original article

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Relationship between body balance, lung function, nutritional status and functional capacity in adults with cystic fibrosis

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ABSTRACT | Background: Cystic fibrosis (CF) is a hereditary condition in which lung disease affects all patients. In addition to pulmonary involvement, the multisystemic components of CF cause significant physical limitations. However, the impact of lung function on balance control in CF has not been studied. **Objective:** To assess body balance in adults with CF and to test its possible associations with lung function, nutritional status, and functional capacity. **Method:** This was a cross-sectional study in which 14 adults with CF underwent pulmonary function testing (spirometry, body plethysmography, and carbon monoxide diffusing capacity (DLco), respiratory muscle strength, 6-min walking distance (6MWD), Berg balance scale (BBS), nutritional analysis (body mass index and bioelectrical impedance), and stabilometry. Body balance was quantified using stabilometry; all participants performed the following two trials: opened base, eyes open (OBEO); closed base, eyes closed (CBEC). **Results:** In stabilometry, the median for the lateral range and anterior-posterior range in the CBEC trial was 0.10 (0.08-0.11) and 0.13 (0.11-0.22), respectively ($p<0.05$). The maximal inspiratory pressure (MIP) correlated inversely with the lateral standard deviation ($\rho=-0.61$; $p<0.05$) as the DLco correlated positively with the anterior-posterior range ($\rho=0.54$; $p<0.05$). There were significant relationships between body composition indexes and almost all stabilometric variables measured. There were no relationships of the BBS and 6MWD with the stabilometric variables. **Conclusions:** In adults with CF, imbalance occurs mainly in the anterior-posterior direction and is especially associated with body composition.

Keywords: cystic fibrosis; rehabilitation; respiratory function tests; postural balance; psychomotor performance; nutrition assessment.

HOW TO CITE THIS ARTICLE

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Introduction

Cystic fibrosis (CF) is a severe autosomal recessive hereditary disease, with variability in symptom onset and presentation[1]. Although CF is a progressively debilitating disease, in recent years the improvements in its understanding and treatment have been increasing the patients' life expectancy. The median predicted survival of only 16 years in 1970 has currently reached approximately 40 years, and infants born with CF in the beginning of this new millennium are expected to live beyond 50 years of age. The number of middle-aged or older individuals with CF is also increasing[1].

CF is a disorder that affects many systems and can cause various problems. Lung disease is recognized as the factor with the greatest impact on the morbidity and mortality in older people with CF[1,2]. In CF, pulmonary function impairment results in excessive recruitment of the expiratory and accessory inspiratory muscles, which contributes to adaptive hypertrophy. Under high tension, these muscles shorten and lose flexibility, decreasing muscle length and strength. As the involvement of the lungs by CF increases, the hyperinflation and increased work of breathing may cause muscle imbalance due to the altered respiratory mechanics[2,3]. In addition to pulmonary involvement, the multisystemic components of CF cause significant physical limitations in these patients. Musculoskeletal dysfunction, nutritional depletion, malnutrition, diabetes, and depression are expected to become more prevalent in older people with CF. Nutritional status is

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an important predictor of survival in CF[4]. Adults with CF also have more bone and joint disease, including low bone mineral density and postural deformities[2].

Body balance has been studied increasingly in the literature over the last decades[3,5,6]. The maintenance of balance control is important for the correct execution of all daily living activities. One of the most dangerous aspects of changes in body stability is the increased risk of falls. Deterioration in balance function clearly starts at a relatively young age and further accelerates around the age of sixty[7]. Recent studies have noted reduced balance and coordination in individuals with chronic obstructive pulmonary disease (COPD)[3,8]. The postural attitude of a hyperinflated thorax can lead to shoulder, spinal column, and pelvic girdle compensations, including spinal column deformities as increased thoracic kyphosis and lumbar lordosis, which are fairly common in adults with CF[9]. However the information regarding balance in CF is limited, and the relationship between lung function and balance has not been analyzed in CF.

