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Original Research Article

ESTIMATION OF BODY WEIGHT USING ANTHROPOMETRIC MEASUREMENTS IN ADULT POPULATION– A PROSPECTIVE OBSERVATIONAL ANALYTICAL STUDY

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ABSTRACT

Background: Accurate body weight estimation is essential for drug dosing and nutritional planning in resource-limited settings, where direct measurement is often challenging. Existing anthropometric equations, developed for Caucasians, may not suit Indian adults due to body composition differences. This study developed and validated a novel anthropometric- based weight estimation model for Indian adults.

Materials and Methods: A prospective study at Sri Lakshmi Narayana Institute of Medical Sciences, Puducherry, over six months enrolled 400 adults in the derivation phase and 200 in the validation phase. Anthropometric measurements (mid-arm, calf, abdominal, hip circumferences; triceps skinfold thickness; knee-heel distance) were taken. Simple linear regression was done for each of six anthropometric variables. Multiple regression equation models were derived using parameters with Pearson correlation >0.5 with actual body weight (ABW). Thus three equations were derived in this phase, which was subjected to validation in the next phase. Predicted body weight (PBW) was compared to ABW using Bland-Altman plots and residual standard error.

Results: The derivation cohort (183 females, 217 males; mean age 32.6 ± 15.25 years; mean ABW 66.07 ± 15.2 kg) identified mid-arm (MAC), calf (CC), abdominal (AC), hip (HC) circumference as strong predictors (r= 0.53-0.64). Using validation cohort the three equations were used for estimation PBW. Model 3 (ABW = -20.40 + 1.05MAC + 0.284CC + 0.326AC + 0.18HC) showed the highest accuracy (R2 = 0.524, RSE = 9.89 kg, limits of agreement -19.74 to 19.00kg), validated consistently across genders in the validation cohort.

Conclusion: Model 3 offers a reliable, objective method for estimating ABW in Indian adults, ideal for resource-constrained settings. Further validation in non-ambulatory and diverse South Asian populations is needed.

Keywords: Body weight, anthropometric measurements, actual body weight, predicted body weight.

INTRODUCTION

Weight estimation plays a vital role in the treatment strategies and adjustment of drug doses in day to day clinical practice. Various terminologies such as ideal body weight, estimated body weight, lean body mass, adjusted body weight, etc are used for dose calculation and nutritional requirements.

Further accurate measurement of body weight is a critical clinical parameter in hospital settings, underpinning precise drug dosing, nutritional assessment, and fluid management, particularly for critically ill or immobile patients. For medications with narrow therapeutic range, such as thrombolytics for acute ischemic stroke, vasopressors, anticoagulants, and antibiotics, weight-based dosing is essential to optimize efficacy and minimize adverse effects, such as intracerebral haemorrhage from overdosing or treatment failure from underdosing.[1] Similarly, body weight tells us the nutritional status, plan for fluid regimens, which are vital for patient recovery, especially in conditions like burns, sepsis, or malnutrition.[2] However, obtaining an actual body weight (ABW) measurement is often challenging in emergency and critical care settings, where patients may be unconscious, bedbound, or unable to stand due to conditions like stroke, myocardial infarction, or severe trauma.

In resource-limited settings, such as many hospitals in low- and middle-income countries like India, the challenge is compounded by the lack of specialized equipment, such as bed scales, which are costly and often unavailable. In such scenarios, clinicians rely on subjective weight estimates by healthcare workers or patients, which are prone to inaccuracy and variability, particularly for underweight or obese individuals.[3,4] These estimates lack reproducibility and depend heavily on the clinician's experience, posing risks to patient safety in time-sensitive treatments. As an alternative, anthropometric measurements—such as mid-arm circumference, calf circumference, skin fold thickness etc—offer a potential solution for objective and reproducible weight estimation. These measurements are simple to obtain, require minimal equipment (e.g., a measuring tape), and are feasible in supine patients, making them ideal for resource-constrained environments.

During literature search we found several anthropometric-based weight estimation equations, most were developed in Caucasian, limiting their applicability to Asian adults due to differences in body composition, such as higher subcutaneous fat and variations in limb circumferences.[5,6] Recent studies in Sri Lanka have validated such equations but found that patient or clinician guesses often outperform them, underscoring the need for population-specific models.[7] To address this gap, this study aims to derive a novel, equation to estimate body weight using anthropometric measurements in our population.

