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Nutritional Assessment in Children with Cystic Fibrosis: The Role of Body Composition

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ABSTRACT

Introduction: Cystic fibrosis (CF) is a genetic disorder caused by CFTR gene mutations, leading to thick mucus that affects multiple organs, resulting in maldigestion, malabsorption, and poor appetite. These factors increase energy needs, causing undernutrition in CF patients. Body mass index (BMI) is commonly used but does not differentiate lean body mass (LBM) and bone mass. Bioelectrical impedance analysis (BIA) provides a more detailed assessment of body composition. This study aims to evaluate the nutritional status of children with CF by analyzing fat mass (FM) and fat-free mass (FFM) using BIA.

Methods: This study included CF patients aged 7 to 18 years from the Cystic Fibrosis Specialty Clinic at Akbar Children's Hospital in Mashhad, Iran. Excluded were patients with pulmonary exacerbation, severe diarrhea-induced dehydration, or those who did not give informed consent. Body composition were assessed using the Tanita BC 418 BIA device.

Results: 47 patients (48.9% female, 51.1% male) with a mean age of 10.74 ± 2.99 years were evaluated. Significant positive correlations were found between FM and weight Z-score (r=0.512, p<0.001), BMI (r=0.430, p=0.003), and BMI Z-score (r=0.633, p<0.001). FFM was strongly correlated with age (r=0.814, p<0.001), height (r=0.931, p<0.001), and weight (r=0.977, p<0.001). The prevalence of low FM and FFM was 21.3% and 40.4%, respectively. Low FM was significantly associated with increased hospital admission (p=0.021, OR=15.62).

Conclusion: FM and FFM are strongly linked to growth and nutritional indicators in CF, with low FM correlating to more hospital admissions, highlighting the need for targeted nutritional interventions to improve outcomes.

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Introduction

Cystic fibrosis (CF) is caused by recessive mutations in the CFTR gene, leading to thick mucus secretions that impact multiple organs. Loss of CFTR function results in maldigestion, malabsorption, poor appetite, and increased energy needs, often causing undernutrition(1).

Assessing body composition is crucial in cystic fibrosis (CF) care and is recommended in guidelines to understand nutritional status and health outcomes better. **Body mass index (BMI)** is traditionally used to evaluate nutritional status; however, it has limitations as it combines **fat mass (FM)** and **fat-free mass (FFM),** which includes **lean body mass (LBM)** and bone mass. Differences in body composition by sex, age, and race challenge BMI's effectiveness in accurately reflecting nutritional status(2).

Body composition assessment evaluates the roles of muscle, bone, and fat in energy metabolism, commonly using **2-compartment models (FM + FFM)** or **3-compartment models (FM, LBM + bone mass).** Although BMI is often used to assess fat mass and cardiometabolic risk, fat distribution, and LBM have distinct health implications(3). Various methods, such as **dual-energy X-ray absorptiometry (DXA), bioelectrical impedance analysis (BIA), magnetic resonance imaging (MRI),** and **computed tomography (CT),** are used to assess body composition, each with advantages and limitations. DXA is widely used in CF for monitoring bone and body composition, whereas BIA provides a quick, cost-effective alternative. MRI and CT serve as gold standards for evaluating

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muscle and fat quality, with newer methods such as **quantitative magnetic resonance (QMR)** offering rapid scanning capabilities(4).

In individuals with CF, BMI may not accurately reflect body composition. Studies have shown that **lower FFM** is associated with worse pulmonary function and greater disease severity, while **higher FFM** correlates with better bone mineral density(2). Adults with CF generally have lower **FFM, LBM,** and **skeletal muscle mass,** although recent research suggests no significant differences in LBM, potentially due to improved health management(5). Findings on FM remain inconsistent; some studies report lower FM, particularly in children, while others find no significant difference. Additionally, some research indicates an increase in central fat in CF patients(6).

Body composition varies across sex, race, and age. Women tend to have higher FM, while men have greater LBM(7). Fat distribution patterns differ between sexes, and African Americans typically exhibit greater LBM than Caucasians(8). Aging is associated with an increase in FM and a decline in LBM(9). This study aims to assess the nutritional status of children with cystic fibrosis (CF) by analyzing body composition using **Bioelectrical Impedance Analysis (BIA).**

Method

This study included patients with cystic fibrosis aged 7 to 18 who visited the Cystic Fibrosis Specialty Clinic at Akbar Children's Hospital in Mashhad, Iran. Patients were excluded if they were experiencing pulmonary exacerbation, dehydration due to severe diarrhea, or if they did not provide informed consent. Anthropometric assessment was performed on patients meeting the inclusion criteria, including measurements of weight, height, and BMI. Nutritional status was evaluated through body composition analysis using the Tanita BC 418 BIA device.

