The effects of different body positions on pulmonary function in healthy adults

Os efeitos de diferentes posições corporais na função pulmonar em adultos saudáveis

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Abstract

Introduction: Pulmonary function testing, or spirometry, is a validated, globally recognized test that contributes to the diagnosis, staging, and longitudinal follow-up of lung diseases. The exam is most often performed in a sitting position in clinical practice; hence, there are no predicted values for its performance in other positions, such as in different decubitus. **Objective:** The present study aimed to evaluate the effects of position on pulmonary function test results in healthy adults. **Methods:** Forty-two healthy adults of both sexes, divided into male (MG) and female groups (FG), were provided respiratory questionnaires. Subsequently, the pulmonary function test was conducted to evaluate the ventilatory parameters of forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), and FEV_1/FVC ratio in the sitting (S), dorsal decubitus (DD), right lateral decubitus (RLD), and left lateral decubitus (LLD) positions. A comparison of the parametric data was performed via one-way analysis of variance followed by Tukey post-hoc tests. Correlations between the S position variables along with the other positions were evaluated using the Pearson test. **Results:** The mean and standard error for the FVC values of the MG at positions DD (4.3 ± 0.7/L), RLD (4.1 ± 0.6/L) and LLD (4.1 ± 0.6/L) were lower when compared to S (5.05 ± 0.6 L). There was a strong positive correlation between the values of FVC, FEV_1, and FEV_1/FVC in the S position compared to other positions analyzed in both groups. **Conclusion:** Body positioning altered the parameters of the pulmonary function test in healthy adults.

Keywords: Pulmonary ventilation. Respiratory function tests. Spirometry.

Resumo

Introdução: *A prova de função pulmonar, ou espirometria, é um teste validado e reconhecido mundialmente que contribui para o diagnóstico, estadiamento e acompanhamento longitudinal das doenças pulmonares. O exame é mais frequentemente realizado na posição sentada na prática clínica; portanto, não há valores previstos para seu desempenho em outras posições, como em decúbitos diferentes.* ***Objetivo:*** *O presente estudo teve como objetivo avaliar os efeitos da posição nos resultados dos testes de função pulmonar em adultos saudáveis.* ***Métodos:*** *Quarenta e dois adultos saudáveis de ambos os sexos, divididos nos grupos masculino (GM) e feminino (GF), receberam questionários respiratórios. Posteriormente, realizou-se o teste de função pulmonar para avaliar os parâmetros ventilatórios de capacidade vital forçada (CVF), volume expiratório forçado no primeiro segundo (VEF_1) e relação VEF_1/CVF nas posições sentada (S), decúbito dorsal (DD), decúbito lateral direito (DLD) e decúbito lateral esquerdo (DLE). A comparação dos dados paramétricos foi realizada por meio de análise de variância unidirecional seguida do pós-teste de Tukey. As correlações entre as variáveis da posição S com as demais posições foram avaliadas por meio do teste de Pearson.* ***Resultados:*** *A média e o erro padrão dos valores de CVF do MG nas posições DD (4,3 ± 0,7/L), DLD (4,1 ± 0,6/L) e DLE (4,1 ± 0,6/L) foram menores quando comparados com S (5,05 ± 0,6 L). Houve forte correlação positiva entre os valores de CVF, VEF_1 e VEF_1/CVF na posição S em relação às demais posições analisadas em ambos os grupos.* ***Conclusão****: O posicionamento corporal alterou os parâmetros do teste de função pulmonar em adultos saudáveis.*

Palavras-chave: *Ventilação pulmonar. Testes de função respiratória. Espirometria.*

Introduction

Spirometry, or pulmonary function test, is the most common method to evaluate lung volumes and capacities.[1] It is widely used internationally, offering extremely useful data for the diagnostic assessment of general respiratory symptoms or effort limitations, longitudinal assessments of patients, disorder severity classification, occupational capacity assessments, and preoperative management.[2-5] Moreover, this technique can infer the prognosis of various respiratory or systemic diseases, contributing to the detection of early airway diseases, a common condition of great importance in medical practice.[3,6]

Conventional spirometry is performed according to international and national guidelines and generates accurate data when correctly and systematically calibrated and when associated with the use of properly defined protocols, thus contributing to the final quality and accuracy of the exam.[1,7,8] Several parameters can be measured from the maneuvers performed during the test, the most commonly used being vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), and forced expiratory ratio (FEV_1/FVC; Tiffeneau index), flow-volume (FV) curve and peak expiratory flow (PEF) values. The exam is complemented by an analysis of the volume-time curves.[9] During the dynamic lung function test, the presence of obstructive, obstructive with reduced FVC, restrictive, mixed (obstructive-restrictive), and nonspecific disorder may be observed. Ventilatory disorders can be classified, according to severity, as mild, moderate, or severe.[9,10]

Preferably, pulmonary function tests should be performed in the sitting or standing position, and the position in which the test was performed should be recorded on the report.[11] The sitting position is recommended for safety reasons to avoid falls due to syncope, and it can also be more convenient due to the measuring devices and patient comfort.[11,12] However, in some circumstances, especially when the mobility of the patient is compromised, it is necessary to perform the pulmonary function test in different positions, which may compromise the test result. There is little evidence in the literature with predictive values for patients with compromised mobility, who need to have their pulmonary function evaluated in other positions.

In addition, there are few studies that evaluate the influence of body positioning on lung function results in healthy young adults. In this study, in order to understand if the body positioning can influence the results of the spirometry test, we performed the lung function test in young adult men and women in the following positions: sitting (S), dorsal decubitus (DD), right lateral decubitus (RLD), and left lateral decubitus (LLD).