MATERIALS AND METHODS

This was a prospective, observational analytical study conducted in Department of Anesthesiology at Sri Lakshmi Narayana Institute of Medical Sciences, Puducherry, over a period of 6 months from September 2024 to February 2025. Institutional Ethics Committee approval was obtained (IEC/C-P/3/2024) before enrolling patients in the study.

Patients presenting with symptoms to various outpatient departments of our hospital were recruited. Patients who were consenting for the study, age more than 18 years were included. Those who were non consenting, unable to stand, having altered mental status, one or more limb amputated, chronic illness likely to cause fluid retention (eg, CKD, CLD, CHF), pregnant females were excluded.

The study was conducted in two phases. For the derivation phase, a sample size of 400 participants was estimated using OpenEpi software (Version 3.01), based on a confidence level of 95%, power of 80%, and an expected effect size (Cohen's d) of 0.5 for the difference between actual body weight (ABW) and predicted body weight (PBW), consistent with the approach in Herath et al. (2023).[7] This sample size also satisfies Green's rule of thumb for linear regression (n = 50 + 8 × number of predictors, i.e., 50 + 8 × 6 = 98), ensuring robustness for six predictors.[8]

For the validation phase, a sample size of 200 participants was determined using OpenEpi with the same confidence level (95%) and power (80%), adhering to Green's rule (n = 104 + number of predictors, i.e., 104 + 6 = 110) and supported by Herath et al.'s validation cohort of 217 participants.[7]

In the derivation cohort, eligible patients were recruited by consecutive sampling from September 2024 to December 2024. Informed written consent was obtained. Demographic details were recorded. Investigators who measured the anthropometric values were blinded from patient's ABW. Anthropometric measurements were done using standard protocols.[9] Weight was measured with patient in light clothes without footwear using digital scale, value recorded to the nearest 0.1kg. Height was measured using stadiometer. Circumferences were recorded to the nearest 0.1mm, using measuring tape. Midarm circumference (MAC) was measured at the midpoint between the tip of acromion and olecranon process with the arm flexed at 90□. Calf circumference (CC) was measured at the widest area of calf. Abdominal circumference (AC) was measured at the level of iliac crest. Hip circumference (HC) was measured at the widest part of the buttock. Triceps skinfold thickness (TST) using caliper, on posterior surface of right upper arm same as the marked midpoint for MAC. Measurements of Knee Heel Distance (KHD) were defined proximally by the thigh prominence with the knee bent at 90° and distally by the plantar aspect of the foot at the heel with the ankle bent at 90°. Circumferences and skin fold thickness were measured thrice and the average of the values was used in analysis.

In the validation cohort, the eligible patients were recruited by same method in the period of January and February 2025. Demographic details of age, gender, height, weight was recorded. Using the equations from derivation phase, PBW was calculated and compared with ABW. Bland-Altman plots were generated to assess the agreement between predicted and actual body weights.

Data was analyzed using Statistical Package of Social Science (SPSS, v25, IBM, USA). Continuous data were summarized as mean □ standard deviation (SD). Categorical data presented as frequency and percentage. Simple and multiple linear regression analyses was carried out for estimation of weight.

RESULTS

Derivation cohort: In this phase a total of 400 participants were included, (183 females, 217 males) with a mean age of 32.6 ± 15.25 years (range: 18–87 years). The mean actual body weight was 66.07 ± 15.2 kg, and the mean height was 163.9 ± 10.7 cm.

To identify anthropometric parameters with a sufficiently strong linear relationship with ABW for inclusion in multiple regression models, simple linear regression was performed for each of the six parameters against ABW, and Pearson correlation coefficients (r) were calculated [Table 1].

Parameters with a Pearson correlation coefficient less than 0.5 were excluded from further modelling, as this threshold indicates a moderate-to-strong linear association necessary for reliable prediction, minimizing the inclusion of weak predictors that could reduce model precision.[7,8] We found that TST and KHD were statistically weak predictors having correlation coefficient less than 0.5, hence excluded from multiple regression models. The remaining parameters (MAC, CC, AC, HC) were used to develop multiple linear regression models to estimate ABW. Multiple regression equations were derived by sequential inclusion of independent variables. Thus three different models were obtained to calculate PBW [Table 2]. The significance level for all analyses was set at $p < 0.05$. Bland-Altman plots were generated to assess the agreement between predicted and actual body weights for each anthropometric measure [Figure 1].

Validation cohort: A total of 200 patients were recruited to validate the equation obtained in derivation phase. Demographic parameters were comparable between the derivation (n=400) and validation cohorts (n=200), with no significant differences in age, ABW, height, or gender distribution [Table 3].

