Original Article

Validation of Fat-Free Mass Estimation Using Prediction Equations in Male Patients with Chronic Obstructive Pulmonary Disease

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Abstract

Context: The use of predictive equations in hospital settings lacking access to dual energy X-ray absorptiometry or bioelectrical impedance analysis (BIA) can be beneficial because cachexia, muscle wasting and related increase in morbidity and mortality are known occurrences in patients with chronic obstructive pulmonary disease (COPD). **Aim:** To analyse the predictive performance of reported equations for fat-free mass (FFM) prediction against BIA-derived FFM in patients with stable COPD. **Design/Materials and Methods:** Seventy-two male patients aged between 40 and 75 years with stable COPD were evaluated for FFM by BIA. FFM was also predicted for the same patients using equations reported by Kulkarni *et al.*, Solomon Yu *et al.*, Janmahasatian *et al.*, as well as Deurenberg equation. **Statistical Analysis Used:** The predictive performance was assessed by Bland–Altman plots, with subsequent calculations of bias, precision and accuracy. The performance was also analysed across the age and body mass index sub-groups. **Results:** The mean differences (95% confidence intervals) in the prediction of FFM using equations by Kulkarni *et al.* and Deurenberg equation were −0.33 kg (−4.910, 4.258) and 0.31 kg (−3.330, 3.946), respectively. The equation by Solomon Yu *et al.* and Janmahasatian *et al.* overestimated FFM with a mean difference of 3.99 kg (−2.449, 10.428) and 3.76 kg (−0.443, 7.956), respectively. **Conclusion:** The equation by Kulkarni *et al.* provides an acceptable prediction of FFM in patients who were underweight or had normal weight with COPD and were aged between 50 and 69 years. The Deurenberg equation was used to predict FFM in patients aged between 40–49 and 60–75 years. Further validation of the predictive performance in overweight and obese COPD patients is required.

Keywords: Anthropometry, bioelectrical impedance analysis, COPD, fat-free mass, prediction equation

Introduction

Chronic obstructive pulmonary disease (COPD) is a progressive respiratory disease characterised by persistent airway obstruction and inflammation. COPD is the fourth leading cause of death in the world with 3.2 million deaths globally in the year 2015.[1] The systemic manifestations of COPD, important from a nutritional perspective, are weight loss, cachexia and muscle wasting or the loss of fat-free mass (FFM).[2] FFM is a compartment of the body based on the two-compartment model and comprises of water, protein, minerals and glycogen, with the other compartment being fat mass. The techniques in body composition analysis allow for a non-invasive approach to assess and understand the body compartments and changes occurring in them because of normal life processes, disease conditions or an intervention.[3] Recent research indicates fat-free mass index obtained from the measurement of FFM as a better indicator of nutritional status in COPD patients. The major proportion of the weight lost in these patients is found to be FFM; thus, FFM measurement is a better indicator of nutritional depletion than body mass index (BMI) alone. Studies report patients having COPD with low FFM and normal BMI.[4,5] FFM is also considered to be an independent predictor of mortality with negative consequences on the progression of the disease, exercise capacity and the quality of life of patients with COPD.[6,7]

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The measurement of FFM by the dual energy X-ray absorptiometry is accepted to be the gold standard for body composition analysis in these patients.[8] The other commonly used methods for analysing body composition in research are computerised actual tomography, magnetic resonance imaging and bioelectrical impedance analysis (BIA). Majority of these methods are complex, require extensive labour, are costly and are not frequently available for use in clinical/nutritional practice.[9] BIA is relatively easy to practice and less expensive. In addition, the use of BIA for the determination of body composition has been validated.[4,10] The evaluation of body composition based on anthropometric measures such as height, weight, skinfold thickness at various sites and/or the measurement of the arm, abdomen and calf circumference is a common practice in resource-limited settings. Such a practice involves the use of statistically validated prediction equations in comparison to standard assessment methods.[9] Limited research is available on the validation of the use of predictive equations to estimate FFM in patients with COPD.

Considering the usefulness of the measurement of FFM in clinical settings lacking standardised equipment for FFM analysis, this study aims to assess the predictive performance of four FFM predicting equations using anthropometric variables against FFM derived by BIA using appropriate statistical methods.