The accumulation of fat can also cause a reduction in body balance and contribute to falls, particularly when combined with low muscle mass, which, in turn, can impair the biomechanical responses and reduce the stability mechanisms. It is believed that obesity might affect the selection of motor strategies employed to maintain body balance[6]. However, to our knowledge, no study has previously attempted to investigate the correlation between body mass and balance in the adult population with CF.

The changes in thoracic biomechanics influence the overall body mechanics[10]. Thus, any respiratory imbalance might result in altered total body balance. It is therefore possible to assume that all of these changes may culminate in a reduction in functional capacity. Such knowledge can be an important tool for planning the most appropriate mode of therapeutic exercise in adults with CF. Therefore, we sought to assess body balance in adults with CF, as well as to verify the relationship between body balance, lung function, nutritional status, and functional capacity in these patients.

Method

Participants

This was a cross-sectional study that included patients treated at Centro de Referência para Adultos com Fibrose Cística da Policlínica Piquet Carneiro, Rio de Janeiro, RJ, Brazil. A convenience sample of adults with CF was recruited between September 2011 and February 2012. The diagnosis of CF was based on at least two of the following criteria: sweat chloride concentration >60 mEq/mL; two clinical features consistent with CF; or genetic testing demonstrating two mutations associated with CF[11]. Inclusion criteria were: a) age ≥ 18 years, diagnosed with CF, b) clinically stable, c) no injuries or previous surgery on the lower limbs; and d) absence of knee or ankle clinical instability. Exclusion criteria were: a) hospitalized patients, b) acute intercurrent respiratory infection during the 3 weeks preceding enrollment; c) unable to perform pulmonary function evaluation or 6-min walking test (6MWT); d) neurological, cardiovascular, metabolic, rheumatic or vestibular diseases; e) abnormal accumulation of fluid (edema), mainly in the limbs, as assessed by physical examination, f) any implanted electronic or metallic device. Home medication (antibiotics, bronchodilators, pancreatic enzyme supplements, and vitamins) was maintained over the course of the study.

The present study was approved by the Research Ethics Committee of Centro Universitário Augusto Motta (UNISUAM), Rio de Janeiro, RJ, Brazil (approval no. 012/2011). All participants signed an informed consent form.

Measurements

The body mass index (BMI) was calculated on the basis of weight and height [weight (Kg) / height (m^2)] using an analog balance scale which includes a stadiometer (R110, Welmy, Santa Bárbara d'Oeste, São Paulo, Brazil), and the results were classified according to the World Health Organization[12]. Body composition was analyzed using a bioelectrical impedance device (BIA 310e, Biodynamics, Seattle, WA, USA). The participants were instructed to rest for 5 minutes before the test. During the test, they were barefoot, away from metallic objects, and stood with their feet 15 to 30 cm apart[13]. Two electrodes were placed on the dorsum of the right hand, and two were placed on the dorsum of the right foot. Resistance and reactance were calculated and used to estimate fat-free mass (FFM). The selected equation has been previously validated for Brazilian individuals[13].

Pulmonary function testing consisted of spirometry, body plethysmography, carbon monoxide diffusing capacity (DLco), and respiratory muscle strength. Measurements were conducted using the Collins Plus Pulmonary Function Testing Systems (Warren E. Collins, Inc., Braintree, MA, USA), following the standards for the procedure and interpretation[14]. For the body plethysmography, measurements were taken during shallow panting at a rate of one to two breaths/second with an open glottis. Airway resistance (Rwa) was also measured simultaneously during the open-shutter panting; reported thoracic gas volume was the calculated average of three to five acceptable panting maneuvers. Carbon monoxide diffusing capacity (DLco) maneuvers were performed after the participant had been seated for at least 5 minutes. Because exercise increases DLco, the participant was asked to refrain from exertion immediately before the test; the participant was also instructed about the requirements of the maneuver. Respiratory muscle strength was measured using a pressure transducer. Maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) were measured from residual volume (RV) and total lung capacity (TLC), respectively. The participants had to maintain maximal effort against the occluded airway for one to three seconds. At least three MIP and three MEP maneuvers were recorded. The pulmonary function testing results were expressed as percentage of the predicted values for the Brazilian population[15-17]. The participants also completed two encouraged 6MWT in a 30-m hospital corridor, following recommendations[17]. The maximal distance covered was recorded for further analysis. Results were expressed as a percentage of the predicted values according to the reference equations[18].