Statistical analysis

The statistical package for social sciences (SPSS) software version 24 (SPSS Corp, USA) was used for data analysis. The Kolmogorov-Smirnov test was used to assess the normality of continuous variables. Normally distributed variables were presented using mean and standard deviation (SD) while non-normally distributed variables were presented using median and interquartile range (IQR). The independent t-test and Mann-Whitney tests were used to compare normally and non-normally distributed variables, respectively. Categorical variables were presented using frequency and percentage. The chi-square test was used to assess the association between variables and the odds ratio (OR) was calculated for the contingency table. The level of statistical significance was $p<0.05$.

Results

Forty seven patients (23, 48.9% female and 24, 51.1% male) were evaluated in this study. The mean age of the participants was 10.74 ± 2.99 years. The majority of the participants (14, 60.87%) were outpatients, while 7 (30.43%) were admitted due to pulmonary and 2 (8.7%) were admitted due to gastrointestinal complaints (Figure 1). Admission data was missing for 24 participants.

Table 1 presents the anthropometric characteristics of the study participants and their comparison between genders. There was a significant difference in fat mass ($p<0.001$) and total fat percentage ($p=0.014$), and BMR ($p=0.006$) between genders.

Table 1. Anthropometric characteristics of the participants and comparison of the characteristics between genders

Variable	Total	Female	Male	p
Height (cm)	136.60 ± 15.84	131 (121-153)	138.33 ± 15.66	0.302†
Height (Z-score)	-0.91 ± 1.09	-0.93 ± 1.26	-0.88 ± 0.982	0.861‡
Weight (kg)	25.6 (19.9-36.1)	25.5 (18.2-39.6)	26.05 (20.38-34.25)	0.587†
Weight (Z-score)	-.174 ± 1.39	-1.65 ± 1.25	-1.83 ± 1.53	0.489‡
Body mass index (kg/m2)	14.1 (13.1-15.8)	14.83 ± 2.06	13.9 (13.18-15.13)	0.292†
Body mass index (Z-score)	-1.88 ± 1.61	-1.54 ± 1.19	-2.21 ± 1.90	0.158‡
Fat mass (%)	16 (13.6-19.6)	19.3 (16.1-21)	13.75 (11.55-16)	<0.001*†
Fat mass	3.9 (3-5.8)	5 (3.5-6.2)	3.6 (2.85-4.13)	0.070†
Fat-free mass (kg)	21.9 (16.8-30.4)	19.3 (15.3-32.6)	22.6 (17.7-29.1)	0.349†
Total body water (kg)	16 (12.3-22.3)	14.1 (11.2-23.9)	16.55 (13-21.28)	0.338†
Tfat (%)	11.53 ± 4.86	12.46 ± 3.96	9.85 (7.2-11.15)	0.014*†

Tfat mass (kg)	1.6 (1.2-2.3)	1.99 ± 0.97	1.5 (1.13-1.78)	0.277†
Tfat free mass (kg)	13.3 (11.4-17.9)	12.5 (9.8-18.8)	13.95 (11.88-17.15)	0.176†
BMI for age	2.57 (0.12-21.56)	4.31 (0.2-32.42)	1.4 (0.03-8.9)	0.186†
Basal metabolic rate (Kcal)	1096.23 ± 169.61	074 (889-1174)	11158.5 (10.62-1218.75)	0.006*†

† The Mann-Whitney test was used for the comparison
‡ The independent t-test was used for the comparison