Materials and Methods

Subjects

A total of 72 patients with stable COPD visiting the outpatient department of Pulmonology at JSS Multispeciality Hospital, Mysuru were selected consecutively for the study. Patients aged between 40 and 75 years without exacerbation of COPD, infection, evident oedema, heart disease, diabetes mellitus, renal failure and malignancy were included for the study after obtaining their informed consent. Ethical clearance was obtained from the Institutional Human Ethics Committee of University of Mysore (IHEC-UOM No. 100 Ph.D/2014-15 dated 07.08.2014) and JSS Hospital Mysore (JSS/MC/IEC/01/6903/2014-15 dated 03.03.2015). The pulmonary function was evaluated by spirometry (Easy one Pro LAB), and the staging of COPD was performed as per the global initiative for chronic obstructive lung disease classification.[11] Height was measured using a stadiometer to the nearest 0.1 cm, and weight was measured with the patients wearing light clothes. BMI was derived from the same.

Estimation of fat-free mass of patients by bioelectrical impedance analysis

The patients were analysed for FFM in a fasting state (or at least 4 h after a meal), with the patients lying in supine position for 10 min on a non-conducting surface with the legs slightly separated and the arms slightly away from the trunk. Surface electrodes were placed on the dorsal surfaces of the hand and foot proximal to the metacarpal phalangeal and metatarsal phalangeal joints, respectively. In addition, surface electrodes were also placed at the pisiform prominence of the wrist and between the medial and lateral malleoli of the ankle.[12] The analyses were performed using a ‘Bioscan 916’ analyser (50 kHz single frequency, Maltron International Ltd, UK).

Estimation of fat-free mass by prediction equations

The age of the patients in the study group ranged between 40 and 75 years. Because there are no reported predictive equations for predicting FFM specifically for this age group (with COPD), four predictive equations were selected for validation keeping in mind the age range of the study group (40–75 years). The selected equations were developed in patients from both gender aged between 18 and 82 years. Among the four equations, three equations predicted FFM while the Deurenberg equation estimated fat mass (in %). This was further converted to kilograms of fat mass and subtracted from the total body weight to obtain FFM values.

The four prediction equations chosen for analysis are as follows:

(1) Kulkarni *et al.*[13]

$$\begin{aligned}\text{Lean mass (kg)} = &-15.605-(0.032\times \text{age in years})\\ &+(0.192\times \text{height in cm})\\ &+(0.502\times \text{weight in kg})\end{aligned}$$

(2) Solomon Yu *et al.*[14]

$$\begin{aligned}\text{Lean body mass (kg)} = &\ 22.93+0.68\,(\text{weight in kg})\\ &-1.14(\text{BMI})-0.01\,(\text{age in years})\\ &+9.94\,(\text{if male})\end{aligned}$$

(3) Janmahasatian equation[15]

$$\text{Fat}-\text{free mass (kg)}_{\text{male}} = (9270\times \text{weight})/\{6680+(216\times \text{BMI in kg/m}^2)\}$$

(4) Deurenberg equation[16]

$$\begin{aligned}\text{Body fat (\%)} = &\ (1.2\times \text{BMI in kg/m}^2)\\ &+(0.23\times \text{age in years})\\ &-(10.8\times \text{gender})-5.4\\ &\text{Male}=1,\ \text{Female}=0\end{aligned}$$

Statistical analyses

The demographic data of the study population were expressed as mean and standard deviation (SD) or number and percentage, as appropriate. The Bland and Altman plot analysis was performed for the evaluation of the agreement between the predicted FFM and FFM by BIA, which involves the study of mean differences and establishes a limit of agreement into which 95% of the differences fall. The limits of agreement were defined as the difference between FFM values from each one of the selected predictive equations and FFM by BIA ± 1.96 s. The normality of distribution was assessed by Shapiro–Wilk test.[17] The bias, precision and accuracy of the predictive equations were calculated for assessing the performance of the equations considering FFM values from BIA as standard with 95% confidence intervals. The bias was measured in terms of mean error, which is also known as 'mean difference', meaning the average of all the differences between FFM values by predictive equations and FFM by BIA. The 95% confidence interval (CI) of the mean difference was calculated to analyse the precision of the systematic difference. The bias was considered to be insignificant when the line of equality was within this interval. The line of equality being outside these limits indicate constant over/underestimation compared to the standard measurement.[17,18] The accuracy was defined in terms of the root mean square error (RMSE), which is the square root of the mean squared differences.[19] The performance of the predictive equations was analysed on all the samples as a whole and after categorising them into sub-groups on the basis of BMI and age. The patients were categorised based on the BMI classification recommended for use among the South Asian population.[20] All the statistical tests were performed using the Statistical Package for the Social Sciences version 19.0 software for Windows (SPSS Inc., Chicago, IL, United States).