Using the three multiple regression equations derived in the derivation phase, PBW was calculated for each participant and compared with their ABW. Bland-Altman plots were generated to assess the agreement between PBW and ABW for each model [Figure 2].

The sequential addition of anthropometric parameters improved model performance. Model 1, incorporating MAC and CC, provided a baseline fit. Model 2, with the addition of AC, increased the R² value and reduced the residual standard error (RSE), indicating improved explanatory power and precision. Model 3, which included MAC, CC, AC, and HC, further enhanced the model fit, achieving the highest R² and lowest RSE among the three models, reflecting the strongest predictive accuracy [Table 4]. Bland-Altman plots [Figure 2] illustrated the agreement between PBW and ABW for each anthropometric measure, with tighter limits of agreement observed as parameters were added.

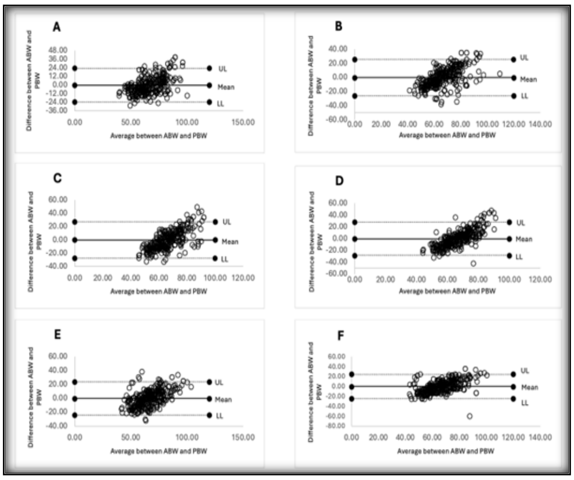

Figure 1: Bland and Altman plots for comparison of PBW using six anthropometric measures with actual body ABW. (A) Mid Arm Circumference (B) Calf Circumference (C) Triceps Skinfold Thickness (D) Knee Heel Distance (E) Abdominal Circumference (F) Hip Circumference

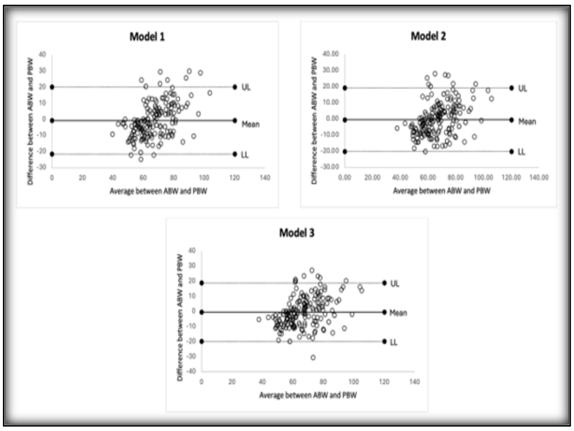

Figure 2: Bland and Altman plots for comparison of PBW using multiple regression models with actual body ABW.

Table 1: Correlation coefficients between actual body weight and the predicted body weight calculated for six anthropometric parameters

	Equation for PBW	Pearson correlation (actual/ predicted)	R²
MAC	7.03+(2.09)*MAC	0.64	0.413
CC	21.38+(1.25*CC)	0.53	0.28
TST	50.93+(0.8*TST)	0.416	0.173
KHD	11.77+(1.10*KHD)	0.369	0.136
AC	1.2+(0.73*AC)	0.619	0.383
HC	7.35+(0.6*HC)	0.6	0.36

Table 2: Anthropometric based multiple regression equations

Models	**Equation**
Model 1	-0.03 + 1.66*MAC + 0.55*CC
Model 2	-17.54+(1.15*MAC)+(0.38*CC)+(0.41*AC)
Model 3	-20.40+(1.05*MAC)+(0.284*CC)+(0.326*AC)+(0.18*HC)

Table 3: Demographic details of derivation and validation cohort

	Derivation group n= 400	Validation group n= 200	p value
Age (mean ± SD)	32.6 ± 15.25	32.06 ± 14.18	0.335
Weight (mean ± SD)	66.07 ± 15.2	66.45 ± 14.31	0.385
Height (mean ± SD)	163.95 ± 10.7	165.08 ± 10.6	0.111
Gender (M / F)	217 : 183	110 : 90	0.861

SD : standard deviation.

