod compass	Singh and Bhasin (33)
Sagittal Chest Breadth	Mesosternale	It measures the straight distance of mesosternale to the horizontally placed point in the vertebral column. The arms should hang normally on the sides.	The first segment of Anthropometer or Rod compass	Singh and Bhasin (33)
Bi-iliac Breadth	Iliocristale	It measures the straight distance between the two iliocostale points.	The first segment of Anthropometer or Rod compass	Singh and Bhasin (33)
Femur Bicondylar Breadth	Lateral epicondyle and Medial epicondyle	It measures the straight distance taken across the two epicondyles of the femur when the knee is bent to a right angle.	Sliding Caliper	Weiner and Lourie (34)
Ankle Breadth	Lateral malleolus and Medial malleolus	It measures the straight distance across the lateral and medial malleolus of fibula and tibia respectively.	Sliding Caliper	Weiner and Lourie (34)
Hand breadth	Metacarpal radiale and Metacarpal ulnare	It measures the straight distance between metacarpal radiale and metacarpal ulnare	Sliding Caliper	Singh and Bhasin (33)
Foot breadth	Metatarsal tibiale and Metatarsal fibulare	It measures the straight distance directly between metatarsal tibiale and metatarsal fibulare	First Segment of Anthropometric Rod or Campass	Singh and Bhasin (33)
Body weight	-----	Weight should be taken using a standard weighing machine with fine accuracy.	Weighing machine	Singh and Bhasin (33)

Statistical analysis

The statistical analysis for the present study was carried out with the help of IBM-SPSS (Statistical Product's and service solution, version 16.0) computer software. From the total data, 5% of the data was segregated for the validation study by using the random data selection method in IBM-SPSS software. The normality of the data was assessed by using different methods which include a visual examination of their histograms, normal Q-Q plots, and box plots, then by investigating the descriptive statistics, and finally by using a confirmatory test i.e., Shapiro Wilk's test ($p>0.05$). While, four parameters (height vertex, sagittal chest breadth, bi-iliac breadth, and foot breadth) showed normal distribution, the others (mid-arm circumference, humerus bicondylar breadth, femur bicondylar breadth, hand breadth, transverse chest breadth, ankle breadth, and body weight) were not normally distributed. As a result, both parametric, as well as non-parametric tests were applied. For the evaluation of sex differences, the independent student t-test was applied for normally distributed parameters while the Mann-Whitney U test was used for all other measurements. Further, the correlation between the body weight and the anthropometric variables was conducted by using Karl Pearson's correlation coefficient in the case of normally distributed parameters, whereas, Spearman's rank correlation coefficient for the other parameters to verify the association between them. Simple linear and multiple linear regression models were formulated for the estimation of body weight. Step-wise regression models were developed with stepping criteria of f-probability (f-to-enter or f-to-remove threshold). The measurements with f-probability between 0.05 and 0.5 were included in the study and the rest were excluded. Further, the accuracy and utility of the regression models were tested by substituting the segregated data in the regression models. For this purpose, the predicted values were then compared by descriptive statistics, and the calculated mean absolute percent prediction error (MAPPE).

Results

Test of normality by descriptive statistics and Shapiro-Wilk's test is shown in table 2, and the descriptive statistics and sex differences among males and females participants are documented in table 3. Parametric tests deal with the mean of the sample population whereas non-parametric tests use the median for further calculation. Therefore, both mean and median were recorded in the descriptive statistics. Significant sex differences were observed among all the recorded anthropometric measurements (Table 3). For the evaluation of the

Table 2. Test of normality by descriptive statistics and Shapiro-Wilk's test.

Measurements	Minimum (cm)	Maximum (cm)	Mean (cm)	Median (cm)	Mode (cm)	Standard Deviation (cm)	Shapiro-Wilk's test	p-value
Height vertex	142.40	187.30	163.14	162.80	163.50	8.47	0.992	0.069
Mid arm circumference	16.30	30.50	22.76	22.50	22.00	2.53	0.983	<0.01
Humerus bicondylar breadth	4.90	7.40	6.24	6.20	6.00	0.51	0.984	<0.01
Hand breadth	6.10	9.60	7.87	7.80	7.20	0.64	0.983	<0.01
Transverse Chest width	21.80	32.80	25.92	25.50	25.50	2.21	0.977	<0.01
Sagittal Chest depth	15.90	24.10	19.71	19.70	20.50	1.70	0.992	0.076
Billiac breadth	21.40	29.60	25.58	25.50	25.50	1.62	0.993	0.137
Femur bicondylar breadth	7.40	10.70	9.02	8.95	8.90	0.62	0.989	0.013
Ankle width	4.50	8.00	6.27	6.20	6.50	0.64	0.989	0.010
Foot breadth	7.10	11.20	9.07	9.05	8.60	0.77	0.995	0.287
Body weight	32.00	84.00	53.02	52.00	47.00	9.06	0.982	<0.01

Table 3. Descriptive statistics and sexual dimorphism in the studied population.