Table 1: Demographic characteristics of the participants

Parameter	Mean ± SD or *n* (%) as appropriate
Age (years)	61 ± 9.1
Gender – Male	72 (100%)
Height (cm)	166.47 ± 5.78
Weight (kg)	58.38 ± 12.56
BMI (kg/m^2)	20.99 ± 4.13
Percentage of predicted FEV_1	48.36 ± 16.06
Percentage of predicted FVC	70.22 ± 16.78
FEV_1/FVC ratio	0.55 ± 0.09

BMI = body mass index, FEV_1 = forced expiratory volume in 1 s, FVC = forced vital capacity.

Results

Characteristics of the subjects

The age, anthropometric measures and pulmonary function of the patients involved in the study are presented in Table 1. The age of the patients ranged from 40 to 74 years. An age-wise distribution of the patients revealed 10 (13.9%) patients in the age group of 40–49 years, 15 (20.8%) aged 50–59 years, 32 (44.4%) aged 60–69 years and 15 (20.8%) aged 70–75 years. On evaluation of pulmonary function, 35 (48.6%) patients were diagnosed with moderate COPD, 26 (36.1%) patients with severe COPD, 8 (11.1%) patients with mild COPD and 3 (4.1%) patients with very severe COPD. The BMI of the patients ranged between 13.67 and 33.12 kg/m^2. Among the patients, based on their BMI, 22 (30.6%) were underweight, 32 (44.4%) were normally nourished, 5 (6.9%) were overweight and 13 (18.1%) were obese.

Predictive performance of the equations

The Bland–Altman plots comparing the FFM estimated by BIA and by the predictive equations are presented in Figure 1. The study sample follows normal distribution after the assessment of test of normality by Shapiro–Wilk test. The plots indicated best agreement between FFM by BIA and FFM predicted by the equations of Kulkarni *et al.* and the Deurenberg equation as evident by the proximity of the mean error near zero (a mean error of '0' indicates the absence of error in the predicted value). Statistically significant differences were absent between the BIA-derived FFM and FFM derived by the above mentioned equations on analysis by paired samples *t*-test. The mean error observed in the prediction of FFM by the equation of Kulkarni *et al.* and the Deurenberg equation was not significant because they included the line of equality in the 95% CI value for the mean error. The equation by Yu *et al.* and Janmahasatian equation overestimated the FFM values and had a significant mean error. The performance of predictive equations in terms of bias (mean error) and accuracy (RMSE) is presented in Table 2. Prediction equation by Kulkarni *et al.* and Deurenberg equation had the least bias, RMSE and SD compared to the equation by Yu *et al.* and Janmahastian equation, which overestimated the FFM values as measured by BIA. The CI values of the equation by Kulkarni *et al.* and Deurenberg equation indicate a near equal distribution of the

Table 2: Predictive performance of equations compared to FFM by BIA

FFM estimation methods (*n* = 72)	FFM (kg) Mean (SD)	Mean error (95% CI) (kg)	RMSE (95% CI) (kg)	Paired *t*-test, *P* value	SEE
FFM by BIA	44.03 (6.79)	–	–	–	–
Kulkarni *et al.* equation	43.71 (6.86)	−0.33 (−4.910, 4.258)	2.35 (−1.889, 2.559)	$t(71) = 1.182$, $P = 0.241$	2.354
Solomon Yu *et al.* equation	48.02 (4.35)	3.99 (−2.449, 10.428)	5.11 (1.761, 6.219)	$t(71) = -10.518$, $P = 0.000$	2.063
Janmahasatian equation	47.79 (6.82)	3.76 (−0.443, 7.956)	4.32 (1.531, 5.989)	$t(71) = 14.881$, $P = 0.000$	2.157
Deurenberg equation	44.34 (6.95)	0.31 (−3.330, 3.946)	1.83 (−1.919, 2.539)	$t(71) = -1.439$, $P = 0.154$	1.824

FFM = fat-free mass in kg, RMSE = root mean square error, BIA = bioelectrical impedance analysis, CI = confidence intervals, SEE = standard error of estimate.