Correlation between fat mass and fat-free mass indices and other study parameters are presented in Table 2. There was a significant and positive correlation between FM (%) and weight Z-score (r=0.512, p<0.001), BMI (r=0.430, p=0.003), BMI Z-score (r=0.633, p<0.001), and BMI for age (r=0.616, p<0.001). There was a significant and positive correlation between FM and age (r=0.368, p=0.011), height (r=0.450, p<0.001), height Z-score (=0.289, p=0.049), weight (r=0.667, p<0.001), BMI (r=0.719, p<0.001), BMI Z-score (r=0.650, p<0.001), TBW (r=0.576, p<0.001), BMI for age (r=0.618, p<0.001), and BMR (0.468, p=0.001). There was a significant and positive correlation between FFM and age (0.814, p<0.001), height (r=0.931, p<0.001), height Z-score (r=0.0.304, p=0.038), weight (r=0.977, p<0.001), weight Z-score (r=0.390, p=0.007), BMI (0.698, p<0.001), BMI Z-score (0.340, p=0.020), TBW (r=1.00, p<0.001), BMI for age (r=0.322, p=0.027), and BMR (r=0.889, p<0.001). There was a significant and positive correlation between TFM and weight Z-score (r=0.452, p=0.001), BMI (r=0.384, p=0.008), BMI Z-score (r=0.584, p<0.001), and BMI for age (r=0.570, p<0.001). There was a significant and positive correlation between TFM and height (r=0.317, p=0.030), weight (r=0.549, p<0.001), weight Z-score (r=0.650, p<0.001), TBW (r=0.420, p=0.003), BMI for age (r=0.629, p<0.001), and BMR (r=0.389, p=0.007). There was a significant and positive correlation between TFFM and age (r=0.811, p<0.001), height (r=0.932, p<0.001), height Z-score (r=0.94, p=0.045), weight (r=0.967, p<0.001), weight Z-score (r=0.372, p=0.010), BMI (r=0.682, p<0.001), BMI Z-score (r=0.326, p=0.025), TBW (r=0.988, p<0.001), BMI for age (r=0.307, p=0.036), and BMR (r=0.906, p<0.001).

Table 2. Correlation between fat mass and fat-free mass indices and other study parameters

Variable		FM (%)	FM	FFM	TFM (%)	TFM	TFFM
Age	r	-0.128	0.368	0.814	-0.109	0.252	0.811
	p	0.390	0.011*	<0.001*	0.467	0.087	<0.001*
Height	r	-0.130	0.450	0.931	-0.135	0.317	0.932
	p	0.383	0.001*	<0.001*	0.366	0.030*	<0.001*
Height Z-score	r	0.084	0.289	0.304	0.001	0.203	0.294
	p	0.576	0.049*	0.038*	0.992	0.172	0.045*
weight	r	0.147	0.667	0.977	0.129	0.549	0.967
	p	0.323	<0.001*	<0.001*	0.387	<0.001*	<0.001*
Weight Z-score	r	0.512	0.629	0.390	0.452	0.596	0.372
	p	<0.001*	<0.001*	0.007*	0.001*	<0.001*	0.010*
BMI	r	0.430	0.719	0.698	0.384	0.629	0.682
	p	0.003*	<0.001*	<0.001*	0.008*	<0.001*	<0.001*
BMI Z-score	r	0.633	0.650	0.340	0.584	0.650	0.326
	p	<0.001*	<0.001*	0.020*	<0.001*	<0.001*	0.025*
TBW	r	-0.008	0.576	1.000	-0.025	0.420	0.988
	p	0.958	<0.001*	<0.001*	0.869	0.003*	<0.001*

BMI for age	r	0.616	0.618	0.322	0.570	0.629	0.307
	p	<0.001*	<0.001*	0.027*	<0.001*	<0.001*	0.036*
BMR	r	-0.096	0.468	0.889	-0.044	0.389	0.906
	p	0.522	0.001*	<0.001*	0.767	0.007*	<0.001*

FM: Fat mass, FFM: Fat-free mass, TBW: Total body water, BMI: Body mass index, BMR: Basal metabolism rate
The Spearman correlation coefficient was used.
* Significant correlation

Based on the FM and FFM -2 Z-score cut-off, the prevalence of low FM and low FFM among the patients was 10 (21.3%) and 19 (40.4%) respectively. The association between the distribution pattern of FM and FFM categories among admission status is presented in Table 3.

There was a significant association between FM and admission status (p=0.021). This finding indicated that having low FM increased the odds of being admitted by 15.62 times.

The relationship between Fat Mass Index (FMI) and Age in Both Genders is shown in Figure 2 and Figure 3.