Measurements	Females (N=172)					Males (N=172)					Student's t-test/ Mann Witney test	p-value
	Minimum (cm)	Maximum (cm)	Mean (cm)	Median (cm)	Standard Deviation (cm)	Minimum (cm)	Maximum (cm)	Mean (cm)	Median (cm)	Standard Deviation (cm)		
HV	142.40	169.40	156.88	157.20	5.30	152.00	187.30	169.32	169.00	6.11	19.994	<0.001
SCB	16.00	24.00	20.14	20.20	1.59	15.90	24.10	19.27	19.15	1.70	4.681	<0.001
BB	21.40	29.60	25.37	25.40	1.69	22.70	29.60	25.78	25.70	1.53	2.388	0.018
FB	7.30	10.40	8.61	8.60	0.60	7.10	11.20	9.52	9.50	0.65	13.374	<0.001
MAC	16.30	27.00	21.69	21.40	2.19	19.20	30.50	23.82	23.50	2.39	6926.00	<0.01
HBB	4.90	6.70	5.87	5.90	0.33	5.40	7.40	6.61	6.60	0.36	1903.00	<0.01
HB	6.10	8.40	7.39	7.40	0.37	7.10	9.60	8.34	8.35	0.47	1494.00	<0.01
TCB	21.80	29.20	24.54	24.45	1.43	23.30	32.80	27.26	27.20	1.95	3374.00	<0.01
FBB	7.40	10.40	8.67	8.65	0.44	7.50	10.70	9.39	9.40	0.55	3871.00	<0.01
AB	4.90	7.10	5.99	6.00	0.43	4.50	8.00	6.56	6.60	0.68	6329.00	<0.01
BW	32.00	74.00	47.91	47.00	6.88	44.00	84.00	58.05	57.00	8.14	4383.00	<0.01

Height vertex= HV, Mid Arm Circumference= MAC, Humerus Bicondylar breadth= HBB, Hand Breadth= HB, Transverse Chest Breadth= TCB, Sagittal Chest Breadth= SCB, Bi-iliac Breadth= BB, Femur Bicondylar Breadth= FBB, Ankle Breadth= AB, Foot Breadth= FB, Body Weight= BW.`

relationship between the body weight and other anthropometric measurements, both the Spearman's correlation coefficient and Karl Pearson's correlation coefficient were assessed (Table 4). The correlation was measured for the known sex as well as for combined sex. All the anthropometric measurements show a statistically significant correlation with body weight. The transverse chest breadth and mid-arm circumference were found to be strongly correlated with the body weight, whereas a good correlation was observed in the case of height vertex, hand breadth, humerus bicondylar breadth, bi-iliac breadth, femur bicondylar breadth, sagittal chest breadth, and foot breadth except for the ankle breadth (Table 4).

Based on this relationship, simple linear and multiple linear prediction models were devised. The derived simple and multiple linear regression models are shown in table 5. Along with the models, the correlation coefficient (r), the adjusted coefficient of multiple determination (R^2), the standard estimated error for the model and the significance level of each measurement used as well as the significance level of the model (p-value) were recorded for all regression models. In multiple linear regression models, the correlation coefficient "r" indicates the combined effect of all the independent variables whereas, in the simple linear regression model, it simply represents the correlation coefficient. The coefficient of multiple determinations i.e. "R^2", and its value adjusted for sample size i.e., adjusted R^2, help to assess the amount of variations in the body weight accounted for by the independent variables can be explained by the model (13). The adjusted R^2 is used to judge the goodness-of-fit for the regression model. While observing the simple linear regression models the highest goodness-of-fit i.e. 50% to 60%, for the models were found to be recorded only in case of the mid-arm circumference and transverse chest breadth equation for females and combined sex. Whereas 40% to 50% goodness-of-fit were documented in the case of the mid-arm circumference and bi-iliac breadth prediction equations for males, transverse chest breadth, and sagittal chest breadth equations for females and height vertex, femur bicondylar breadth and foot breadth prediction equations for combined sex. Moreover, 30% to 40% goodness-of-fit for the model was reported in the case of humerus bicondylar breadth, hand breadth and bi-iliac breadth equations for combined sex, transverse chest breadth and sagittal chest breadth equations for males, and bi-iliac breadth and femur bicondylar breadth for females while the rest prediction models were found to have below 30% goodness-of-fit. The simple regression SEEs for female models fall in the range of 3.8-6.8. This range was slightly less in the case of males and combined sex i.e., 5.3-8.0 and 5.8-8.5 respectively.

The accuracy of the multiple regression models was found to be more than the linear ones. The regression model for combined sex with almost all measurements shows 81% goodness-of-fit. Since the f-probability

Table 4. Karl Pearson's and Spearman's correlation of various anthropometric measurements with body weight

Karl Pearson's correlation(for variables that were normally distributed)			
Measurements	**Females**	**Males**	**Unknown**
Height vertex	0.386**	0.499**	0.671**
Sagittal Chest breadth	0.648**	0.579**	0.342**
Billiac breadth	0.617**	0.649**	0.583**
Foot breadth	0.466**	0.453**	0.643**
Spearman's correlation (for variables that were not normally distributed)			
Mid arm circumference	0.705**	0.657**	0.761**
Humerus bicondylar breadth	0.443**	0.365**	0.648**
Hand breadth	0.470**	0.301**	0.651**
Transverse Chest breadth	0.658**	0.598**	0.782**
Femur bicondylar breadth	0.580**	0.450**	0.691**
Ankle width	0.154*	0.204**	0.397**

Table 5. Body weight estimation regression models (both linear and multiple regression models).