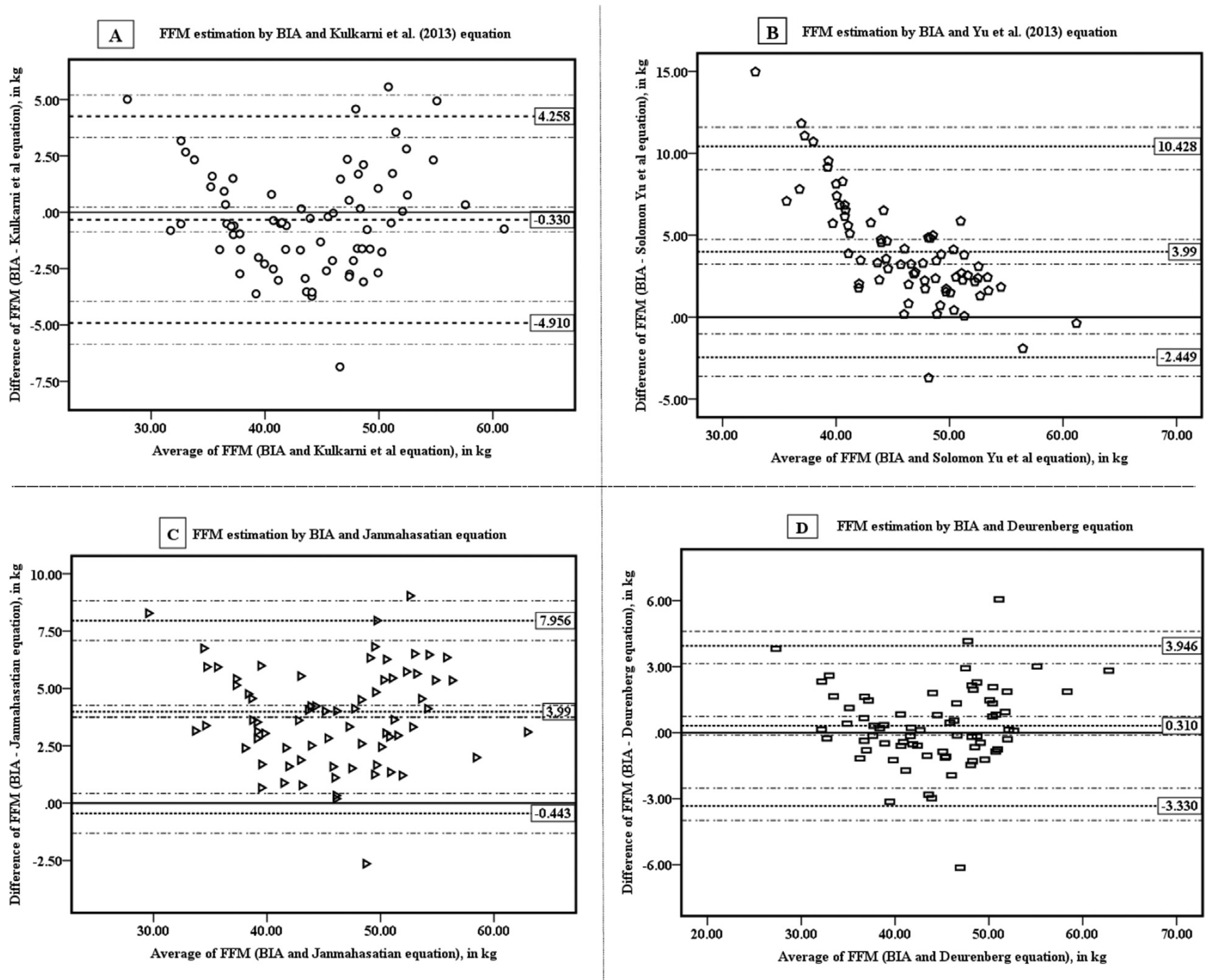

Figure 1: Bland–Altman plots comparing the FFM estimated by BIA and by the predictive equations (n = 72). Straight line (—) indicates zero difference; (- - -) is the mean difference and upper and lower limits of 95% confidence intervals; (- – -) indicates the limits of agreement for the mean difference and confidence intervals

upper and lower limits, that is an underestimation and overestimation to a similar extent. The other two equations indicate a higher proportion of overestimation of FFM values as evident by a higher upper limit value of CI than the lower limit values for both mean error and RMSE. Overall, the equations by Kulkarni *et al.* and Deurenberg equation appear to have the least bias and better accuracy than the other two predictive equations.