Table 3. Association between the distribution pattern of FM and FFM categories among admission status

Variable		Outpatient	Admitted	p
Fat mass	Normal or high	14 (100%)	6 (66.7%)	0.027*
	Low	0 (0%)	3 (33.3%)	
Fat-free mass	Normal or high	9 (64.3%)	6 (66.7%)	0.907
	Low	5 (35.7%)	3 (33.3%)	

The chi-square test was used for the analysis
* Significant association

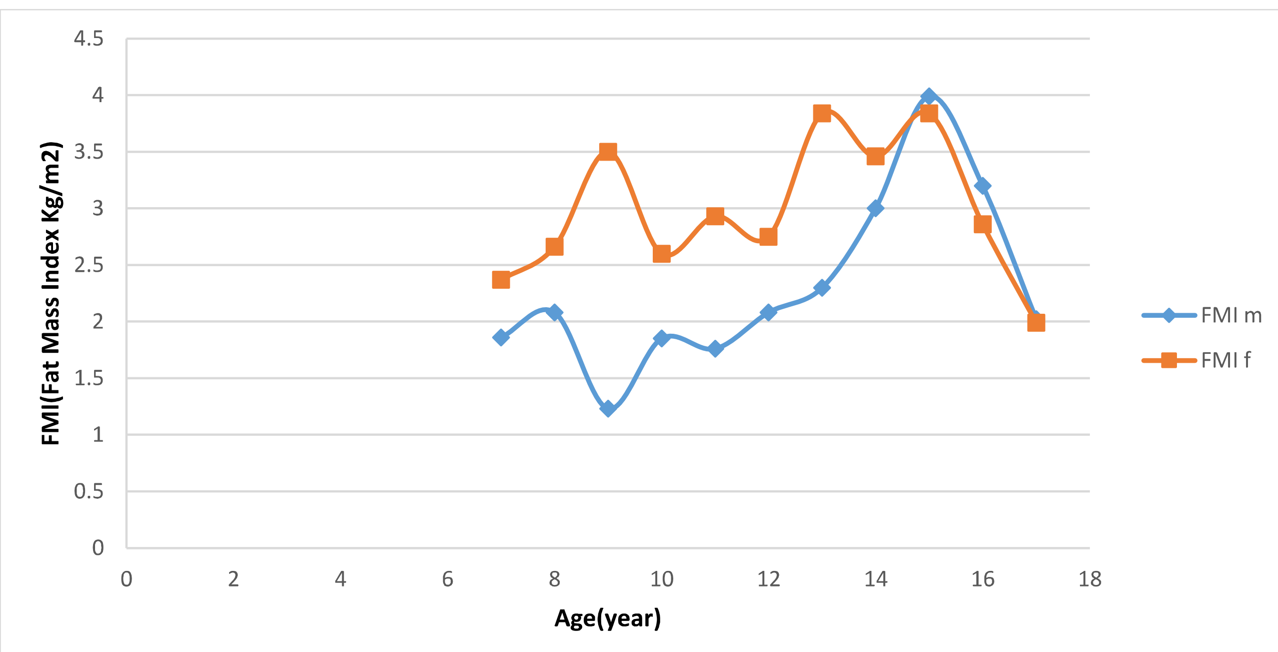

Figure 2: Relationship Between Fat Mass Index (FMI) and Age in Both Genders

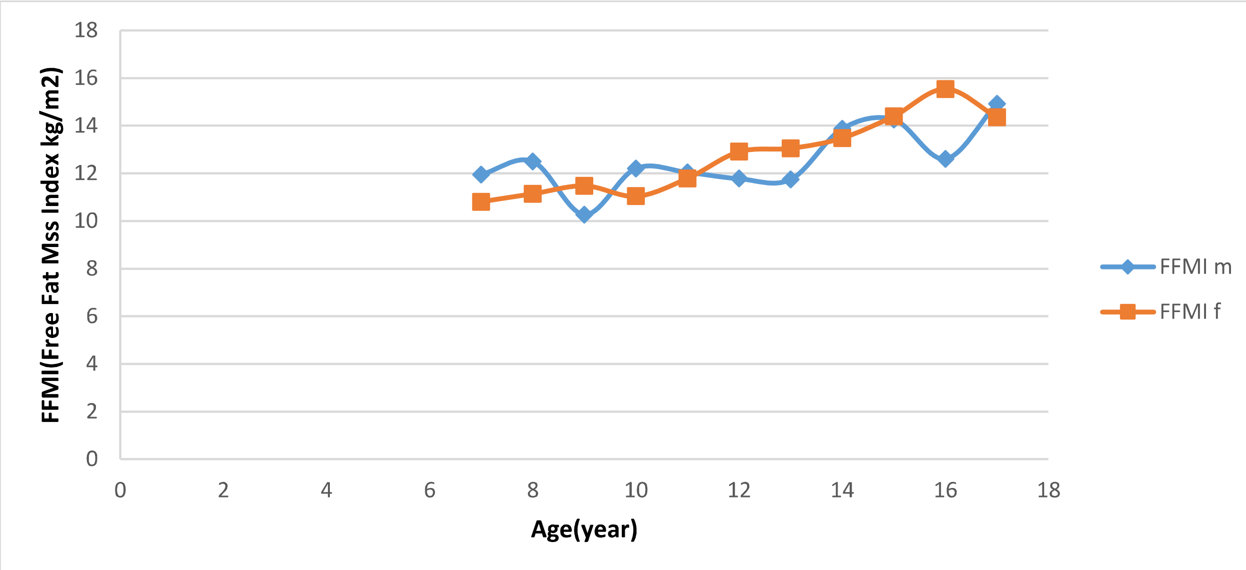

Figure 3: Relationship Between Fat-Free Mass Index (FFMI) and Age in Both Genders

Discussion

This study demonstrated significant positive correlations between fat mass (FM) and fat-free mass (FFM) with various growth and nutritional parameters, reinforcing their importance in nutritional assessment and metabolic health. FM was strongly associated with weight Z-score, BMI, BMI Z-score, and BMI-for-age, while FFM showed strong correlations with age, height, weight, total body water (TBW), and basal metabolic rate (BMR). Moreover, total fat mass (TFM) and total fat-free mass (TFFM) were positively linked with BMI, TBW, and BMR, highlighting their relevance in evaluating body composition. Additionally, the significant association between FM and hospital admission status suggests that low FM increases the likelihood of hospitalization, emphasizing the need for nutritional interventions to improve FM levels potentially reduce hospital admissions, and enhance overall health outcomes in individuals with cystic fibrosis.

In cystic fibrosis (CF), BMI alone is insufficient to detect fat-free mass (FFM) depletion and normal-weight obesity, where individuals may have a normal BMI but a high percentage of body fat (%BF), increasing metabolic risks(10). Therefore, more comprehensive body composition assessments are needed for accurate nutritional evaluation. A study examining body composition changes in children with CF found that BMI-z and FMI-z slightly decreased with age, while FFMI-z increased. It also reported that females had higher FFMI-z and FMI-z than males from 12.5 years of age(11). Another study