Nutritional assessment and rehabilitation in children with bronchiectasis and childhood interstitial lung diseases: effects on pulmonary functions and clinical severity

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Abstract

Background: Nutrition is recognized as a modifiable contributor to bronchiectasis and interstitial lung diseases (ChILD) development and progression. Nutritional interventions have great potential in reducing respiratory illness related morbidity and mortality. The study was done to assess nutritional state and body composition of children with bronchiectasis and interstitial lung diseases (ChILD) and to study the effect of short course nutritional intervention program on their growth, clinical symptoms, pulmonary functions and frequency of acute exacerbations and hospitalization. Seventeen patients with bronchiectasis and thirteen patients with interstitial lung diseases and 40 healthy children as controls were enrolled. Nutritional status, chest symptoms, anthropometry, body composition, and spirometric pulmonary function were evaluated. A short course nutritional intervention program was done for patients and then they were re-evaluated.

Results: In total, 56.67% of studied patients were moderately malnourished and 23.33% were severely malnourished. A total of 66.7% of studied patients were underweight and 50% of patients had stunted growth. Anthropometric indices were significantly lower than control groups ($P < 0.05$). Body composition indices were lower in patients than control but not with a statistical significance. Forced vital capacity was positively correlated to body mass index ($P = 0.045$). Nutritional rehabilitation significantly improved patient anthropometry (weight, body mass index, height, triceps skin-fold thickness, mid arm circumference), body composition (body fat, fat free mass, and muscle mass), respiratory symptoms, and FEV1. Needs to asthma rescue medications, school absence, acute exacerbation attacks, and hospitalization were reduced.

Conclusion: Patients with bronchiectasis and interstitial lung diseases (ChILD) have malnutrition and body composition changes that improved significantly after short nutritional intervention program with significant improvement in FEV1, frequency of acute exacerbations, and hospitalization.

Keywords: Nutrition, Bronchiectasis, Childhood interstitial lung disease, Body composition, Pulmonary functions

Background

Nutrition plays an important role in the etiopathophysiology of acute illnesses [1]. Malnutrition is an underlying cause of approximately half of the fatal acute respiratory tract infections [2]. Nutritional improvement is a keystone of current global efforts to reduce the burden of mortalities and morbidities resulting from acute lower

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respiratory infections (ALRIs) [3]. Not only the acute respiratory infections but also chronic respiratory diseases are interrelated with malnutrition. Now, many studies have tried to investigate nutritional status among CF and other respiratory diseases. Here, we are trying to assess nutritional state and body composition of children with bronchiectasis and interstitial lung diseases (ChILD) and to study the effect of short course nutritional intervention program on their growth, clinical symptoms, pulmonary function, and frequency of acute exacerbations and hospitalization.

Methods

This case control study was done in outpatient Chest Clinic of the Children's Hospital, Ain Shams University. The study was done to assess nutritional state and body composition of children with bronchiectasis and interstitial lung diseases (ChILD) and to study the effect of short course nutritional intervention program on their growth, pulmonary function, and frequency of acute exacerbations and hospitalization. Ethics approval was obtained from Ain Shams University, Faculty of Medicine, Research Ethics Board on 22 December 2014. Written informed consent of participation was obtained from the parents of each child enrolled in the study. The study included 30 patients (2-16 years old) with chronic lung diseases randomly selected from those attending pediatric chest clinic for follow-up (7 patients with cystic fibrosis, 10 patients with non-CF bronchiectasis, and 13 patients with interstitial lung diseases). The study included 40 apparently healthy age- and sex-matched control children. Children with other associated chronic illness that affects nutrition like chronic liver diseases, juvenile diabetes, and chronic heart diseases were excluded. This pilot study was performed over 9-month duration. The study consisted of 3 phase: initial assessment phase (pre rehabilitation), rehabilitation phase, and final assessment phase (post rehabilitation).