Functional balance was measured using the Berg Balance Scale (BBS), which has been previously validated for the Brazilian population[19]. The BBS examines balance by using different standardized positions and actions related to 14 daily life items. The items are scored according to the time that the body position can be maintained and the distance at which the arm is capable of reaching forward[19,20]. Each item has an ordinal scale of five alternatives, ranging from 0 to 4 points. The maximum score that can be reached is 56. A cutoff score of 46 or lower has been used to identify patients at risk of falling[21].

Body balance was quantified using a force platform system (AccuSway Plus, AMTI, Watertown, Massachusetts, USA), and center-of-foot pressure signals were recorded using EBG Software version 1.0 (PGSM, France). This measurement system contains 2,288 force sensors arranged in rows and columns of the platform and connected to a data acquisition system controlled by software. All participants performed the following two trials: opened base, eyes open (OBEO); closed base, eyes closed (CBEC) (feet parallel and <1 cm apart). The participants were asked to maintain a static position with their eyes focused on a target on the wall located 1.5 m for 30 seconds. A randomized block design (four possible sequences of the described trials) was used to minimize fatigue and learning effects. The calculated stabilometric variables included the lateral standard deviation (X SD), anterior-posterior standard deviation (Y SD), lateral range (X range), and anterior-posterior range (Y range)[6].

Anthropometry, BBS, bioelectrical impedance, and stabilometry were evaluated at the same location. Pulmonary function tests and 6MWT were performed elsewhere with a maximum interval of one week between tests.

Data analysis

To check the homogeneity of the sample, a Shapiro-Wilk test was used; if a meaningful number of variables did not have a normal distribution, nonparametric tests were selected. The results were expressed as the median and interquartile range values or frequencies (percentage). Numerical variables were compared using the Mann-Whitney test. Spearman's rank correlations were calculated to investigate associations. Data analysis was performed using SAS 6.11 software (SAS Institute, Inc., Cary, NC, USA). The statistical significance level was set at $p<0.05$.

Results

Thirty-eight individuals were initially eligible for assessment; however, 5 did not meet inclusion criteria because they were under the age of 18. Among the 33 individuals recruited for the investigation, 19 were excluded. Of the excluded individuals, 8 did not agree to participate, 6 had limited mobility, 4 were not able to perform the pulmonary function tests, and 1 had vestibular disease. Thus, 14 adults with CF completed the study.

Anthropometric and clinical characteristics, pulmonary function, and respiratory muscle strength are summarized in Table 1. Pancreatic insufficiency and CF-related diabetes were common findings in the sample studied (Table 1). Overall, 8 participants (57%) were male, and the median age was 24.5 years (range, 20-34 years). Six participants had a BMI <18.5 Kg/m^2; 4 had a BMI between 18.5 and 25 Kg/m^2; 2 had a BMI between 25 and 30 Kg/m^2; and 2 had a BMI $\geq$30 Kg/m^2. Ten participants (71.4%) had obstructive impairment and 4 participants (28.6%) had no ventilatory defect. In the sample studied, all subjects had significant air trapping (increased RV) and 4 (28.6%) had lung hyperinflation (increased TLC).

