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Correlation between Nutritional Parameters, Peripheral muscle strength, and functional capacity of Children and Adolescents with Cystic Fibrosis

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ABSTRACT

Introduction: Cystic fibrosis (CF) is an autosomal recessive genetic disorder caused by different mutations in the cystic fibrosis transmembrane conductance regulator (*CFTR*) gene, responsible for chloride ion transport across apical membranes of epithelial cells in tissues and bicarbonate secretion. **Objective:** To investigate the correlation of anthropometric parameters of nutritional status, lung function, peripheral strength, and functional capacity in children and adolescents diagnosed with CF. **Methods:** A cross-sectional study was carried out with 18 children, adolescents with CF aged between 6 and 15 years old. Anthropometric, body composition, bioimpedance, lung function, and peripheral muscle strength and functional capacity data were collected. **Results:** The pulmonary function assessment indexes FEV1 and FVC presented a statistically significant correlation with the nutritional status parameters - corrected lean mass (CLM), mid-upper arm circumference (MUAC), mid-arm muscle circumference (MAMC), with manual dynamometry. Concerning the parameters of the peripheral muscle strength and functional capacity, both the six-minute walk test and manual dynamometry showed a positive correlation with the height/age, CLM, MUAC, and MAMC index. **Conclusion:** Given the correlation between nutritional parameters that reflect muscle mass with lung function, peripheral muscle strength, and functional capacity, the incorporation of these anthropometric measures in the clinical routine could allow a better assessment of the muscular component and the health status of these patients.

Keywords: Cystic fibrosis; body mass index; respiratory function tests; Forced Expiratory Volume; Biomarkers.

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Declaration of interests: nothing to declare

INTRODUCTION

Cystic Fibrosis (CF) is a genetic, autosomal-recessive disease caused by dysfunction in the cystic fibrosis transmembrane conductance regulator (CFTR). This protein is found, among other places, in the apical membrane of epithelial cells of the respiratory tract,

exocrine pancreas, sweat ducts, and reproductive system. In these locations, its main function is to act as a chlorine transport channel and, when dysfunctional, it leads to a greater flow of sodium and water into the cells, causing dehydration and increased viscosity of mucous secretions[1,2].

CF is more common in Caucasian populations with an estimated incidence of 1:2,500-3,500 live births, showing regional differences[3]. The Brazilian Cystic Fibrosis Registry (REBRAFC) identified 6,112 patients with CF in Brazil in 2020, and the number of records has been growing annually[4]. In addition to the thickening of mucous secretions causing obstruction of the airways and predisposing to recurrent lung infections and decline in lung function, it is already well established that malnutrition is directly related to this decline and survival as it affects the respiratory muscles, decreases exercise tolerance, and harms the immune system[5,6].

Individuals with CF are in a chronic state of catabolic stress and malnutrition, this being one of the main challenges in managing this disease. The nutritional deficit in CF has a multifactorial origin. Malabsorption of nutrients related to pancreatic insufficiency and recurrent infectious and inflammatory processes is involved, leading to a greater energy need, and, when associated with insufficient food intake, it results in energy imbalance[7,8]. It then becomes a vicious cycle as poor nutritional status impairs lung function, and this impairment also interferes with individuals' ability to achieve nutritional adequacy[9].

Considering the relevance of recovering and/or maintaining an adequate nutritional status in patients with CF, the Brazilian guidelines for the diagnosis and treatment of cystic fibrosis state the indispensability of nutritional monitoring, including periodic anthropometric and body composition assessments[10]. This monitoring provides an early nutritional diagnosis, enabling individualized and effective interventions in the nutritional management of these individuals.

Therefore, a comprehensive and detailed assessment of body composition and functional capacity was carried out, identifying potential predictive tools for this population, expanding and deepening the existing literature.

This way, considering the high importance of nutritional status in the quality of life and survival of individuals with CF and its close relationship with the lung function of these patients, the objective of this study is to analyze the correlation of anthropometric and body composition parameters with lung function, peripheral muscle strength and functional capacity of patients diagnosed with CF.