DISCUSSION

This prospective study developed and validated a novel anthropometric-based regression model to estimate actual body weight (ABW) in Indian adults, addressing the critical need for accurate weight estimation in emergency and critical care settings where direct measurement is often impractical. Our results demonstrate that triceps skinfold thickness (TST) and knee-heel distance (KHD) were poor predictors of ABW, with Pearson correlation coefficients of 0.416 and 0.369, respectively, and R^2 values of 0.173 and 0.136 [Table 1], indicating weak linear associations. In contrast, mid-arm circumference (MAC), calf circumference (CC), abdominal circumference (AC), and hip circumference (HC) showed stronger correlations ($r = 0.53–0.64$, $R^2 = 0.28–0.413$). Among the three regression models developed, Model 3, incorporating MAC, CC, AC, and HC ($ABW = -20.40 + 1.05MAC + 0.284CC + 0.326AC + 0.18HC$), exhibited the highest predictive accuracy, with an R^2 of 0.524 and the lowest residual standard error (RSE) of 9.89 kg, and the tightest limits of agreement (LOA) in Bland-Altman plots (-19.74 to 19.00 kg) [Table 4, Figure 2]. These findings highlight the potential of Model 3 as a robust tool for weight estimation in resource-constrained clinical environments.

The poor predictive performance of TST and KHD aligns with the need to prioritize anthropometric parameters with stronger correlations to ABW to ensure model precision. TST, which measures subcutaneous fat, yielded an R^2 of 0.173, suggesting limited reliability, likely due to variability influenced by age, gender, and nutritional status, which can disproportionately affect skinfold measurements in diverse populations.[5] Similarly, KHD, intended to reflect skeletal frame size, had an R^2 of 0.136, indicating minimal contribution to weight estimation. These findings are consistent with Herath et al. (2023), who excluded knee height and tibial length from their regression models for Sri Lankan adults due to low correlation coefficients (<0.3).[7] This suggests that limb length measurements may have limited utility for anthropometric weight estimation in South Asian populations, possibly due to differences in body composition, such as higher subcutaneous fat and variations in limb proportions compared to Caucasian populations.[5,6]

The superior performance of Model 3, incorporating four anthropometric parameters, underscores the value of combining multiple measurements to capture diverse aspects of body composition. MAC and CC reflect muscle mass and limb girth, while AC and HC account for central adiposity and lower body frame, respectively [Table 1]. The sequential addition of parameters from Model 1 to Model 2 and Model 3 progressively improved model fit and precision, as evidenced by increasing R^2 values and decreasing RSE (Table 4). Bland-Altman plots further confirmed tighter LOA for Model 3 (-19.74 to 19.00 kg) compared to Model 1 (-21.43 to 20.13 kg) and Model 2 (-20.04 to 19.24 kg) [Figure 2], indicating enhanced agreement with ABW. This aligns with Buckley et al. (2012), who found that a regression model using abdominal and thigh circumferences ($R^2 = 0.89$) outperformed subjective estimates for male patients in a U.S. emergency department setting.[1] However, Buckley et al. reported reduced accuracy for females (27% with errors >10 kg), whereas our Model 3 showed consistent performance across genders, likely due to the inclusion of HC, which captures gender-specific fat distribution patterns prevalent in Indian adults.[5]

The robustness of Model 3 is supported by the demographic similarity between the derivation and validation cohorts, with no significant differences in age, ABW, height, or gender distribution [Table 3]. This consistency enhances the model's reliability for clinical application in Indian adults. However, limitations must be acknowledged. The study was conducted at a single centre, potentially limiting ethnic and regional diversity, though the hospital's diverse patient population mitigates this to some extent. Additionally, patients with altered mental status or immobility—those most likely to benefit from anthropometric weight estimation—were excluded due to the requirement for standing measurements, a limitation also noted by Buckley et al. and Herath et al.[1,7] Furthermore, while Model 3's use of four measurements improves accuracy, it may increase measurement time, posing practical challenges in time-sensitive emergency settings.

CONCLUSION

In conclusion, our study demonstrates that a regression model incorporating MAC, CC, AC, and HC (Model 3) provides a robust and objective method for estimating ABW in Indian adults, outperforming simpler models with fewer parameters. Model 3 offers a practical alternative for critically ill or unconscious patients in resource-constrained settings lacking bed scales. Future research should validate this model in non-ambulatory patients and explore its applicability across diverse South Asian populations to further enhance its clinical utility.

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