Measurements	Sex	Regression model	R	Adjusted R^2	p-value	SEE
HV	Male	BW = -54.477 + 0.665x HV**	0.499	0.249	<0.01	7.071
	Female	BW = -30.563 + 0.500x HV**	0.386	0.143	<0.01	6.364
	Combined sex	BW = -64.088 + 0.718 x HV**	0.671	0.448	<0.01	6.733
MAC	Male	BW = 4.327 + 2.257x MAC**	0.662	0.438	<0.01	6.117
	Female	BW = -0.864 + 2.248x MAC**	0.717	0.512	<0.01	4.806
	Combined sex	BW = -8.642 + 2.709x MAC**	0.755	0.569	<0.01	5.953
HBB	Male	BW = 6.725 + 7.767x HBB**	0.343	0.113	<0.01	7.665
	Female	BW = -1.384 + 8.391 x HBB**	0.403	0.158	<0.01	6.312
	Combined sex	BW = -16.753 + 11.174x HBB**	0.624	0.387	<0.01	7.094
HB	Male	BW = 11.646 + 5.569x HB**	0.324	0.100	<0.01	7.721
	Female	BW = -13.115 + 8.254x HB**	0.444	0.193	<0.01	6.179
	Combined sex	BW = -17.283 + 8.937x HB **	0.627	0.391	<0.01	7.071
TCB	Male	BW = -9.742 + 2.489x TCB**	0.597	0.353	<0.01	6.546
	Female	BW = -35.686 + 3.407x TCB**	0.707	0.499	<0.01	4.881
	Combined sex	BW = -27.985 + 3.126x TCB**	0.761	0.578	<0.01	5.888
SCB	Male	BW = 4.758 + 2.768x SCB**	0.579	0.331	<0.01	6.655
	Female	BW = -8.559 + 2.804x SCB**	0.648	0.417	<0.01	5.251
	Combined sex	BW = 17.114 + 1.821x SCB**	0.342	0.114	<0.01	8.530
BB	Male	BW = -30.744 + 3.446x BB**	0.649	0.417	<0.01	6.210
	Female	BW = -15.780 + 2.511x BB**	0.617	0.380	<0.01	5.429
	Combined sex	BW = -30.329 + 3.258x BB**	0.583	0.338	<0.01	7.375
FBB	Male	BW = 0.313 + 6.154x FBB**	0.418	0.170	<0.01	7.413
	Female	BW = -34.497 + 9.530xFBB**	0.616	0.379	<0.01	5.436
	Combined sex	BW = -34.660 + 9.722x FBB**	0.669	0.446	<0.01	6.746
AB	Male	BW = 42.662 + 2.355x AB*	0.194	0.032	<0.01	8.006
	Female	BW = 30.201 + 2.958x AB*	0.187	0.035	<0.01	6.776
	Combined sex	BW = 17.604 + 5.647x AB**	0.397	0.155	<0.01	8.333
FB	Male	BW = 3.879 + 5.695x FB**	0.453	0.201	<0.01	7.275
	Female	BW = 1.724 + 5.365x FB**	0.466	0.213	<0.01	6.102
	Combined sex	BW = -15.362 + 7.543x FB**	0.631	0.412	<0.01	6.950
TCB, MAC	Male	BW = -18.289 + 1.380x TCB** + 1.627x MAC**	0.717	0.508	<0.01	5.708
	Female	BW = -32.499 + 2.029x TCB** + 1.411x MAC**	0.788	0.616	<0.01	4.263
	Combined sex	BW = -31.523 + 1.872x TCB** + 1.585x MAC**	0.830	0.687	<0.01	5.091
TCB, MAC, HV	Male	BW = -79.080 + 1.145x TCB** + 1.457x MAC** + 0.421x HV**	0.778	0.597	<0.01	5.162
	Female	BW = -89.060 + 1.753x TCB** + 1.471x MAC** + 0.396 x HV**	0.843	0.706	<0.01	3.731
	Combined sex	BW = -68.619 + 1.139x TCB** + 1.533x MAC** + 0.351 x HV**	0.872	0.758	<0.01	4.479

(*continued*)

Measurements	Sex	Regression model	R	Adjusted R^2	p-value	SEE
TCB, MAC, HV, BB	Male	BW = -81.902 + 0.869x TCB** + 1.222x MAC** + 0.295 x HV** + 1.447 x BB**	0.806	0.640	<0.01	4.879
	Female	BW = -89.518 + 1.499x TCB** + 1.306x MAC** + 0.340 x HV** + 0.751 x BB**	0.856	0.727	<0.01	3.596
	Combined sex	BW = -83.299 + 1.025x TCB** + 1.306x MAC** + 0.327 x HV** + 1.042 x BB**	0.886	0.783	<0.01	4.241
TCB, MAC, HV, BB, FBB	Male	BW = -89.827 + 0.856x TCB** + 1.187x MAC** + 0.211 x HV** + 1.378x BB** + 2.677 x FBB**	0.823	0.666	<0.01	4.699
	Female	BW = -93.855 + 1.425x TCB** + 1.171x MAC** + 0.298x HV** + 0.625 x BB** + 2.225 x FBB**	0.863	0.738	<0.01	3.522
	Combined sex	BW = -85.030 + 0.939x TCB** + 1.209x MAC** + 0.249 x HV** + 0.972 x BB** + 2.299 x FBB**	0.893	0.795	<0.01	4.118
TCB, MAC, HV, BB, FBB, SCB	Male	BW = -92.205 + 0.624x TCB** + 0.991x MAC** + 0.206 x HV** + 1.329 x BB** + 2.241x FBB** + 1.009 x SCB**	0.841	0.696	<0.01	4.483
	Female	BW = -94.889 + 1.253x TCB** + 0.969x MAC** + 0.285 x HV** + 0.481 x BB** + 2.380 x FBB** + 0.672 x SCB**	0.871	0.749	<0.01	3.444
	Combined sex	BW = -96.517 + 0.895x TCB** + 1.053x MAC** + 0.297 x HV** + 0.739 x BB** + 2.326 x FBB** + 0.713 x SCB**	0.901	0.808	<0.01	3.990
TCB, MAC, HV, BB, FBB, SCB, FB	Male	BW = -90.099 + 0.598x TCB** + 0.953 x MAC** + 0.141 x HV** + 1.394x BB** + 1.500 x FBB** +1.000 x SCB** + 1.680 x FB**	0.848	0.706	<0.01	4.413
	Female	BW = -94.068 + 1.219x TCB** + 0.953 x MAC** + 0.262x HV** + 0.440x BB** + 2.224 x FBB** + 0.684 x SCB** + 0.710 x FB**	0.872	0.750	<0.01	3.436
	Combined sex	BW = -94.645 + 0.858x TCB** + 1.039x MAC** + 0.254 x HV** + 0.733 x BB** +1.877 x FBB** + 0.722 x SCB** + 1.146 x FB**	0.903	0.811	<0.01	3.951