METHODS

Study design

This is a cross-sectional observational study with patients treated at the multidisciplinary outpatient clinic of the Cystic Fibrosis Reference Center of the University Hospital of the Federal University of Juiz de Fora, Minas Gerais, Brazil (HU-UFJF/EBSERH). Data were collected from assessments routinely performed on patients during consultations between June 2019 and February 2020. The target audience for the research consisted of patients diagnosed with CF according to the diagnostic criteria of the Brazilian guidelines for the diagnosis and treatment of cystic fibrosis (sweat chloride level > 60 mmol/l, in two samples) and with genetic testing for a mutation in the *CFTR* gene[10]. Children and adolescents under 18 years old with CF were included, and those who did not present the spirometry test were excluded. The sample, therefore, is composed of 18 individuals of both sexes, aged between 6 and 15 years.

Respecting the eligibility criteria, the following variables were collected: age, sex, bacterial colonization, *CFTR* gene mutation (ΔF508 homozygotes, ΔF508 heterozygotes, and other mutations), anthropometric data, body composition, assessment of lung function, and functional capacity. All data collected is part of the clinical routine at the service and was obtained through physical records.

The Human Research Ethics Committee of HU-UFJF/EBSERH approved the present study under number 3.411.575.

Anthropometric and body composition measurements

As anthropometric measurements, data on body weight, height, mid-upper arm circumference (MUAC), tricipital skinfold thickness (TSF), and mid-arm muscle circumference (MAMC) were obtained, following the standardized techniques established by The International Society for the Advancement of Kinanthropometry (ISAK)[11]. Using body weight and height measurements, the nutritional status of children and adolescents was assessed with the help of the AnthroPlus software of the World Health Organization[12] in z-scores for the indices weight for age (W/A), height for age (H/A), and body mass index (BMI) for age (BMI/A). The MAMC was calculated from the MUAC and TSF measurements by a standard calculation: MAMC (cm) = MUAC (cm) – π x [TSF (mm)/10[13,14].

Weight and height were measured on a digital scale with an attached stadiometer (Welmy-W200A). Triceps fold measurements and body perimeters were obtained using an adipometer (Cescorf-INNOVARE) and a metal measuring tape (Cescorf).

Body composition was also measured using electrical bioimpedance (Biodynamics Model 450), which estimates, through resistance, reactance, and phase angle, body composition parameters such as fat mass, lean mass, intra- and extracellular mass, total body water, intra- and extracellular and basal energy metabolism. Those evaluated were previously instructed to avoid the consumption of alcohol and caffeine in the 24 hours before the test, not to perform intense physical activity, and to avoid heavy meals 4 hours before and to suspend diuretic medication 1 day

before the test, except in the case of individuals with systemic arterial hypertension. Corrected lean mass (CLM) was evaluated according to the equation generated and validated for patients with CF represented below[15].

CLM = −2.844 - (0.184 × Weight) + (1.202 × CLMBIA). Therefore, CLMBIA is the fat-free mass generated by bioelectrical impedance.

Lung function

Lung function was assessed using the KoKo Sx 1000 spirometer (nSpire Health Inc., Longmont, CO, USA), performed by a properly trained physiotherapist. The exam measures the volume of exhaled air and flows by providing the forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and their ratio (FEV1/FVC). FEV1 allows us to quantify the obstructive ventilation disorder characteristics of CF. The examination technique followed the recommendations of the American Thoracic Society[16]. The values obtained were calculated according to the equations proposed by Mallozi[17].

6-minute walk test

The 6-minute walk test (6MWT) was performed by evaluating the maximum distance covered in six minutes, in which the individual could dictate the speed of the steps and the need to interrupt the process, in the presence of limiting symptoms. This test makes it possible to measure the patient's functional capacity[18].

Dynamometry

Dynamometry was performed using a manual dynamometer (Saehan, SH5001), which analyzed handgrip strength (HGS) through three measurements on each side, with an interval of 30 seconds between them. The highest value achieved was used as a reference in the study. To carry it out, the standards of the American Society of Hand Therapists[19] were followed, and the dynamometry values of the dominant arm were considered.