Initial assessment phase (pre rehabilitation)

Subjective Global Nutritional Assessment (SGNA) was done [4], and 24-h dietary recalls history was taken from studied children. All data were calculated by local food analysis software program, developed by National Nutrition Institute in Egypt 2006. Anthropometric measurements including height (centimeters), weight (kilograms), skin-fold thickness (SFT) in millimeters by the Harpenden skinfold Caliper, mid-arm circumference (MAC) in centimeters by a non-stretchable measuring tape were taken. Body mass index (BMI) values were calculated. Data was plotted against Z-scores charts of the Center for Disease Control (CDC) from National Health and Nutrition Examination Survey (NHANES)

III data 2010. Body composition: body fat (BF), fat free mass (FFM), muscle mass (MM) as absolute and percentage from total body weight were measured by bioelectric impedance analysis technique (BIA) using the Tanita SC-330P scale Body Composition Analyzer (Tanita Corporation, Tokyo, Japan). The impedance scales used in this study have been validated against DEXA in mixed populations of children and adults and found to be superior to previous BIA methods [5]. Measurements were expressed as Z-scores and plotted to WHO charts for individuals under 5 years of age, and of the National Center for Health Statistics for those above 5 years of age.

A tailored miniquestionnaire was designed and used to ask every child/caregiver about the child's chest symptoms during the last 3-month period preceding the study. The child/caregiver was asked about presence of colored sputum, dyspnea and its grade, wheezes, dose of short acting β2 rescue (puffs/day), and how many days he was absent from school. He was asked also how many times he experienced exacerbation (fever attacks and/or worsening of symptoms and/or ER visit) and how many times he needed admission to hospital during the last 3 months. FVC spirometry was performed in pulmonary function lab in Chest Clinic, Pediatric Hospital, Ain Shams University, for children 5 years and older using VIASYS Healthcare GmbH (Leibnizstrasse 7). FVC spirometry was done according to "ATS/ERS task force: standardization of lung function testing." Data obtained from spirometry were as follows: forced expiratory volume in first second (FEV1), forced vital capacity (FVC), ratio between forced expiratory volume in one second and forced vital capacity (FEV1/FVC), and maximal mid-expiratory flow (MMEF). All data were expressed as % of predicted value for age, sex, and height. FEV1 and FVC were considered low if they were below < 80% of the predicted values for age and sex. Restrictive lung disease was defined as FVC below 80% of the predicted values for age and sex, obstructive lung disease was defined as FEV1/FVC below 80%, small airway disease was diagnosed if MMEF was below 60% of the predicted values for age and sex. Seven patients did not perform spirometry because of their young age (< 5 years).

Control subjects enrolled in the study were subjected to anthropometry, body composition analysis, and FVC spirometry using same tools and techniques as in patients group.

Rehabilitation phase

All patients were kept on their regular medications. Every patient received the nutritional rehabilitation support for 3 months. Each patient was given an individualized plan 150% of energy requirements for same-age healthy children and adolescents (50% CHO and 20% protein

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and 30% fats). Fifty percent of energy requirements were given through high-calorie supplements (1.5 Kcal/ml). This plan was implemented for 3 months. Patients were followed up through telephone calls, short messages, and weekly clinic visit to follow up symptoms progress and to allow nutrition counseling.

Final assessment phase (post rehabilitation)
At the end of the 3-month nutrition program, the mini-questionnaire was repeated to record the progress of the clinical pulmonary status. Anthropometry, body mass composition analysis, and FVC spirometry were all repeated with the same tools as in the initial assessment phase.

Data were collected, coded, and entered to the Statistical Package for Social Science (IBM SPSS) version 20.

Results
Demographic data of patients and control are shown in Table 1. According to SGNA, 56.67% of studied patients were moderately malnourished and 23.33% were severely malnourished. In the patient group, 66.7% were underweight (WAZ <-2) and 50% were stunted (HAZ <-2). All basic anthropometric values of patients were significantly lower than control groups (WAZ, HAZ, BMIZ, mid-arm circumference, and skin-fold thickness) ($p < 0.001$). Body composition indices were lower in patients compared to controls but not with a statistical significance (Table 2). After nutritional intervention, prevalence of chest symptoms, prevalence of SABA needs (short-acting B2 rescue), prevalence of acute exacerbation, prevalence of school absence and hospitalization, all were improved (Tables 3 and 4). Also, anthropometric measurements, body composition analysis parameters as well as FEV1 showed significant improvement (Tables 5, 6). FVC% was positively correlated to BMI (Table 7).