Height vertex= HV, Mid Arm Circumference= MAC, Humerus Bicondylar breadth= HBB, Hand Breadth= HB, Transverse Chest Breadth= TCB, Sagittal Chest Breadth= SCB, Bi-iliac Breadth= BB, Femur Bicondylar Breadth= FBB, Ankle Breadth= AB, Foot Breadth= FB, Body Weight= BW.

of 0.05 to 0.5 was used for building multiple linear regression models so the combinations with less than 0.5 f-probabilities were excluded from the models. The rest of the models also show 60% to 80% goodness-of-fit. The standard error estimates in the case of multiple linear regression models for combined sex fall in the range of 3.9-5.1. These values in the case of males and females vary from 4.4-5.7 and 3.4-4.3 respectively. When the SEE of both the regression models was compared, it was found that the multiple linear regression models show less error as compared to the simple linear regression models.

The regression models were validated and statistics related to this are represented in table 6. The sample that was randomly selected during the first stage of the study was used for this validation study. For this purpose, the difference between the estimated body weight and the actual body weight was computed. This difference was further used to calculate the mean absolute percent prediction error (MAPPE) followed by Ruff et al. (35). After that, the descriptive statistics of the actual body weight and the estimated body weight were calculated (Table 6). In the simple linear regression models, the mean of the estimated body weight ranges from 50.91cm-59.16cm (Std. ±2.85-7.75) and 46.19cm-52.28cm (Std. ±1.81-12.21) in the case of males and females respectively, whereas the actual body weight for males and females was found to be 57.08cm (Std. ±7.42) and 47.67cm (Std. ±11.91) respectively. On the other hand, for the combined sex, the estimated body weight was varied from 50.8cm-53.89cm (Std. ±3.83-10.2) and the actual body weight was 52.68cm (Std. ±10.66). The calculated mean absolute percent prediction error for the female equations (range: 5.97-20.73) was more than males (range: 5.44-10.53) and combined sex (range: 7.82-15.64) equations (Table 6). When the body weight was estimated using multiple linear regression models, it was found that mean of estimated body weight among males and females ranges from 54.26cm-56.10cm (Std. ±3.39-7.67) and 42.44cm-43.03cm (Std. ±8.53-9.76) respectively. While the actual body weight recorded was 57.08cm (Std. ±7.42) and 47.67cm (Std. ±11.91) in the case of males and females respectively. In the case of combined sex, the estimated body weight was found to be 48.95cm-49.90cm (Std. ±8.69-9.68) which is almost close to the mean of the actual body weight i.e., 52.68cm (Std. ±10.66). Even the mean absolute percent prediction error was less in the case of multiple linear regression models than the linear ones. In multiple linear regression models, 7.59-8.41 was recorded in the case of combined sex, whereas 4.39-8.11 and 9.68-11.06 were documented in the case of males and females, respectively.

Table 6. Descriptive statistics with mean absolute percent prediction error of the validation study.

Sex	Regression model	Minimum (cm)	Maximum (cm)	Mean (cm)	Standard Deviation (cm)	MAPPE (cm)
Male	Actual body weight	46.50	65.00	57.08	7.42	----------
	BW = -55.271 + 0.669 x HV**	54.60	65.01	59.16	4.14	6.33
	BW = 3.737 + 2.282 x MAC**	48.52	60.44	54.39	4.52	5.44
	BW = 5.189 + 7.991 x HBB**	50.29	62.58	58.11	4.30	8.13
	BW = 10.722 + 5.684 x HB**	46.17	62.26	54.21	5.30	7.13
	BW = -8.581 + 2.443 x TCB**	52.67	71.42	58.61	6.77	10.53
	BW = 4.477 + 2.782 x SCB**	48.25	56.45	51.75	2.89	7.37
	BW = -29.062 + 3.383 x BB**	41.35	62.20	50.91	7.75	5.48
	BW = -1.283 + 6.322 x FBB**	47.00	61.59	55.92	6.10	6.09
	BW = 43.290 + 2.250 x AB*	49.23	61.65	56.57	4.40	10.43
	BW = 2.830 + 5.799 x FB**	52.53	60.07	57.43	2.85	8.34
	BW = -18.289 + 1.380 x TCB** + 1.627 x MAC**	51.64	61.98	56.10	3.39	8.11
	BW = -79.080 + 1.145 x TCB** + 1.457 x MAC** + 0.421 x HV**	51.34	64.34	56.43	5.31	4.91
	BW = -81.902 + 0.869 x TCB** + 1.222 x MAC** + 0.295 x HV** + 1.447 x BB**	49.96	66.69	55.05	6.91	5.24
	BW = -89.827 + 0.856 x TCB** + 1.187 x MAC** + 0.211 x HV** + 1.378 x BB** + 2.677 x FBB**	48.01	67.27	54.80	7.67	5.28
	BW = -92.205 + 0.624 x TCB** + 0.991 x MAC** + 0.206 x HV** + 1.329 x BB** + 2.241 x FBB** + 1.009 x SCB**	47.10	65.86	54.26	7.60	4.80
	BW = -90.099 + 0.598 x TCB** + 0.953 x MAC** + 0.141 x HV** + 1.394 x BB** + 1.500 x FBB** +1.000 x SCB** + 1.680 x FB**	47.30	65.79	54.35	7.37	4.39