Statistical analyzes

Statistical analyses were performed using SPSS® 20.0 software (SPSS Inc., Chicago, IL, USA). Data normality was assessed using the Shapiro-Wilk test. To characterize the sample, mean values (Standard Deviation, SD) or relative frequency were used. Correlations between variables were verified using the Pearson (normal distribution) or Spearman (non-normal distribution) tests. The results were considered significant when $p<0.05$.

RESULTS

A total of 18 patients were included in this study, with a mean age of 11 years (range 6-15 years old), 72% were male, and 28% were female. The most frequently found mutation was heterozygotes for ΔF508 (44.5%). The descriptive characteristics of the sample in the present study are represented in Table 1.

The clinical lung profile of the patients, considering the spirometric parameters of FVC and FEV1 as a percentage of predicted (≥80%) and FEV1/FVC ratio, considering 75% of predicted as the cut-off point, demonstrated that half of the population had preserved pulmonary function values (Table 2). Ninety-five percent of the sample tested positive for bacterial colonization, with the majority being *Staphylococcus aureus*. Regarding nutritional status, it is observed that the larger part of the sample studied presents a BMI/A and H/A classification within the cut-off points for eutrophy, demonstrating the good nutritional status of the individuals studied concerning these indicators. However, when evaluating body composition parameters, we observed that 72% of the sample (n=13) was below the 50th percentile in terms of TSF and MAMC, showing depletion of adipose tissue and lean mass (Table 2).

To better understand the relationship between nutritional status and lung function, we conducted a correlation analysis. Regarding the pulmonary function assessment indexes FEV1 (L/s) and FVC (L/s), both showed a statistically significant positive correlation ($p<0.05$) with the nutritional status assessment parameters CLM, MUAC, and MAMC and with HGS (Table 3).

Concerning the HGS and 6MWT, peripheral muscle strength and functional capacity indicators, both showed a moderate to strong positive correlation with the nutritional status assessment measures H/A, CLM, MUAC, and MAMC (Table 4).

DISCUSSION

In this study, we found a correlation between respiratory, body composition, and muscular parameters, making it a useful tool for nutritional and functional assessment in CF patients. In children and adolescents with CF, nutritional status parameters that reflect lean mass (MAMC and CLM) were positively correlated with markers of peripheral muscle strength, functional capacity

Table 1: Age, sex, mutation, and bacterial colonization of patients with cystic fibrosis at the University Hospital of the Federal University of Juiz de Fora.

Age (years) [a]	11(3.15)
Sex	
Female[b]	5 (28%)
Male[b]	13 (72%)
Mutation	
ΔF508 homozygous[b]	2 (11%)
ΔF508 heterozygotes[b]	8 (44.5%)
Others[b]	8 (44.5%)
Bacterial colonization	
Yes[b]	17 (95%)
No[b]	1 (5%)

Values expressed as mean (SD)[a] or n (%)[b].

Table 2: Anthropometry, body composition, lung function, peripheral muscle strength, and functional capacity of patients with cystic fibrosis at the University Hospital of the Federal University of Juiz de Fora.

Anthropometry and body composition	
Weight (kg) [a]	33.62 (12.39)
Height (cm)[a]	142.3 (18.52)
BMI/Age z score[a]	-0.46 (1.37)
Severe thinness	2 (11%)
Thinness[b]	1 (5.6%)
Normal[b]	12 (66.7%)
Overweight[b]	3 (16.7%)
H/A z score[a]	-0.56 (0.86)
Wasted[b]	1 (5%)
Normal[b]	17 (95%)
Triceps skinfold (mm) [a]	8.15 (3.44)
≥ P50[b]	5 (28%)
< P50[b]	13 (72%)
Mid-upper arm circumference measurements (cm)[a]	19.04 (3.38)
Mid-arm muscle circumference (cm)[a]	16.8 (2.91)
≥ P50[b]	5 (28%)
< P50[b]	13 (72%)
Adjusted lean mass (kg)[a]	23.44 (9.8)
Lung Function	
FEV1 (%)[a]	77.38 (24.89)
≥80%[b]	9 (50%)
< 80%[b]	9 (50%)
FVC (%)[a]	90.72 (22.97)
≥80%[b]	13(72%)
<80%[b]	5 (18%)
FEV1/FVC (%)[a]	84.77 (11.98)
≥75%[b]	14 (78%)
<75%[b]	4 (22%)
FEV1 (L/s) [a]	1.62 (0.65)
FVC (L/s) [a]	2.12 (1.01)
Peripheral muscle strength and functional capacity	
Dominant handgrip strength (kgf) [a]	17.05 (8.62)
6MWT (m) [a]	498.31 (76.58)