The 6-min walking distance (6MWD) was abnormally low in 6 participants (42.8%). The median 6MWD was 636.5 m (range, 450-750 m), and the median 6MWD% was 83.3 (67.6-92.3). Of the 14 participants, 11 had a score at the 56-point, 2 at the 55-point, and 1 at the 54-point on the BBS. The data obtained by stabilometry are presented in Table 2. There was a greater displacement in the anterior-posterior direction, especially when participants were tested with eyes and base closed ($p<0.05$ for all).

There were no relationships between the BBS, 6MWD, and stabilometric variables. However, we found associations between stabilometric variables and body composition indexes, pulmonary function parameters and respiratory muscle strength (Tables 3 and 4).

Discussion

Our study demonstrated that, in adults with CF, the changes in st abilometry are primarily in the anterior-posterior direction. The nutritional status, inspiratory muscle strength, and pulmonary diffusion capacity are significantly correlated with postural balance in these subjects. In addition, there is no relationship between BBS or 6MWD and stabilometry. To date, there seem to be no studies that have focused on this issue.

Stabilometry assesses body balance through the quantification of postural oscillations in the standing position on a force platform, involving the recording of the center of pressure displacement in the anterior-posterior and lateral directions[6,21]. Many investigators have attempted to understand which factors affect body balance and, consequently, tend to increase the incidence of falls[3,4]. Despite different underlying etiologies and time of onset, both CF and COPD lead to parallel pathological changes in a way that can be compared in stabilometric measurements. Similarly to the current study, some authors demonstrated greater displacement in the anterior-posterior direction in COPD patients[3]; however, Rocco et al.[22] observed increased lateral center of pressure displacement (but no increased anterior-posterior center of pressure displacement) compared to healthy controls. Interestingly, balance in the lateral direction is primarily maintained by torques at the trunk muscles and movement, whereas anterior-posterior direction is primarily maintained by torques at the ankle[23]. Despite not having a control group, our study suggests that lateral imbalance in adults with CF may also be due to a marked impairment in respiratory muscle strength. As expected, we observed changes in all stabilometric variables when the trial was modified[3,6]. The CBEC trial was the condition with

Table 1. Anthropometric and clinical characteristics, pulmonary function testing, and respiratory muscle strength.

Variables	Values
Demographic characteristics	
Age (years)	24.5 (22-29.3)
Sex - male (%)	8 (57)
BMI (Kg/m^2)	19.9 (17.6-23.9)
FFM (Kg)	44.6 (36.9-49.1)
FM (%)	23.6 (18.3-28.8)
Clinical data	
ΔF508 homozygous mutation (%)	5 (35.7)
Pancreatic insufficiency (%)	13 (93)
Cystic fibrosis related diabetes (%)	6 (43)
Pulmonary function parameters	
FVC (% pred)	84 (59-88.8)
FEV_1 (% pred)	54 (40.3-76.8)
FEV_1/FVC (%)	57.5 (55.3-72)
MIP (% pred)	51.5 (47.3-64)
MEP (% pred)	32.5 (26.5-39.8)
TLC (% pred)	106.5 (102-121)
RV (% pred)	178 (148.3-273.5)
DLco (% pred)	80.5 (71.8-89.3)

Results are medians (interquartile range) or number (%) of 14 adults with cystic fibrosis. BMI = body mass index; FFM = fat-free mass; FM = fat mass; FVC = forced vital capacity; % pred = % predicted; FEV_1 = forced expiratory volume in one second; MIP = maximal inspiratory pressure; MEP = maximal expiratory pressure; TLC = total lung capacity; RV = residual volume; DLco = diffusing capacity for carbon monoxide.

Table 2. Stabilometric variables.