Table 1 Demographic data and diagnosis of the studied groups

	Patients ($n = 30$)	Controls ($n = 40$)
Male	12 (40%)	25 (62.5%)
Female	18 (60%)	15 (37.5%)
Age (years) (mean ± SD)	8.46 ± 4.32	8.63 ± 2.50
Residence		
Urban	20 (66.7%)	21 (52.5%)
Rural	10 (33.3%)	19 (47.5%)
Diagnosis		
Bronchiectasis (CF and non CF)	17 (56.7%)	
Childhood interstitial lung diseases (ChILD)	13 (43.3%)	

Table 2 Comparison between values of anthropometry and body composition components among patients and control groups

	Patients	Control	t test	*p* value
Weight centile z-score				
Mean ± SD	−2.18 ± 0.90	0.20 ± 1.21	81.250	**< 0.001***
Range	−3.70-0.80	−2.91-2.16		
Height centile z-score				
Mean ± SD	−1.86 ± 0.83	0.15 ± 1.16	64.572	**< 0.001***
Range	−3.60-0.17	−2.48-1.65		
Triceps skinfold thickness centile z-score				
Mean ± SD	0.82 ± 0.46	1.67 ± 0.35	75.172	**< 0.001***
Range	0.04-1.73	0.80-2.14		
Body mass index centile z-score				
Mean ± SD	−1.73 ± 1.08	0.39 ± 1.11	63.699	**< 0.001***
Range	−4.90-1.87	−1.99-2.03		
Mid arm circumference centile z-score				
Mean ± SD	−1.30 ± 0.71	1.10 ± 0.86	11.787	**< 0.001***
Range	−2.7-1.4	−1.02-1.71		
Body fat (kg)				
Mean ± SD	5.095 ± 2.829	7.9 ± 6.278	1.867	**0.067**
Range	1.5-14.7	2.4-23.5		
Muscle mass (kg)				
Mean ± SD	24.45 ± 6.702	25.96 ± 7.40	0.879	0.382
Range	16.3-38.3	15.50-42.50		
Fat free mass (kg)				
Mean ± SD	26.02 ± 6.81	27.30 ± 7.76	0.719	0.475
Range	17.30-40.41	16.50-44.80		

* significant

Discussion
In the current study, significant portion of the studied patients were malnourished and had reduced basic anthropometric values. White et al. (2015) observed that the prevalence of malnutrition and nutritional risk in

Table 3 Frequency of chest symptoms among patients before and after nutritional intervention

Chest symptoms	Pre ($n = 30$)	Post ($n = 30$)	*p* value
Attacks of exacerbation	12 (40%)	0 (0%)	**< 0.001**
Yellow-greenish sputum	16 (53.3%)	0 (0%)	**< 0.001**
Dyspnea			
On severe exertion	16 (53.3%)	11 (36.7%)	
On moderate exertion	3 (10%)	2 (6.7%)	**0.004**
On mild exertion	6 (20%)	1 (3.3%)	
At rest	2 (6.7%)	0 (0%)	
Wheezes	25 (83.3%)	12 (40%)	**< 0.001**
Hospitalization	20 (66.6%)	1 (3.3%)	**< 0.001**

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Table 4 School absence and SABA use among patients (pre-intervention and post-intervention)

		Range	Mean ± SD	t	P
Absence of school (days)	Pre	0-40	11.75 ± 9.23	3.888	**< 0.001**
	Post	0-7	4.38 ± 2.70		
Short acting β2 agonist (puffs/day)	Pre	0-6	2.70 ± 1.70	8.437	**< 0.001**
	Post	0-4	1.20 ± 1.10		

Patient needs for SABA and school absence decreased significantly after nutritional intervention

Table 5 Anthropometric data and body composition components among patients before and after nutritional intervention