(*continued*)

Sex	Regression model	Minimum (cm)	Maximum (cm)	Mean (cm)	Standard Deviation (cm)	MAPPE (cm)
Female	Actual body weight	33.00	64.00	47.67	11.91	----------
	BW = -33.146 + 0.157 x HV**	44.04	55.17	48.02	3.77	17.12
	BW = -0.933 + 2.255 x MAC**	37.41	67.21	47.21	12.16	9.37
	BW = -1.495 + 8.241 x HBB**	36.88	52.53	46.19	5.32	18.91
	BW = -13.446 + 8.302 x HB**	43.49	52.43	47.96	3.30	19.03
	BW = -35.277 + 3.393 x TCB**	37.35	62.98	46.26	9.57	10.61
	BW = -10.423 + 2.899 x SCB**	48.07	60.64	52.28	4.83	11.58
	BW = -18.108 + 2.603 x BB**	45.58	60.90	51.61	5.89	14.84
	BW = -34.326 + 9.514 x FBB**	43.12	58.67	48.14	5.55	17.94
	BW = 32.043 + 2.649 x AB*	48.66	54.31	51.20	1.81	19.45
	BW = 4.713 + 5.018 x FB**	44.98	58.56	49.26	5.52	20.73
	BW = -32.499 + 2.029 x TCB** + 1.411 x MAC**	34.60	53.31	42.44	8.10	10.17
	BW = -89.060 + 1.753 x TCB** + 1.471 x MAC** + 0.396 x HV**	34.30	56.90	42.84	9.76	9.68
	BW = -89.518 + 1.499 x TCB** + 1.306 x MAC** + 0.340 x HV** + 0.751 x BB**	35.05	56.65	43.03	9.27	9.73
	BW = -93.855 + 1.425 x TCB** + 1.171 x MAC** + 0.298 x HV** + 0.625 x BB** + 2.225 x FBB**	35.41	54.34	42.80	8.53	10.93
	BW = -94.889 + 1.253 x TCB** + 0.969 x MAC** + 0.285 x HV** + 0.481 x BB** + 2.380 x FBB** + 0.672 x SCB**	35.11	54.44	42.76	8.53	10.98
	BW = -94.068 + 1.219 x TCB** + 0.953 x MAC** + 0.262 x HV** + 0.440x BB** + 2.224 x FBB** + 0.684 x SCB** + 0.710 x FB**	34.98	54.48	43.02	8.53	11.06
Combined sex	Actual body weight	33.00	65.00	52.38	10.66	----------
	BW = -64.195 + 0.718 x HV**	44.04	65.01	53.59	6.94	11.36
	BW = -8.430 + 2.701 x MAC**	37.41	67.21	50.80	9.52	7.82
	BW = -16.276 + 11.094 x HBB**	36.88	62.58	52.15	7.75	12.94
	BW = -17.462 + 8.961 x HB **	43.49	62.26	51.19	5.33	13.67
	BW = -28.013 + 3.127 x TCB**	37.35	71.42	52.43	10.20	10.47
	BW = 15.604 + 1.897 x SCB**	48.07	60.64	52.26	3.83	12.95
	BW = -30.450 + 3.264 x BB**	41.35	62.20	51.26	6.57	12.24
	BW = -34.835 + 9.739 x FBB**	43.12	6158	52.03	6.88	11.64
	BW = 18.332 + 5.519 x AB**	48.66	61.65	53.89	4.26	15.64
	BW = -14.569 + 7.449 x FB**	44.98	60.07	53.34	5.98	14.32
	BW = -31.523 + 1.872 x TCB** + 1.585 x MAC**	35.34	61.50	49.10	8.69	8.41
	BW = -68.619 + 1.139 x TCB** + 1.533 x MAC** + 0.351 x HV**	36.07	64.25	49.90	9.68	7.59
	BW = -83.299 + 1.025 x TCB** + 1.306 x MAC** + 0.327 x HV** + 1.042 x BB**	36.34	65.95	49.31	9.51	7.68
	BW = -85.030 + 0.939 x TCB** + 1.209 x MAC** + 0.249 x HV** + 0.972 x BB** + 2.299 x FBB**	36.02	66.37	49.19	9.49	8.27
	BW = -96.517 + 0.895 x TCB** + 1.053 x MAC** + 0.297 x HV** + 0.739 x BB** + 2.326 x FBB** + 0.713 x SCB**	35.75	65.25	48.95	9.63	7.75
	BW = -94.645 + 0.858 x TCB** + 1.039 x MAC** + 0.254 x HV** + 0.733 x BB** +1.877 x FBB** + 0.722 x SCB** + 1.146 x FB**	35.39	65.05	49.14	9.49	7.67