[a] Mean (SD); [b]n(%); H/A, Height-for-age; BMI, Body mass index; FEV1, Forced expiratory volume in the first second; FVC, Forced vital capacity; 6MWT, six-minute walk test.

Table 3: Correlation between lung function parameters, nutritional status, peripheral muscle strength, and functional capacity.

	FEV1 (l)	FVC (l)
H/A[b]	0.419 (p=0.084)	0.405 (p=0.096)
BMI/A[b]	0.432 (p=0.073)	0.362 (p=0.140)
CLM[a]	0.797 (p=0.001)*	0.919 (p=0.001)*
MUAC[b]	0.718 (p=0.001)*	0.764 (p=0.001)*
MAMC[b]	0.758 (p=0.001)*	0.831 (p=0.001)*
TSF[a]	0.356 (p=0.147)	0.313 (p=0.207)
HGS[b]	0.688 (p=0.002)*	0.844 (p=0.000)*
6MWT[b]	0.464 (p=0.052)	0.392 (p=0.108)

[a]Spearman correlation; [b]Pearson correlation; *p<0.05; HGS, Handgrip strength; TSF, triceps skinfold thickness; H/A, Height-for-age; BMI/A, Body mass index-for-age; CLM, Corrected lean mass; FEV1, Forced expiratory volume in the first second; FVC, Forced vital capacity; 6MWT, six-minute walk test; MUAC, mid-arm measurements; MAMC, mid-arm muscle circumference.

Table 4: Correlation between peripheral muscle strength, functional capacity parameters, and nutritional status assessment.

	HGS	6MWT
H/A[b]	0.496 (p=0.036)*	0.486 (p=0.041)*
BMI/A[b]	0.132 (p=0.602)	0.203 (p=0.418)
CLM[a]	0.821 (p=0.001)*	0.595 (p=0.009)*
MUAC[b]	0.675 (p=0.002)*	0.632 (p=0.005)*
MAMC[b]	0.745 (p=0.001)*	0.682 (p=0.002)*
TSF[a]	0.233 (p=0.351)	0.325 (p=0.188)

[a]Spearman correlation; [b]Pearson correlation; *p<0.05; HGS, Handgrip strength; TSF, triceps skinfold thickness; H/A, Height-for-age; BMI/A, Body mass index-for-age; CLM, Corrected lean mass; 6MWT, six-minute walk test; MUAC, mid-arm measurements; MAMC, mid-arm muscle circumference.

(HGS and 6MWT), and pulmonary function (FEV1 and FVC in liters). Thus, muscle mass (an important component of lean mass) appears to be the nutritional status component determining lung function in children and adolescents with CF.

The nutritional assessment of the individuals studied showed that the majority were classified in the eutrophic range according to BMI/A. Although it is an important predictor of nutritional status in children, when considering only body weight and height, it does not differentiate individuals as to their body composition[20]. Body composition, in turn, showed a depletion of lean mass and adipose tissue in the larger part of the sample, demonstrating that, despite the eutrophic profile found, there is an already established nutritional deficit.

It is already well established that the imbalance between nutrient intake, absorption, and requirement in patients with CF is an important determinant of protein-energy malnutrition, which, associated with recurrent infections and inflammatory processes, contributes to the increase in muscle protein catabolism, which reflects in greater depletion of body muscle mass in these individuals[21]. However, we have not observed a correlation between BMI/A, lung function, peripheral muscle strength, and functional capacity parameters. Other authors have also shown a higher percentage of malnutrition when evaluating parameters that reflect muscle mass, such as MAMC, compared to the use of BMI/A in patients with CF[22,23].

