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Original Article

# Estimating body composition from skinfold thicknesses and bioelectrical impedance analysis in cystic fibrosis patients

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**Abstract**

*Background:* The accuracy of body composition estimates based on skinfold thickness measurements and bioelectrical impedance analysis (BIA) is not yet adequately explored in cystic fibrosis (CF). Using DXA as reference method we verified the accuracy of these techniques and identified predictors of body composition specific for CF.
*Methods:* One hundred forty-two CF patients (age range: 8–31 years) underwent a DXA scan. Body fat percentage (BF%) was estimated from skinfolds, while fat free mass (FFM) from single-frequency 50 kHz BIA.
*Results:* Bland–Altman analysis showed poor intra-individual agreement between body composition data provided by DXA and BF% estimated from skinfolds or FFM estimated from BIA. The skinfolds of the upper arm were better predictors of BF% than BMI, while compared to other BIA measurements the best predictor of FFM was the R-index (Height$^2$/Resistance).
*Conclusions:* Due to poor accuracy at individual level, the estimates of body composition obtained from these techniques cannot be part of the standard nutritional assessment of CF patients until reliable CF-specific equations will become available. BMI has limited value in predicting body fatness in CF patients and should be used in combination with other predictors. Skinfolds of the upper arm and *R*-index are strongly related to BF% and FFM and should be tested in a large CF population to develop specific predictive equations.


*Keywords:* Body composition; DXA; Skinfold thicknesses; Bioelectrical impedance analysis; Cystic fibrosis

## 1. Background

Cystic fibrosis (CF) is a common recessive genetic disease, caused by mutations of CF trans-membrane conductance regulator (CFTR) gene. The major clinical consequences of impaired CFTR function are pancreatic insufficiency, recurrent infections and progressive lung disease. CF patients are at high risk for malnutrition because of anorexia with reduced food intake, increased fecal energy loss and high resting energy expenditure during pulmonary exacerbations. Furthermore chronic inflammation and reduced physical activity contribute to alterations in body composition [1]. In CF patients the chronic inflammatory process has been shown to reduce fat free mass (FFM), that in turn leads to a reduction in skeletal muscle mass, inspiratory muscle wasting and impairment of inspiratory muscle function [1–3]. In addition, recent studies have documented an association between FFM depletion and poor respiratory muscle strength or impaired pulmonary function [4,5].

*Abbreviations:* BIA, bioelectrical impedance analysis; BMD, bone mineral density; CF, cystic fibrosis; FEV1, forced expiratory volume in one second; FM, fat mass; FFM, fat free mass; BF%, body fat percentage; ICC, intraclass coefficient of correlation; LA, limits of agreement; R, resistance; RMSE, root mean square error; SF, skinfold; SF-BIA, single-frequency bioelectrical impedance analysis; MF-BIA, multi-frequency bioelectrical impedance analysis.

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However standard nutritional indicators such as height, weight and BMI do not allow identifying the body composition alteration frequently found in CF patients [5–7].

Given the above mentioned reasons, the possibility to evaluate body composition in these patients is clinically relevant and in-depth assessment of nutritional status should include fat mass (FM) and FFM analysis.

The European CF bone mineralization guidelines recommend routine bone density DXA scans in the age range between 8 and 10 years to assess bone mineral density (BMD) [8]. DXA is a widely recognized method of body composition analysis that beyond BMD provides information of the nutritional status of the patients, including fat reserve and lean soft tissue. DXA can also be used for nutritional monitoring over an extended period of time because the radiation exposure is low. However, access to DXA may be limited in many situations and the cost of the measurement may be relevant, therefore DXA may not be used extensively for nutritional follow-up.

For many years researchers have been looking for simple, easy to perform and sufficiently accurate methods to estimate and monitor body composition in routine clinical practice. Skinfold thickness measurement and bioelectrical impedance analysis (BIA) have proved to be useful in population studies, but perform worse on individual basis.