Performance across body mass index sub-groups

The performance of the equations across different BMI sub-groups is presented in Table 3. The Deurenberg equation exhibited lower bias and RMSE across all BMI sub-groups indicating better accuracy, precision and prediction followed by the Kulkarni *et al.* equation across underweight and normal BMI sub-groups. The other two equations constantly overestimated FFM values as evident by a higher mean error, as well as lower precision and RMSE values. The Deurenberg equation performed better than the other equations in the normal BMI group. In the overweight group, FFM by Deurenberg equation had the least mean error but similar RMSE as other equations. The prediction by Kulkarni *et al.* underestimated the FFM, whereas the prediction equation by Solomon Yu *et al.* and Janmahasatian equation overestimated FFM. The mean error in the prediction of FFM by the selected equations ranged from 0.75% in the equation by Kulkarni *et al.* to 9% in the equation by Yu *et al*. Overall, the Deurenberg equation had lower bias, as well as better precision and accuracy across underweight and normal BMI sub-groups. The equation by Kulkarni *et al.* displayed better prediction in the underweight group only. All the equations constantly overestimated FFM in the overweight and obese sub-groups as evident by lower precision and similar RMSE values.

Performance across sub-groups classified according to the age

The performance of the equations across different age groups is presented in Table 4. The Deurenberg equation had the best performance in the age group of 40–49 years as

Table 3: Performance of predictive equations across patients with COPD who were classified on the basis of their BMI

BMI groups	FFM estimation methods	Mean (SD) (kg)	Mean error (95% CI) (kg)	RMSE (95% CI) (kg)
Underweight (*n* = 22)	FFM by BIA	36.18±4.33	–	–
	Equation by Kulkarni *et al.*	36.30±2.92	0.12 (–3.744, 4.014)	1.94 (–2.109, 2.349)
	Equation by Solomon Yu *et al.*	43.75±2.18	7.57 (1.962, 13.179)	8.05 (5.341, 9.799)
	Janmahasatian equation	40.19±3.16	4.01 (0.370, 7.651)	4.4 (1.781, 6.239)
	Deurenberg equation	36.59±3.22	0.41 (–2.505, 3.317)	1.48 (–1.819, 2.639)
Normal (*n* = 32)	FFM by BIA	46±3.55	–	–
	Equation by Kulkarni *et al.*	44.48±3.44	-1.52 (–4.367, 1.336)	2.08 (–3.749, 0.709)
	Equation by Solomon Yu *et al.*	48.61±3.06	2.61 (–0.278, 5.496)	2.97 (0.381, 4.839)
	Janmahasatian equation	48.96±4.0	2.96 (1.960, 6.269)	3.39 (0.731, 5.189)
	Deurenberg equation	45.67±4.01	-0.32 (–2.835, 2.186)	1.28 (–2.549, 1.909)
Overweight (*n* = 5)	FFM by BIA	46.72±2.73	–	–
	Equation by Kulkarni *et al.*	45.26±2.18	-1.46 (–8.349, 5.43)	3.47 (–3.689, 0.769)
	Equation by Solomon Yu *et al.*	48.15±2.05	1.43 (–5.252, 8.108)	3.31 (–0.799, 3.659)
	Janmahasatian equation	49.51±2.38	2.79 (–4.158, 9.744)	4.23 (0.561, 5.019)
	Deurenberg equation	46.23±2.01	–0.48 (–7.600, 6.632)	3.22 (–2.709, 1.749)
Obese (*n* = 13)	FFM by BIA	51.46±4.3	–	–
	Equation by Kulkarni *et al.*	53.74±3.42	2.28 (–1.550, 6.117)	2.96 (0.051, 4.509)
	Equation by Solomon Yu *et al.*	53.77±2.79	2.31 (–1.734, 6.358)	3.02 (0.081, 4.539)
	Janmahasatian equation	57.11±3.04	5.66 (2.004, 9.307)	5.93 (3.431, 7.889)
	Deurenberg equation	53.46±4.27	2.01 (–1.520, 5.533)	2.63 (–0.219, 4.239)

BMI = body mass index, FFM = fat-free mass in kg, RMSE = root mean square error, BIA = bioelectrical impedance analysis, CI = confidence intervals.