		Range	Mean ± SD	T	P
Weight centile z-score	Pre	−3.7-0.8	−2.18 ± 0.90	−8.242	**< 0.001**
	Post	−3.1-0.7	−1.44 ± 0.79		
Height centile z-score	Pre	−3.6-0.17	−1.86 ± 0.83	−8.251	**< 0.001**
	Post	−3.4-0.7	−1.55 ± 0.95		
Mid arm circumference centile z-score	Pre	−2.7-1.4	−1.30 ± 0.71	−0.488	**< 0.001**
	Post	−1.9-0.91	−0.71 ± 0.63		
Triceps skinfold thickness centile z-score	Pre	0.04-1.73	0.82 ± 0.46	−7.983	**< 0.001**
	Post	0.4-2.05	1.40 ± 0.36		
Body mass index centile z-score	Pre	−4.9-1.87	−1.73 ± 1.08	−7.007	**< 0.001**
	Post	−2.9-1.85	−0.97 ± 1.00		
Body fat (kg)	Pre	1.5-14.7	5.095 ± 2.83	4.19	**0.0005**
	post	1.7-14.5	5.689 ± 2.91		
Fat-free mass (kg)	Pre	**17.3-40.41**	**26.02 ± 6.81**	**−8.605**	**< 0.001**
	Post	**19-41.2**	**27.07 ± 6.78**		
Muscle mass (kg)	Pre	16.3-38.3	24.45 ± 6.702	9.065	**< 0.0001**
	Post	16.7-39	25.32 ± 6.740		

Nutritional rehabilitation significantly improved patient anthropometry and body composition

Table 6 Spirometric pulmonary function testing among the patients groups before and after nutritional intervention

		Range	Mean ± SD	T	P
FEV1%	Pre	33.1-95.5	61.33 ± 17.12	2.826	0.0116
	Post	32.5-97.6	64.26 ± 17.07		
FVC%	Pre	47.6-113.6	74.12 ± 18.40	1.666	0.1140
	Post	55.9-134.9	77.45 ± 14.67		
FEV1/FVC	Pre	57.1-106.4	83.27 ± 12.96	0.4524	0.6567
	Post	58.2-9303	82.17 ± 10.97		
MEF 25-75%	Pre	11.6-73.6	35.69 ± 18.25	1.170	0.2583
	Post	11.4-68.8	38.66 ± 16.97		

Australian pediatric patients with chronic lung diseases were much higher when compared with the healthy children [6]. Many studies focused on nutritional assessment in CF patients, for example, Isa and colleagues and Gaskin reported poor nutritional status and stunted growth [7, 8], Lusman and Sullivan reported multiple nutritional deficiencies [9], Hauschild et al. (2016) reported reduction in triceps skin-fold thickness—z score, mid-upper-arm circumference—z score, and BMI [10]. Weight loss in CF patients and other chronic lung diseases can be explained by effect of systemic inflammation caused by inflammatory cytokines and increase the basal metabolic rate which leads to a negative nutrition balance and eventually weight loss. In addition, anorexia and associated gasteroinestinal disorders markedly reduce caloric and nutritional input. Also, impaired physical activity level especially after flare-ups leads to disuse atrophy [11]. In our study, body fat, muscle mass, and fat free mass values were lower among patients than control but not with statistical significance. Several studies demonstrated reduced fat and fat-free mass depletion among children with chronic lung disease. Olveira et al. and Hauschild et al. reported FFM depletion among bronchiectatic children, independent of the etiology of bronchiectasis, and this depletion was related to disease severity [10, 12]. Engelen et al. stated that low fat-free mass is consistently associated with pulmonary functions decline,

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Table 7 Correlation between anthropometric measurements and spirometric measurements

Anthropometric measurements (pre)		FEV1% pre	FVC% pre	+FEV1/FVC pre	MEF 25-75% pre
Wt. (kg)	R	0.410	0.371	0.115	0.212
	P	0.081	0.118	0.638	0.384
Ht. (cm)	R	0.010	−0.216	0.307	0.166
	P	0.967	0.373	0.202	0.498
Mid-arm circumference (cm)	R	0.323	0.403	−0.058	0.024
	P	0.178	0.087	0.814	0.922
Triceps (mm)	R	0.368	0.196	0.284	0.345
	P	0.121	0.422	0.239	0.148
BMI (kg/m^2)	R	0.351	0.465	−0.102	0.021
	P	0.141	**0.045**	0.677	0.932