Discussion

The relationship between the body weight and percutaneous bone and joint widths may be useful in the assessment of the body size of an individual which may help in forensic identification. In cases, where skeletal remains and body parts are recovered for forensic examinations, identification of the deceased is a prior concern. One can easily estimate the age, sex, and ancestry but estimation of body weight from skeletal remains is a challenge for forensic anthropologists. Authors have devised prediction equations for the estimation of body weight based on skeletal remains (9-14, 36) however; the literature is scanty regarding the estimation of body weight from the percutaneous measurements of the bone and joint widths. In this regard, Ruff et al. (9) tried to devise an equation of conversion of skeletal bi-iliac breadth (SBIB) to the living/percutaneous bi-iliac breadth (LBIB) (LBIB=1.17 x SBIB − 3(cm)). They have derived these equations for the Pleistocene Homo by comparing them with the modern human species. Further, Ruff (29) has an estimated body mass of elite athletes from stature and bi-iliac breadth. The SEE was found to be 3.6 Kg and 4.1 kg in males and females respectively. But the present study has recorded the SEE from 5.4 – 7.4 kg in the case of bi-iliac breadth whereas 6.3-7.1 kg in the case of stature.

Studies have been conducted on the estimation of body weight of the hospitalized patients with abnormalities (3, 4, 17-19, 37-40). In such studies, doses of the drug are based on the body weight so accuracy during estimation of body weight is a major concern. For that purpose, the regression equation is the best method to accomplish the desired results. Mostly, these prediction equations were based on the data from hospitalized patients whereas very few studies were carried out on the normal adult population (40). The equations derived in the present study are specific for the normal adult population.

Most of the studies have derived body weight estimation equations based on the percutaneous anthropometric measurements (3, 4, 17-19, 37-41). Despite this, studies have used either the computed tomography (27) or dual-energy x-ray absorptiometry (DXA) scans (15). The most common method used in the hospital emergency departments is the visual examination of body weight but the error rate in this method was quite high (35-37). In a study conducted by Martin et al. (37) on 133 cardiac arrest patients, estimated body weight by visual examination and the error rate was found to be more than 10% in 26% cases. Almost similar results were documented by Coe et al. (38) and Leary et al. (39) in their studies. The error rate in the present study was recorded in the form of SEE. The value for SEE in simple linear regression models was found to be 5.8-8.5 in the case of combined sex whereas 5.3-8.0 and 3.8-6.8 were recorded in the case of males and females respectively. This error was found to be quite small in the case of multiple linear regression models. It was 3.9-5.1 for combined sex whereas these values in the case of males and females vary from 4.4-5.7 and 3.4-43 respectively (Table 5). However, in the validation study, this error was measured in the form of a mean absolute percent prediction error (MAPPE). The MAPPE for the female equations (range: 5.97-20.73) was found to larger than males (range: 5.44-10.53) and combined sex (range: 7.82-15.64) equations. The MAPPE was found to be less in the case of multiple linear regression models i.e. 7.59-8.41 was recorded in case of combined sex whereas, 4.39-8.11 and 9.68-11.06 were documented in the case of males and females respectively (Table 6).

In the pediatric emergency department, the stature is mostly used to predict body weight (22-26). They used a tape measure (i.e., Broselaw tape) with the approximated body weight printed over it. The present study also used stature and derived simple linear regression models. But the value of adjusted R^2 was very low (0.143-0.448) whereas SEE was very high (6.4-7.1) which indicates that it is not a good predictor of body weight which suggests that its simple linear regression model has less practical utility (Table 5).

The earlier studies have also used skinfolds thickness and body circumferences as a predictor of body weight (42, 43). In the present study, in addition to the bone and joint widths, the mid-arm circumference was also used for the estimation of body weight which was found to have a good correlation with body weight. Darnis et al. (3) derived two prediction equations of body weight estimations separately for males and females in hospitalized patients; one equation was based on height, waist circumference, and hip circumference whereas the other was on height and arm circumference. Crandall et al. (19) derived body weight estimation equations by using arm circumference and height. The R^2 value for the equation with arm circumference and height was found to be 59.2% in males and 54.7% in females. In the present study also, the arm circumference and height show a good correlation with body weight i.e. 0.7 and 0.6 respectively (Table 4). The simple linear regression model based on mid-arm circumference show 43.8% -56.9% goodness-of-fit for the model with SEE ranges from 4.8-6.1 (Table 5). Moreover, Lorenz et al. (39) conducted a study on 7000 participants and constructed regression equations based on anthropometric measurements which include body height, and waist and hip circumference. They have validated their formulae on a sample of 178 patients and calculated error in the form of mean absolute difference. According to them, these simple anthropometric measurements gave the most accurate estimation with the mean absolute difference of 3.1 (2.6) kg.

Body weight is a highly variable parameter of the human body. It may show significant diurnal variations which may alter the results of such prediction investigations. However, in the present study, this aspect was not taken into consideration; further investigations are suggested in such more controlled conditions for reliable and accurate results.

In the present study, it was found that the multiple linear regression models show better results than linear models in the estimation of body weight from the bone and joint breadths, stature, and mid-arm circumference as they indicate lower values of SEE and MAPPE. Finally, it was observed that as more parameters with good correlation coefficients are added, the accuracy of the model increases, and the value of the SEE decreases. The present study indicates that multiple linear regression models have more practical utility than the linear ones in the estimation of body weight.

Conclusion

The present study investigates the relationship of percutaneous body widths, joint widths, stature, and mid-arm circumference with body weight which may help in the assessment of body size of an individual in forensic and other examinations.