Variables	Trials	Values
X SD (cm)	OBEO	0.01 (0.01-0.01)
	CBEC	0.09 (0.07-0.10)
Y SD (cm)	OBEO	0.02 (0.01-0.02)
	CBEC	0.12 (0.08-0.13)
X range (cm)	OBEO	0.01 (0.01-0.01)
	CBEC	0.10 (0.08-0.11)
Y range (cm)	OBEO	0.03 (0.02-0.04)
	CBEC	0.13 (0.11-0.22)

Results are medians (interquartile range) of 14 adults with cystic fibrosis. X SD = lateral standard deviation; Y SD = anterior-posterior standard deviation; X range = lateral range; Y range = anterior-posterior range; OBEO = opened base, eyes open; CBEC = closed base, eyes closed.

Table 3. Spearman's correlation coefficients between body composition, spirometry, respiratory muscle strength and stabilometric variables in adults with cystic fibrosis (n=14).

Variables	Trials	BMI (Kg/m^2)	FFM (Kg)	FM (%)	FEV_1 (% pred)	MIP (% pred)	MEP (% pred)
X SD (cm)	OBEO	0.24	–0.31	0.19	0.31	–0.38	–0.10
	CBEC	0.68†	–0.72†	0.70†	0.13	–0.61*	–0.32
Y SD (cm)	OBEO	0.59*	–0.61*	0.48	0.23	–0.45	–0.12
	CBEC	0.78†	–0.81†	0.67†	0.31	–0.37	–0.17
X range (cm)	OBEO	0.24	–0.32	0.34	0.31	–0.38	–0.10
	CBEC	0.71†	–0.79†	0.77†	0.07	–0.15	–0.02
Y range (cm)	OBEO	0.65*	–0.70†	0.68†	0.21	–0.46	–0.28
	CBEC	0.65*	–0.68†	0.67†	0.35	–0.40	–0.03

X SD = lateral standard deviation; Y SD = anterior-posterior standard deviation; X range = lateral range; Y range = anterior-posterior range; OBEO = opened base, eyes open; CBEC = closed base, eyes closed; BMI = body mass index; FFM = fat-free mass; FM = fat mass; FEV_1 = forced expiratory volume in one second; % pred = % predicted; MIP = maximal inspiratory pressure; MEP = maximal expiratory pressure. *p<0.05; †p<0.01.

Table 4. Spearman's correlation coefficients between plethysmographic measurements, diffusing capacity and stabilometric variables in adults with cystic fibrosis (n=14).

Variables	Trials	TLC (% pred)	RV (% pred)	RV/TLC (%)	DLco (% pred)
X SD (cm)	OBEO	–0.10	–0.38	–0.27	0.24
	CBEC	0.25	–0.13	–0.24	0.35
Y SD (cm)	OBEO	0.12	–0.30	–0.36	0.53*
	CBEC	0.04	–0.27	–0.39	0.50
X range (cm)	OBEO	–0.10	–0.38	–0.28	0.24
	CBEC	–0.16	–0.46	–0.33	0.39
Y range (cm)	OBEO	0.19	–0.15	–0.26	0.44
	CBEC	0.45	–0.07	–0.34	0.54*

X SD = lateral standard deviation; Y SD = anterior-posterior standard deviation; X range = lateral range; Y range = anterior-posterior range; OBEO = opened base, eyes open; CBEC = closed base, eyes closed; TLC = total lung capacity; % pred = % predicted; RV = residual volume; DLco = diffusing capacity for carbon monoxide. *p<0.05; †p<0.01.

the highest demand for somatosensory and vestibular systems, since the visual feedback is eliminated[6].

The evaluation of the relationship between balance and nutritional status is important for providing information about the factors that can predispose to falls. The current study showed significant relationships between body composition indexes and almost all stabilometric variables measured. Some authors also showed a positive correlation between body adiposity and body balance control[6,24]. Interestingly, almost one third of our participants had a BMI consistent with overweight or obesity; it is possible that fat accumulation and body mass increases can causes a center of pressure displacement, which can generate loss of stability mechanisms[6]. In contrast, it is worth noting that 43% of our sample had BMI compatible with malnutrition. In adults with CF, it is assumed that nutritional depletion is caused by negative energy balance resulting not only from pancreatic insufficiency (causing poor nutrient absorption) but also by the CF-related diabetes and chronic respiratory disease[25]. All of these conditions were common in our sample. Thus, it is possible that malnutrition may have influenced our results, changing the body balance.