Table 4: Performance of predictive equations across patients with COPD who were classified on the basis of their age

Age group	FFM estimation methods	Mean (SD) (kg)	Mean error (95% CI) (kg)	RMSE (95% CI) (kg)
40–49 years (*n* = 10)	FFM by BIA	47.79±7.32	–	–
	Equation by Kulkarni *et al.*	45.47±8.16	–2.32 (–4.821, 0.175)	2.62 (–4.549, –0.091)
	Equation by Solomon Yu *et al.*	49.09±5.62	1.29 (–2.898, 5.484)	2.37 (–0.939, 3.519)
	Janmahasatian equation	49.07±7.94	1.27 (–0.422, 2.967)	1.51 (–0.959, 3.499)
	Deurenberg equation	48.03±8.39	0.24 (–2.340, 2.812)	1.24 (–1.989, 2.469)
50–59 years (*n* = 15)	FFM by BIA	43.68±6.47	–	–
	Equation by Kulkarni *et al.*	43.55±6.71	–0.13 (–4.574, 4.313)	2.19 (–2.359, 2.099)
	Equation by Solomon Yu *et al.*	47.93±4.38	4.25 (–1.555, 10.050)	5.09 (2.021, 6.479)
	Janmahasatian equation	47.51±6.76	3.83 (–0.006, 7.661)	4.27 (1.601, 6.059)
	Deurenberg equation	44.85±6.93	1.17 (–2.506, 4.851)	2.13 (–1.059, 3.399)
60–69 years (*n* = 32)	FFM by BIA	43.08±6.25	–	–
	Equation by Kulkarni *et al.*	42.70±6.20	–0.38 (–4.831, 4.080)	2.27 (–2.609, 1.849)
	Equation by Solomon Yu *et al.*	47.42±3.86	4.34 (–1.954, 10.636)	5.33 (2.111, 6.569)
	Janmahasatian equation	46.93±6.31	3.85 (–0.199, 7.902)	4.36 (1.621, 6.079)
	Deurenberg equation	43.05±6.30	–0.03 (–3.991, 3.940)	1.95 (–2.259, 2.199)
70–75 years (*n* = 15)	FFM by BIA	43.92±7.65	–	–
	Equation by Kulkarni *et al.*	44.84±7.73	0.92 (–3.709, 5.541)	2.46 (–1.309, 3.149)
	Equation by Solomon Yu *et al.*	48.70±4.60	4.78 (–2.481, 12.038)	5.93 (2.551, 7.009)
	Janmahasatian equation	49.06±7.52	5.14 (1.723, 8.554)	5.41 (2.911, 7.369)
	Deurenberg equation	44.13±7.84	0.2 (–2.992, 3.402)	1.56 (–2.029, 2.429)

BMI = body mass index, FFM = fat-free mass in kg, RMSE = root mean square error, BIA = bioelectrical impedance analysis, CI = confidence intervals.

evident by the lowest mean error and RMSE values. Underestimation of FFM was evident by the Kulkarni *et al*. equation, and overestimation was observed by the equations of Yu *et al.* and Janmahasatian equation in this group. In the age group of 50–59 years, the equation by Kulkarni *et al.* had the least mean error, whereas all other equations overestimated the FFM. Deurenberg equation and the equation by Kulkarni *et al.* had the lowest RMSE values, but the latter had a better precision. In the age group of 60–69 years, the Deurenberg equation and the equation by Kulkarni *et al.* had the least mean error and RMSE values, whereas the other three equations overestimated the FFM. Considering the mean error, 95% CI of mean error and RMSE values, the

Deurenberg equation performed the best in the 40–49, 50–59 and 70–75 years sub-groups followed by the equation of Kulkarni *et al.* across the 50–79 years sub-group. An overestimation of FFM was evident in the values predicted by the Janmahasatian and Yu *et al.* predictive equations.