In this sense, a greater association between lean body mass than BMI on lung function was demonstrated[24]. Other authors evidenced that FEV1% was positively associated with fat-free mass and inversely associated with adipose tissue[25]. In our study, in addition to the positive correlation between FEV1 and FVC with fat-free mass measured by bioimpedance and MAMC, a positive correlation with HGS was also observed, a parameter that can be used to characterize skeletal muscle strength[26]. These findings support the hypothesis that the effect of good nutritional status on CF is mediated by both body muscle mass, peripheral muscle strength, and functional capacity.

In addition, regarding the assessment of the peripheral muscle strength and functional capacity of the participants, although the

determination of functional capacity using the 6MWT in adults is already well established in the literature, its applicability and indication in pediatric patients have been expanding, especially regarding clinical conditions that limit cardiorespiratory capacity[27,28]. In studies that analyze the performance of cystic fibrosis patients in the 6MWT, it is observed that this population has, in general, lower results than a healthy population[29,30]. However, few studies have correlated the 6MWT with the anthropometric assessment of CF patients. Height and weight have been described as the anthropometric variables with the greatest relationship with the 6MWT in children[31]. In our study, we did not find a correlation between the 6MWT and the weight, but a positive correlation with H/A.

We found a positive correlation between the 6MWT and muscle mass markers (moderate correlation to CLM and strong to MAMC), which indicates that skeletal muscle mass is an important factor in the functional capacity of patients with CF. Few studies relate lean mass to the physical performance of patients with CF by the 6MWT. The reduction in muscle strength in CF appears to be directly related to the worsening of clinical symptoms and lower tolerance to effort[32,33]. Similar to what was observed for the 6MWT, HGS correlated positively with height, MUAC, MAMC, and CLM in the patients evaluated. The HGS consists of a simple test, which allows for estimating the function of the skeletal muscle, to characterize the muscular functional status and muscular strength[24]. Furthermore,peripheral muscle strength, assessed by HGS, was significantly correlated with pulmonary function variables in our study. A similar result has been observed in another study, comparing CF patients with healthy subjects[34]. Authors have demonstrated that, among other parameters, peripheral muscle strength, functional capacity, and performance in activities of daily living are negatively affected in patients with mild to severe CF compared to healthy individuals[34].

There are limitations to our study, such as the convenience sample and small size. There are limitations to our study, such as the convenience sample and small size. Despite this, the sample was still powerful enough to demonstrate positive correlations between anthropometric variables that measure muscle mass and lung function. Additionally, the cross-sectional design does not allow us to establish a causal relationship between the variables studied. Future prospective studies to understand the factors involved in changes in muscle mass, lung function, and functional capacity should be encouraged in order to contribute to increasingly assertive therapeutic and nutritional approaches in this population. Despite these limitations, we made progress by identifying important markers of nutritional status correlated with lung function. Few studies correlate the variables studied here, which highlights the relevance of the present findings. Furthermore, we demonstrate the relevance of a complete and reliable nutritional assessment of body composition in the treatment of patients with CF.

In summary, positive correlations between lung function variables and anthropometric parameters that reflect muscle mass were observed. Peripheral muscle strength and functional capacity parameters expressed by the 6MWT and dynamometry were also positively correlated with muscle mass parameters. Despite the importance of monitoring variables such as weight, height, and BMI in the assessment of cystic fibrosis patients (especially in children and adolescents), these do not reflect body composition. Incorporating other anthropometric measurements (such as body perimeters and skinfolds) as well as dynamometry is an important strategy in clinical routine, as it allows for better assessment of the muscular component and consequently the health status of these patients. A complete and continuous nutritional assessment allows for the early identification of nutritional disorders and appropriate intervention, impacting patients' survival and quality of life.