Our study showed a significant correlation between maximal inspiratory pressure (MIP) (% predicted) and mean (SD) (cm) measured with eyes and base closed, and all participants had significant air trapping. As a result of the changes occurring in the trunk muscles due to air trapping, respiratory effort increases significantly. This can result in an impaired ability of the trunk to contribute to body balance. Moreover, the limbs and trunk muscles might be atrophied and weak because of the inadequate nutritional status resulting from pancreatic insufficiency (observed in 93% of our participants) and an ongoing catabolic state[26]. In addition, increased lumbar lordosis is often noted in these patients; this change may cause an associated imbalance of the muscular system that will inhibit normal movement. Interestingly, some investigators demonstrated that postural reeducation improves respiratory muscle strength and the ability to expand the rib cage in sedentary subjects[27].

The role of DLco in pulmonary function testing is to provide information on the transport of gas from alveolar air to hemoglobin[28]. In our study, it is not surprising to observe a significant relationship (positive correlation) between DLco (% predicted) and stabilometric variables. During the single-breath DLco maneuver in adults with CF, the maximal inspiration against obstructed airways requires abnormally negative intrathoracic pressures; this increases the pulmonary capillary blood volume and, thereby, increases the DLco. Furthermore, patients with higher BMIs and greater body surface areas tend to have higher DLco values due to increased pulmonary capillary blood volume; this causes a center of pressure displacement[28].

In this study, we chose BBS over other evaluation methods not only because it is inexpensive, easy to administer, and secure, but also because it is widely used in clinical practice and research. The usefulness of the BBS score for the assessment of functional balance has been confirmed in research studies and in clinical practice based on the extensive analysis of its measurement properties, which were found to be reliable[19,20]. In COPD patients, Beauchamp et al.[29] demonstrated differences in the BBS score between fallers and non-fallers (45.2±5.40 vs. 48.8±5; p=0.042). However, our investigation did not find changes in the BBS score among CF individuals, suggesting a low discriminative power of this scale when compared to more refined tests such as stabilometry. Our results are in accordance with Gil et al.[30], who also found no correlation between the force platform parameters and two functional tests to evaluate body balance.

Another focus was the relationship between functional capacity and body balance. Simpler and cheaper tests such as the 6MWT have been used to assess tolerance to exercise in adult patients with CF, and the distance achieved in the walking test allows an estimation of individual response to incremental maximal exercise. Several conditions have been linked to the limited exercise capacity in adults with CF, including the deterioration of pulmonary function, peripheral muscle weakness, and malnutrition[31]. Moreover, the role of body balance as one of the main domains of functional capacity is recognized. Despite these considerations, the association between body balance and the 6MWT has not been previously investigated in patients with chronic lung diseases. In the present investigation, no relationship was noted between stabilometric variables and the 6MWD, suggesting that exercise tolerance is not compromised by imbalance in people living with CF.

The main limitations of our study were the small sample size and the lack of comparisons between the CF results with a paired sample of normal subjects. Despite these limitations, this is the first study to evaluate the relationship between stabilometry results and lung function parameters in adults with CF. Since there are no published studies on body balance in CF, we believe that our results represent an important contribution to the field. Further investigations including a larger sample and a healthy control group are necessary to confirm the body balance impairment in adults with CF, which may bring a new rehabilitative treatment perspective for this group of patients.

In conclusion, the present study showed greater displacement in the anterior-posterior direction in adults with CF. Additionally, body balance is associated with several factors in these subjects, especially with body composition variables (FFM, FM, and BMI). Our results suggest that balance should be considered in the assessment and rehabilitation strategies directed toward adults with CF.

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