The study indicated that the transverse chest breadth and mid-arm circumference were strongly correlated with the body weight, whereas a good correlation was observed in other anthropometric measurements except for the ankle breadth. The multiple linear regression models show better results than linear models. When the SEE of both the regression models was compared, it was found that the multiple linear regression models show less error as compared to simple linear regression models. The value of adjusted R^2 was more in multiple linear regression models which indicates that these models can be more practically applicable. The practical applicability of the models is further verified by evaluating the mean absolute percent prediction error (MAPPE). The MAPPE was found to be smaller in the case of multiple linear regression models than the linear ones. Hence, it can be concluded that multiple linear regression models are more practically valid for the estimation of body weight from the percutaneous bone and joint widths. The present study was conducted on a specific population; there may a lot of variations in estimating body weight from anthropometric measurements among people of different regions and ancestries. Therefore, further studies are suggested among diverse populations residing in different environmental conditions for further validation of body weight estimation.

Conflicts of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement, etc.) that might pose a conflict of interest in connection with the submitted article. This study is a part of Master's Degree dissertation submitted to the Department of Anthropology, Panjab University, Chandigarh, India. The nature of the research work was explained to the participants and written consent was obtained from each participant before initiating the study.

Acknowledgements: This study is a part of the Master's Degree dissertation submitted to the Department of Anthropology, Panjab University, Chandigarh, India. The authors (DR, KK) are supported by UGC Centre of Advanced Study (CAS II) in Anthropology, Department of Science and Technology-Promotion of University Research and Scientific Excellence Grant (DST PURSE Grant) awarded to the Department of Anthropology, Panjab University, Chandigarh, India. We are also grateful to the participants who volunteered for the study and the principals of the colleges of the Shimla city in Himachal Pradesh State of North India who allowed us data collection from their colleges.

Consent for publication: All the authors have given their consent for publication of this article and approved the final version of the manuscript

Availability of data and materials: The study is a part of a Master's project and the raw data is available with the authors (DR, AK) who have been nominated as guarantors for the work. DR accepts full responsibility for the work and/or the conduct of the study had access to the data, and controlled the decision to publish.

Authors' contributions: DR, KK and TK conceived and conceptualized the idea of writing this paper. DR and AK collected the data under the supervision of KK. DR conducted the analysis and compiled the results. DR, KK, AK and TK wrote the initial draft of the manuscript. DR, KK, and TK edited and approved the final version of the manuscript. KK and TK supervised the work.

References

1. Nikita E, Chovalopoulou ME. Regression equations for the estimation of stature and body mass using a Greek documented skeletal collection. HOMO 2017;68:422–32.
2. Jeong Y, Jantz LM, Park CS. Generating equations to estimate body mass of Korean skeletal remains. Anthropol Anz 2017;74: 213–219.
3. Darnis S, Fareau N, Corallo CE, Poole S, Dooley MJ, Cheng AC. Estimation of body weight in hospitalized patients. QJM 2012;105:769–774.
4. Young KD, Korotzer NC. Weight estimation methods in children: a systematic review. Ann Emerg Med 2016;68:441-51.e.10.
5. Breuer L, Nowe T, Huttner HB, Blinzler C, Kollmar R, Schellinger PD, Schwab S, Kohrmann M. Weight approximation in stroke before thrombolysis the waist-study: a prospective observational "dose-finding" study. Stroke 2010;41:2867-71.
6. Anglemyer B, Hernandez C, Brice JH, Zou B. The Accuracy of visual estimation of body weight in the ED. Am J Emerg Med 2004;22:526-9.
7. Erker CG, Santamaria M, Moellmann M. Size does matter – age-related weight estimation in "tall n' thin" and "tiny n' thick" children and a new habitus-adapted alternative to the EPLS-formula. Resuscitation 2014;85:1174–8.
8. Auerbach BM, Ruff CB. Human body mass estimation: a comparison of "morphometric" and "mechanical" methods. Am J Phys Anthropol 2004;125:331–42.
9. Ruff CB, Trinkaus E, Holliday TW. Body mass and encephalization in Pleistocene Homo. Nature 1997;387:173–6.
10. Squyres N, Ruff CB. Body mass estimation from knee breadth, with application to early hominins. Am J Phys Anthropol 2015;158:198–208.
11. Jeanson AL, Santos F, Villa C, Dupej J, Lynnerup N, Bružek J. Body mass estimation from the skeleton: An evaluation of 11 methods. Forensic Sci Int 2017;281:183.e1-e8.
12. Niskanen M, Junno JA, Maijanen H, Holt B, Sladek V, Berner M. Can we refine body mass estimations based on femoral head breadth? J Hum Evol 2018;115:112-21.
13. Suskewicz JA. Estimation of living body weight based on measurements of Anterior superior iliac spine breadth and stature. MA thesis. B.A., Rutgers, The State University of New Jersey, 2004.
14. Ruff CB, Niskanen M, Junno JA, Jamison P. Body mass prediction from stature and bi-iliac breadth in two high latitude populations, with application to earlier higher latitude humans. J Hum Evol 2005;48:381-92.
15. Pomeroy E, Mushrif-Tripathy V, Kulkarni B, Kinra S, Stock JT, Cole TJ, Shirley MK, Wells JCK. Estimating body mass and composition from proximal femur dimensions using dual-energy x-ray absorptiometry. Archaeol Anthropol Sci 2018;11(5):2167-79.
16. Groote ID, Humphrey LT. Body mass and stature estimation based on the first metatarsal in humans. Am J Phys Anthropol 2011;144:625–32.
17. Cattermole GN, Graham CA, Rainer TH. Mid-arm circumference can be used to estimate weight of adult and adolescent patients. Emerg Med J 2017;34:231–6.
18. Bloomfield R, Steel E, MacLennan G, Noble DW. Accuracy of weight and height estimation in an intensive care unit: implications for clinical practice and research. Crit Care Med 2006;34:2153-7.
19. Crandall CS, Gardner S, Braude DA. Estimation of total body weight in obese patients. Air Med J 2009;28:139-45.
20. Stubblefield PR. Body weight estimation in forensic anthropology. Proceedings of the 55th American Academy of Forensic Sciences Annual Meeting, Chicago 2003:16-21.
21. Rativa D, Fernandes BJT, Roque A. Height and weight estimation from anthropometric measurements using machine learning regressions. IEEE J Transl Eng Health Med 2018;6:4400209.
22. Hughes G, Spoudeas H, Kovar IZ, Millington HT. Tape measure to aid prescription in paediatric resuscitation. Arch Emerg Med 1990;7:21–7.
23. Molyneux E, Brogan R, Mitchell G, Gove S. Children's weights: Guess or measure by tape? Lancet 1999;354:1616.
24. Tanner D, Negaard A, Huang R, Evans N, Hennes H. A prospective evaluation of the accuracy of weight estimation using the broselow tape in overweight and obese pediatric patients in the emergency department. Pediatr Emerg Care. 2017;33:675-8.
25. Bowen L, Zyambo M, Snell D, Kinnear J, Bould MD. Evaluation of the accuracy of common weight estimation