indicated that body composition, particularly appendicular lean mass index (ALMI), may better predict clinical outcomes in CF patients than BMI. CF patients had lower ALMI despite having similar BMI to healthy controls, and ALMI was positively associated with lung function, whereas higher fat mass negatively affected it(12). Furthermore, a meta-analysis of 9114 CF patients found that overweight and obesity were associated with better lung function and a lower risk of exocrine pancreatic insufficiency and CF-related diabetes compared to normal BMI, underscoring the vital role of nutritional status in maintaining organ function in CF patients(13). However, this meta-analysis focused solely on BMI, without considering other measures such as FM or FFM. These findings emphasize the need for a more comprehensive approach to body composition assessment in CF patients to improve clinical outcomes.

In our study, a positive correlation was observed between fat mass (FM) and fat-free mass (FFM) with body mass index (BMI). Additionally, an increase in FM was associated with a reduction in hospital admissions, which may indicate the overall positive impact of improved nutritional status, regardless of its composition. The assessment of FM and FFM changes was conducted based on the standards of the Wells J.C.K study(14), which may have influenced the final results. To achieve more accurate findings, it is recommended to develop a standardized index for body composition assessment tailored to the Iranian population, use advanced tools such as DEXA scans, and increase the patient sample size. Moreover, indicators such as the severity of pulmonary involvement based on FEV1 may provide a better evaluation of disease outcomes.

Conclusion

Fat mass (FM) and fat-free mass (FFM) are strongly associated with key growth and nutritional indicators, highlighting their importance in assessing nutritional status in cystic fibrosis (CF) patients. Low FM was linked to higher hospital admissions, emphasizing the need for targeted nutritional interventions to improve health outcomes.

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