Discussion

The objective of this study was to analyse the performance of prediction equations in predicting the FFM considering FFM estimated by BIA as standard in patients with COPD, which is of importance in the assessment of nutritional status and the provision of nutrition therapy.

In the current study, we found a better agreement of predicted FFM values by the Deurenberg equation and the equation by Kulkarni *et al.* with FFM by BIA as demonstrated by a lesser mean error of 0.31 and −0.33 kg, respectively and RMSE values of 1.83 and 2.35 kg, respectively. The bias in the prediction was considered to be absent because the limits of agreement included zero. Researchers have used 'healthy participants' to frame the predictive equations, which could mean that factors related to changes in body composition could not be expected to be equal. The participants in this study had chronic illness associated with the respiratory system that is known to have a marked impact on the body composition and nutritional status.

The prediction equations by Kulkarni *et al.* were derived using 2364 Indian participants of both genders with normal health. The age of the participants ranged between 18 and 79 years and BMI between 14 and 44 kg/m^2. The study by Yu *et al.* included 52 Caucasians of both genders with normal health for the derivation of the equation. The equations derived were validated further in a cohort of 2287 people aged more than 50 years. The mean age was 50.6 ± 15.7 years in the base group, and the mean BMI of the participants was 23.7 ± 2.3 kg/m^2. The validation group included participants aged above 80 years and a higher proportion of patients who were overweight and obese as compared to our study group. The Janmahasatian equation was derived from 373 healthy participants aged between 18 and 82 years, with BMI ranging from 17.1 to 69.9 kg/m^2. Among these, 71% of the patients had BMI above 25 kg/m^2 indicating majority of the participants to be overweight or obese as compared to 25% of participants who were overweight and obese in our study. The Deurenberg equation was derived separately for children and adults from a group of 1229 healthy participants from Netherlands comprising both genders, aged between 7 and 83 years and having a BMI ranging between 13.9 and 40.9 kg/m^2. The participants in the study by Kulkarni *et al.* and Deurenberg *et al.* had a wider age range and a higher degree of patients who were obese as compared to our study group. It is interesting to note that the Deurenberg equation, originally derived from the Dutch population, performed well on the participants in our study hailing from South India. The Janmahasatian equation and the equation by Yu *et al.* exhibited a constant overestimation of FFM values.

The pattern of over- or underestimation observed in the prediction of FFM by these equations may arise from differences in the population race, demographic characteristics such as age and BMI clinical status among the study groups. The proportion of malnourished to normally nourished patients in the study groups and the difference in BMI classification norms applied could also be the reason for the alteration in performances (BMI classification norms for the south Asian population used in our study group vs. the general classification norms in the reference study groups). Although the Deurenberg equation and the equation by Kulkarni *et al.* performed well overall, the performance among sub-groups is inconsistent. Considering the need for accuracy in determining the FFM of a specific patient undergoing assessment in a clinical setting, the predictive performance across various age and BMI groups is necessary besides the overall performance in a heterogeneous population with respect to the nutritional status and age.

To our knowledge, this is the first study evaluating the performance of the selected predictive equations in South Indian patients with COPD for predicting FFM. The Deurenberg equation is used to predict fat mass routinely in clinical practice, and the performance of the same has been evaluated in comparison with equations derived from Indian participants.[21,22] However, studies using Deurenberg equation to derive FFM from fat mass values are not reported. The limitations of the study include the absence of female patients in the study group and insufficient sample size in the sub-groups. The application of the validated equations in other population groups across the country may require further validation.

Conclusion

In summary, the equation by Kulkarni *et al.* and the Deurenberg equation can be useful in a clinical setting lacking advanced and specific equipment for FFM analysis such as BIA. Although these equations provide agreeable performance as evidenced by lower bias, better precision and accuracy on a whole, inconsistency in performance is evident across specific age and BMI sub-groups. The equation by Kulkarni *et al.* provides agreeable performance in patients aged between 50 and 69 years, and the Deurenberg equation can predict FFM accurately in patients aged between 40–49 years and 60–75 years. The performance of these two equations is agreeable in the patients who are underweight and those with normal BMI. The performance across overweight and obese groups requires further validation because of the lack of sufficient sample size. This study supports the assessment of body composition as a simple marker of nutrition depletion and disease severity in COPD staging.

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Conflicts of interest

There are no conflicts of interest.

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