formulae in a Zambian paediatric surgical population. Anaesthesia 2017;72:470-8.
26. Choi JY, Sub D, Kim DK, Kwak YH, Jung JY, Lee JH, Jeong JH, Kwon H, Peak SH. Validation of the mid-arm-based weight estimation formula (the Cattermole formula) for Korean children. Resuscitation 2018;132:13-6.
27. Lorkiewicz-Muszynska D, Przystanska A, Kociemba W, Sroka A, Rewekant A, Zaba C, Paprzycki W. Body mass estimation in modern population using anthropometric measurements from computed tomography. Forensic Sci Int 2013;231:405.e1–e6.
28. Wu CHY. Does the increase in body weight change the knee and ankle joint loading in walking and running? Master Thesis in Biomechanics. Department of Biology of Physical Activity, University of Jyväskylä. 2015:72pp.
29. Ruff CB. Body mass prediction from skeletal frame size in elite athletes. Am J Phys Anthropol 2000;113:507–17.
30. Reilly JJ. Mid-upper arm circumference (MUAC): new applications for an old measure. Arch Dis Child 2017;102:1-2.
31. Verma R, Krishan K, Rani D, Kumar A, Sharma V. Stature Estimation in Forensic Examinations using Regression Analysis: A Likelihood Ratio Perspective. Forensic Sci Int Reports 2020;2:100069, DOI: https://doi.org/10.1016/j.fsir.2020.100069.
32. Verma R, Krishan K, Rani D, Kumar A, Sharma V, Shrestha R, Kanchan T. Estimation of Sex in Forensic Examinations using Logistic Regression and Likelihood Ratios. Forensic Sci Int Reports 2020;2: 100118, DOI: https://doi.org/10.1016/j.fsir.2020.100118.
33. Singh IP, Bhasin MK, Anthropometry, Kamla Raj Enterprises, Delhi, 1968.
34. Weiner JS, Lourie JA, Human Biology: a guide to field methods. Published for the International Biological Programme by Blackwell Scientific, Oxford, Edinburgh, 1969.
35. Ruff CB, Scott WW, Liu AY. Articular and diaphyseal remodeling of the proximal femur with changes in body mass in adults. Am J Phys Anthropol 1991;86:397-413.
36. Chevalier T, Clarys JP, Lefèvre P, Beauthier JP, Louryan S, Cattrysse E. Body mass prediction from femoral volume and sixteen other femoral variables in the elderly: BMI and adipose tissue effects. Am J Phys Anthropol 2018;166:26-42.
37. Martin DR, Soria DM, Brown CG, Pepe PE, Gonzalez E, Jastremski M, Stueven H, Cummins RO. Agreement between paramedic estimated weights and subsequent hospital measurements in adults with out-of-hospital cardiac arrest. Prehosp Disaster Med 1994;9:54–6.
38. Coe TR, Halkes M, Houghton K, Jefferson D. The accuracy of visual estimation of weight and height in pre-operative supine patients. Anesthesia 1999;54:582–6.
39. Leary TS, Milner QJ, Niblett DJ. The accuracy of the estimation of body weight and height in the intensive care unit. Eur J Anaesthesiol 2000;17:698–703.
40. Lorenz MW, Graf M, Henke C, Hermans M, Ziemann U, Sitzer M, Foerch C. Anthropometric approximation of body weight in unresponsive stroke patients. J Neurol Neurosurg Psychiatry 2007;78:1331–6.
41. Larson LL. Relationship of upper arm circumference and body weight. J Emerg Nurs 1985;11:246-8.
42. Chumlea WC, Guo S, Roche AF, Steinbaugh ML. Prediction of body weight for the non ambulatory elderly from anthropometry. J Am Diet Assoc 1988;88:564–8.
43. Atiea JA, Haboubi NY, Hudson PR, Sastry BD. Body weight estimation of elderly patients by nomogram. J Am Geriatr Soc 1994;42:763–5.

Correspondence:
Received: 19 July 2020
Accepted: 24 November 2020
Dr. Kewal Krishan, Ph.D., FRAI
Department of Anthropology,
(UGC Centre of Advanced Study)
Panjab University, Sector-14,
Chandigarh, India, +919876048205 (Mobile)
E-mail: gargkk@yahoo.com; kewalkrishan@pu.ac.in