REFERENCES

1. Shteinberg M, Haq IJ, Polineni D, Davies JC. Cystic fibrosis. Lancet. 2021;397(10290):2195-211. https://doi.org/10.1016/S0140-6736(20)32542-3

2. Grasemann H, Ratjen F. Cystic Fibrosis. N Engl J Med. 2023;389(18):1693-707. https://doi.org/10.1056/NEJMra2216474

3. Myer H, Chupita S, Jnah A. Cystic fibrosis: back to the basics. Neonatal Netw. 2023;42(1):23-30. https://doi.org/10.1891/NN-2022-0007

4. Registro Brasileiro de Fibrose Cística (EBRAFC). Relatório anual de 2020. Available from: http://portalgbefc.org.br/ckfinder/userfiles/files/REBRAFC_2020.pdf

5. Calvo-Lerma J, Hulst JM, Asseiceira I, Claes I, Garriga M, Colombo C, et al. Nutritional status, nutrient intake and use of enzyme supplements in paediatric patients with Cystic Fibrosis; a European multicentre study concerning current guidelines. J Cyst Fibros. 2017;16(4):510-8. https://doi.org/10.1016/j.jcf.2017.03.005

6. Turck D, Braegger CP, Colombo C, Declercq D, Morton A, Pancheva R, et al. ESPEN-ESPGHAN-ECFS guidelines on nutrition care for infants, children, and adults with cystic fibrosis. Clin Nutr. 2016;35(3):557-77. https://doi.org/10.1016/j.clnu.2016.03.004

7. Patel D, Shan A, Mathews S, Sathe M. Understanding Cystic Fibrosis Comorbidities and Their Impact on Nutritional Management. Nutrients. 2022;14(5):1028. https://doi.org/10.3390/nu14051028

8. Dickinson KM, Collaco JM. Cystic Fibrosis. Pediatr Rev. 2021;42(2):55-67. https://doi.org/10.1542/pir.2019-0212

9. Zani EM, Grandinetti R, Cunico D, Torelli L, Fainardi V, Pisi G, et al. Nutritional Care in Children with Cystic Fibrosis. Nutrients. 2023;15(3):479. https://doi.org/10.3390/nu15030479

10. Athanazio RA, Silva Filho LVRF, Vergara AA, Ribeiro AF, Riedi CA, Procianoy EFA, et al. Brazilian guidelines for the diagnosis and treatment of cystic fibrosis. J Bras Pneumol. 2017;43(3):219-45. https://doi.org/10.1590/S1806-37562017000000065

11. Norton KI. Standards for Anthropometry Assessment. In: Kinanthropometry and Exercise Physiology. 4th ed. 2018; p. 70.

12. World Health Organization (WHO). WHO AnthroPlus software. 2007.

13. Tostes NF, da Cunha Antunes Saraiva D, Martucci RB. Association between nutritional status and muscle strength in pediatric cancer patients. Clin Nutr ESPEN. 2021;43:436-41. https://doi.org/10.1016/j.clnesp.2021.03.009

14. Liu Y, Sun G, Li Y. A prospective cohort study on the association of lean body mass estimated by mid-upper arm muscle circumference with hypertension risk in Chinese residents. J Clin Hypertens (Greenwich). 2022;24(3):329-38. https://doi.org/10.1111/jch.14412

15. Charatsi AM, Dusser P, Freund R, Maruani G, Rossin H, Boulier A, et al. Bioelectrical impedance in young patients with cystic fibrosis: Validation of a specific equation and clinical relevance. J Cyst Fibros. 2016;15(6):825-33. https://doi.org/10.1016/j.jcf.2016.05.004

16. Graham BL, Steenbruggen I, Miller MR, Barjaktarevic IZ, Cooper BG, Hall GL, et al. Standardization of Spirometry 2019 Update. An Official American Thoracic Society and European Respiratory Society Technical Statement. Am J Respir Crit Care Med. 2019;200(8):e70-88. https://doi.org/10.1164/rccm.201908-1590ST

17. Mallozi MC. Valores de referência para espirometria em crianças e adolescentes, calculados a partir de uma amostra da cidade de São Paulo [dissertation]. [São Paulo]: Universidade Federal de São Paulo; 1995.

18. ATS Statement Guidelines for the Six-Minute Walk Test. Am J Respir Crit Care Med. 2002;166(1):111-7. https://doi.org/10.1164/ajrccm.166.1.at1102

19. MacDermid J, Solomon G, Valdes K. Grip assessment. In: Clinical assessment recommendations: Impairment-based conditions. 3rd ed. American Society of Hand Therapists; 2015; p. 80.