Several predictive equations based on skinfolds and BIA measurements in healthy subjects and in patients affected by different diseases have been published. These equations have shown low accuracy when applied in a population different from that where they were derived [9].

Therefore the objectives of this study were: 1) to verify the agreement between SF and BIA with DXA in CF patients, using DXA as reference method; and 2) to identify predictors of body composition in a CF population.

## 2. Methods

One hundred forty-two Caucasian CF patients attending the CF Center of Milan underwent DXA scan, BIA and skinfold measurements on the same day.

Height was measured to the nearest 0.5 cm on a standardized stadiometer. Body weight was determined to the nearest 0.1 kg by a standard physician scale with the subjects dressed only in light underwear and without shoes. BMI was calculated as weight (kg) divided by height squared ($m^2$). Age- and gender-specific *Z*-scores of height, weight and BMI were calculated using the CDC references [10]. Forced expiratory volume in one second (FEV1) values were considered to define the severity of lung disease according to the Cystic Fibrosis Foundation (CFF) criteria (severe FEV1 $<40\%$, moderate 40–69%, normal/mild $\geq 70\%$) [11].

Pubertal status was determined using breast and pubic hair stages in girls, testicular and pubic hair stages in boys, according to the Tanner criteria [12]. Written and informed consent was obtained from all of the subjects or their parents. The study protocol was approved from the local ethical committee.

### 2.1. Skinfold thickness measurements

SF thickness was determined to the nearest 0.2 mm at the left biceps, triceps, sub-scapular and supra-iliac sites using a Holtain skinfold caliper calibrated to exert a constant pressure of 10 $g/mm^2$ (Holtain Ltd, Crymych, UK). Triplicate readings were made as recommended by Lohman et al. [13]. In subjects aged less than 17 years, BF% was predicted by the equation of Slaughter et al.[14], while in older patients BF% was predicted using the equation by Durnin and Womersley [15].

### 2.2. Bioelectrical impedance analysis

BIA was performed using a single-frequency BIA analyzer (BIA 101 RJL, Akern Bioresearch, Firenze, Italy) which applies a 50 kHz oscillating current of 800 μA. The subject was set in supine position and the electrodes placed on the dorsal surface of the right foot and ankle, as well as on the right wrist and hand. Resistance (*R*) was recorded and normalized by height (*R*-index: $height^2/R$). FFM (kg) was predicted by the software BodyGramPro 3.0®.

### 2.3. Dual X-ray absorptiometry

Participants underwent whole-body DXA scanning (DXA Hologic Discovery Hologic, Waltham, USA), a technique that is able to estimate FM and FFM by measuring the X-ray attenuation of different tissue components, after the instrument calibration with a phantom (including six fields of lucite and aluminum of varying thickness and known absorptive properties) scanned as an external standard. The whole-body DXA scans were performed at the Istituto Auxologico Italiano and analyzed with the same protocol throughout the entire duration of the study. At our laboratory, the coefficients of variation (CVs) for FM and FFM were 2.9% and 1.7%, respectively. Body composition was assessed by the three compartment model (version 12.3); including FM, bone mineral content, and FFM. FFM was calculated using the sum of the estimates of lean tissue mass and bone mineral content. BMD was determined on total body in adults and in total body excluding the head in pediatric patients, because the skull does not develop at the same rate as the other parts of the skeleton [16]. Age and gender-specific *Z*-scores of BMD were calculated. The *Z*-scores were calculated with reference to the BMD of healthy age- and sex-matched Italian population obtained in our laboratory. Our reference database includes the anthropometric, gender, age, puberty, and DXA data of 410 healthy Italian subjects, 2–25 years of age.

### 2.4. Statistical analysis

Intraclass coefficients of correlation were calculated to analyze correlation between body composition data estimated from skinfolds or BIA and those obtained by DXA. Mean values of body composition data were compared among methods by paired *t*-test to verify the agreement on the overall population. The percent relative difference between skinfolds or BIA data and