Statistically significant (+ve) correlation between FVC% and BMI

high frequency of flare-ups, hospitalizations, and poor survival in CF [13]. Also, an inverse relation between FEV1 and FVC and fat-mass index among CF patients was proved by Alvarez et al. [14]. Lubamba et al. demonstrated that the decrease in fat-free mass (FFM) may result in weakening of the diaphragm and other respiratory muscles, leading to the deterioration of lung function [15]. Gea et al. (2013) attributed these changes to hypoxia which affects mTOR pathway, which is involved in transcription of DNA and translation of mRNA into protein and consequently, contribute to muscle wasting [16]. Systemic steroids may cause steroid-induced myopathy with rhabdomyolysis and the loss of thick myosin filaments resulting in marked decrease in muscle mass and weakness. The effect of malnutrition in interstitial lung disease and cystic fibrosis patients are multifactorial and can be attributed to the energy imbalance caused by chronic respiratory disease, maldigestion, poor absorption (especially if there is pancreatic insufficiency), changes in entero-hepatic circulation and antibiotic therapy. Anorexia caused by gastro esophageal reflux or cough, increased metabolism, especially in the presence of infections, and psychosocial stress can be also additive cofactors [17].

In our study, nutritional rehabilitation significantly improved patients' anthropometry, body fat, fat-free mass, and muscle mass (*P* value < 0.001). This was associated with improvement of patients' pulmonary symptoms, rate of acute exacerbations, needs for acute rescue therapy, and hospitalization. Groleau et al. reported improved weight, height, BMI, fat mass, and fat-free mass over 1 year nutritional rehabilitation program in CF children [18]. Almajan-Guta et al. reported same improvement in body composition after dietary supplements for 6 months [19]. Several studies stated that achieving an optimal nutritional status is important to maintain better pulmonary function, physical performance, fewer complications, and to prolong survivals among these patients with chronic respiratory illness [19–25]. Our study proved that even a short course of adequate feeding can improve body composition and can positively impact respiratory symptoms and severity and even some spirometric functions.

In our study, FEV1 significantly improved. Many factors related to better feeding regimens may explain the FEV1 improvement. Better feeding enhances immunity; reduce the concomitant infection and colonization of lung and airways by bad bacteria; boost friendly microflora, leading to reduction of airways edema and inflammation; and subsequently eliminating congestion, hyperactivity, and bronchospasm. We did not realize correlation between FEV1 and any anthropometric parameters. Some studies like Megías et al. demonstrated that in patients with CF, a relative weight gain is positively associated to FEV1%, while a relative weight loss of at least 2% has a significant negative impact on lung function [26]. In our study, FVC did not show significant improvement, but a strong correlation to BMI was recorded. This clear association between nutrition status and lung function were emphasized in many studies. McPhail et al. demonstrated better lung function and fewer chronic *P. aeruginosa* associated with better nutrition in CF children [27]. Connett found a relationship between nutritional intake, lung function, and metabolic demand [25]. In many studies, BMI-Z was positively associated with FVC% [28] and with FEV1% in children with chronic lung illnes s[13, 25–30]. Del Ciampo et al. stated that BMI values above the 50th percentile correlate with better pulmonary function and a low height-for-age characterized by worse survival among CF patients [28]. BMI is currently the most often used measure of nutritional status in this population; however, it may not identify individuals

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with deficits in FFM which may be a better predictor of pulmonary function.

Conclusion

Children with chronic lung diseases are significantly malnourished compared to their healthy peers. Nutritional rehabilitation has great impact not only on anthropometry and body composition but also on respiratory symptoms and pulmonary functions and it also reduces risk of acute exacerbation and frequency of hospital admissions in children with chronic respiratory diseases. Treatment of chronic respiratory diseases should address the energy and protein deficits, and include long-term monitoring of weight and growth.

Limitations

The study adopted a short-course nutritional regimen, some clinical and spirometric parameters need longer therapy duration to be reversed and corrected.

Authors' contributions
AA shared in study design, data collection, choosing participant, data analysis, and performed spirometry and writing manuscript. IF put the idea of the study, shared in study design, and general supervision on the whole work. AM shared in data collection, anthropometry, and implementation of nutritional program. YG shared in study design, data collection and analysis, performed body composition analysis, and designed the nutritional intervention plan. The authors confirm that they have reviewed and approved the final version of the manuscript.

Availability of data and materials
We declare that all materials and research data are available. The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Obtained from Ain Shams University, Faculty of Medicine, Research Ethics Board on 22 December 2014. Written informed consent was obtained from the parents of each child enrolled in the study.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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