20. Clasey JL, Easley EA, Murphy MO, Kiessling SG, Stromberg A, Schadler A, et al. Body mass index percentiles versus body composition assessments: Challenges for disease risk classifications in children. Front Pediatr. 2023;11:1112920. https://doi.org/10.3389/fped.2023.1112920

21. Gomes A, Hutcheon D, Ziegler J. Association Between Fat-Free Mass and Pulmonary Function in Patients With Cystic Fibrosis: A Narrative Review. Nutr Clin Pract. 2019;34(5):715-27. https://doi.org/10.1002/ncp.10251

22. Chaves CRMM, Britto JAA, Oliveira CQ, Gomes MM, Cunha ALP. Associação entre medidas do estado nutricional e a função pulmonar de crianças e adolescentes com fibrose cística. J Bras Pneumol. 2009;35(5):409-14. https://doi.org/10.1590/S1806-37132009000500004

23. Papalexopoulou N, Dassios TG, Lunt A, Bartlett F, Perrin F, Bossley CJ, et al. Nutritional status and pulmonary outcome in children and young people with cystic fibrosis. Respir Med. 2018;142:60-5. https://doi.org/10.1016/j.rmed.2018.07.016

24. Sheikh S, Zemel BS, Stallings VA, Rubenstein RC, Kelly A. Body Composition and Pulmonary Function in Cystic Fibrosis. Front Pediatr. 2014;2:33. https://doi.org/10.3389/fped.2014.00033

25. Alvarez JA, Ziegler TR, Millson EC, Stecenko AA. Body composition and lung function in cystic fibrosis and their association with adiposity and normal-weight obesity. Nutrition. 2016;32(4):447-52. https://doi.org/10.1016/j.nut.2015.10.012

26. Bohannon RW. Dynamometer Measurements of Hand-Grip Strength Predict Multiple Outcomes. Percept Mot Skills. 2001;93(2):323-8. https://doi.org/10.2466/pms.2001.93.2.323

27. Lammers AE, Hislop AA, Flynn Y, Haworth SG. The 6-minute walk test: normal values for children of 4-11 years of age. Arch Dis Child. 2008;93(6):464-8. http://doi.org/10.1136/adc.2007.123653

28. Okuro RT, Schivinski CIS. Teste de caminhada de seis minutos em pediatria: relação entre desempenho e parâmetros antropométricos. Fisioter Mov. 2013;26(1):219-28. https://doi.org/10.1590/S0103-51502013000100024

29. Lesser DJ, Fleming MM, Maher CA, Kim SB, Woo MS, Keens TG. Does the 6-min walk test correlate with the exercise stress test in children? Pediatr Pulmonol. 2010;45(2):135-40. https://doi.org/10.1002/ppul.21125

30. Gruber W, Orenstein DM, Braumann KM, Hüls G. Health-related fitness and trainability in children with cystic fibrosis. Pediatr Pulmonol. 2008;43(10):953-64. https://doi.org/10.1002/ppul.20881

31. Cunha MT, Rozov T, Oliveira RC, Jardim JR. Six-minute walk test in children and adolescents with cystic fibrosis. Pediatr Pulmonol. 2006;41(7):618-22. https://doi.org/10.1002/ppul.20308

32. Meer K, Gulmans VAM, van der LAAG J. Peripheral Muscle Weakness and Exercise Capacity in Children with Cystic Fibrosis. Am J Respir Crit Care Med. 1999;159(3):748-54. https://doi.org/10.1164/ajrccm.159.3.9802112

33. López-de-Uralde-Villanueva I, Visa TS, Marichalar PM, del Corral T. Minimal detectable change in six-minute walk test in children and adolescents with cystic fibrosis. Disabil Rehabil. 2021;43(11):1594-9. https://doi.org/10.1080/09638288.2019.1663947

34. Arikan H, Yatar İ, Calik-Kutukcu E, Aribas Z, Saglam M, Vardar-Yagli N, et al. A comparison of respiratory and peripheral muscle strength, functional exercise capacity, activities of daily living, and physical fitness in patients with cystic fibrosis and healthy subjects. Res Dev Disabil. 2015;45-46:147-56. https://doi.org/10.1016/j.ridd.2015.07.020