Methods

This research was an observational, descriptive study conducted at the Ambulatory of Respiratory Proceeding in the Medical School at the Universidade Federal de Ouro Preto (EMED-UFOP), in Minas Gerais, Brazil. The project was approved by the UFOP Research Ethics Committee (Nº 158/2012).

Participants

The data was collected between April 2016 and February 2017, and the recruitment of volunteers was done by personal invitation in the UFOP classrooms. The sampling method used in this study was determined for convenience. After accepting the invitation to participate in the study, the volunteers were instructed to go to the EMED-UFOP to schedule the tests. The data were collected during the morning and afternoon periods, according to the clinic's opening hours and the availability of the participants.

Participants were enrolled to the study according to the following inclusion criteria: students of both sexes aged 18 to 30 years; enrolled in undergraduate courses; body mass index (BMI) between 18.5 and 24.9 kg/$m^{2;}$ no reports of previous or current known pneumopathies or recent respiratory infections; and normal lung function. Individuals were excluded if they smoked, used drugs, used depressants of the central nervous system, or were pregnant. The volunteers were informed about the possibility of abandoning the study at any time, without needing to provide justification. All volunteers signed the Free and Informed Consent form and provided written, informed consent in accordance with the tenets of the Declaration of Helsinki.

Measures

The volunteers were provided with a respiratory questionnaire widely used in epidemiological surveys for data collection on asthma and recommended by the American Thoracic Society - Division of Lung Diseases (ATS-DLD-78), further elaborated by Ferris and colleagues.[12-14] After completing the questionnaire, weight and height measurements were obtained using an anthropometric mechanical scale for adults (Welmy, Brazil) and pulmonary function was evaluated by a Koko portable digital pneumotachograph, PFT System, Version 4.14.9, 2007 nSpire Health, Inc. (Pulmonary Data Service, Louisville, CO, USA). The results were saved in the spirometer software database for analysis and interpretation.

The volunteers were divided into two groups according to sex: male group (MG) and female group (FG). For the pulmonary function test, the American Thoracic Society/European Respiratory Society (ATS/ERS)[12] and the Brazilian guidelines for pulmonary function tests of the Brazilian Thoracic Society[15] were followed. About twenty minutes after the reception and the application of the questionnaire, the volunteers were submitted to lung function measurement, divided into slow and fast maneuvers. The results were VC, FVC, FEV_1, and the FVC/FEV_1 ratio values. Pulmonary function tests were performed in the positions S, DD, RLD, and LLD.

The test maneuvers were always performed on a stretcher, where the volunteer was instructed to sit comfortably, keeping his head in a neutral position. For the decubitus positions we used the same stretcher. In the LLD position, the volunteers were instructed to lie with their head on the upper limb on the same side of the decubitus, with the elbow flexed at 45°. The lower limbs were also flexed, but at 90° and overlapped. All subjects wore a nose clip, which prevented air leakage during the maneuvers. At the end of the test, the data were stored in the spirometer software database for future analysis and interpretation. Between the maneuvers performed for each position, a rest period of 5 minutes was allowed.

Following the recommendations, the total of eight maneuvers were performed to avoid fatigue among participants while enabling the acquisition of three acceptable curves with correct morphologies and three reproducible curves when the values between them did not exceed 150 ml. For VC values, two acceptable and two reproducible curves were recommended, with final values not exceeding 100 ml. The volunteers were followed up by the same specialized examiner during and after the functional test, though the exam was easy to perform and presented minimal risks.

Data analysis

Data are expressed as mean ± standard deviation. The normality of the samples was evaluated by the D´Agostino-Pearson test. Parametric data were compared by one-way analysis of variance followed by a Tukey post-test and the correlation between positions was evaluated by a Pearson test. A difference was considered significant with a value of $p < 0.05$. The agreement and error limits were calculated from the Bland-Altman method. All analyses were conducted via GraphPad Prism 7.0 software.

Results

In this study, 42 adult volunteers (21 females and 21 males) were enrolled and their demographic data such as weight, height, and body mass index (BMI) are shown in Table 1. The S position data were compared to those from the DD, RLD, and LLD positions. In the MG, FVC (One-way ANOVA, $p < 0.0001$, $F = 9.21$) in the S position (5.1 ± 0.6 L) was higher compared to the DD (4.3 ± 0.7 L), RLD (4.1 ± 0.6 L), and LLD (4.1 ± 0.6 L) positions ($p = 0.01$). For the other parameters no differences were observed between the analyzed positions ($p > 0.05$) (Figure 1 A-C). Regarding the female group, no differences were observed among the positions (S, DD, RLD, LLD) for the lung function parameters analyzed ($p > 0.05$) (Figure 1 D-F).

Table 1 - Characterization of the participants

Variable	Male (n = 21)	p value	Female (n = 21)	p value
Age (years)	21.5 (± 2.20)	0.27	22.3 (± 2.90)	0.47
Weight (kg)	71.4 (± 8.20)	0.14	56.8 (± 6.70)	0.84
Height (m)	1.7 (± 0.07)	0.70	1.6 (± 0.06)	0.80
BMI (kg/m²)	23.6 (± 2.20)	0.16	21.5 (± 1.40)	0.69

Note: BMI = body mass index. Data expressed as mean ± standard deviation. Data were analyzed for distribution by D'Agostino-Pearson's normal test.

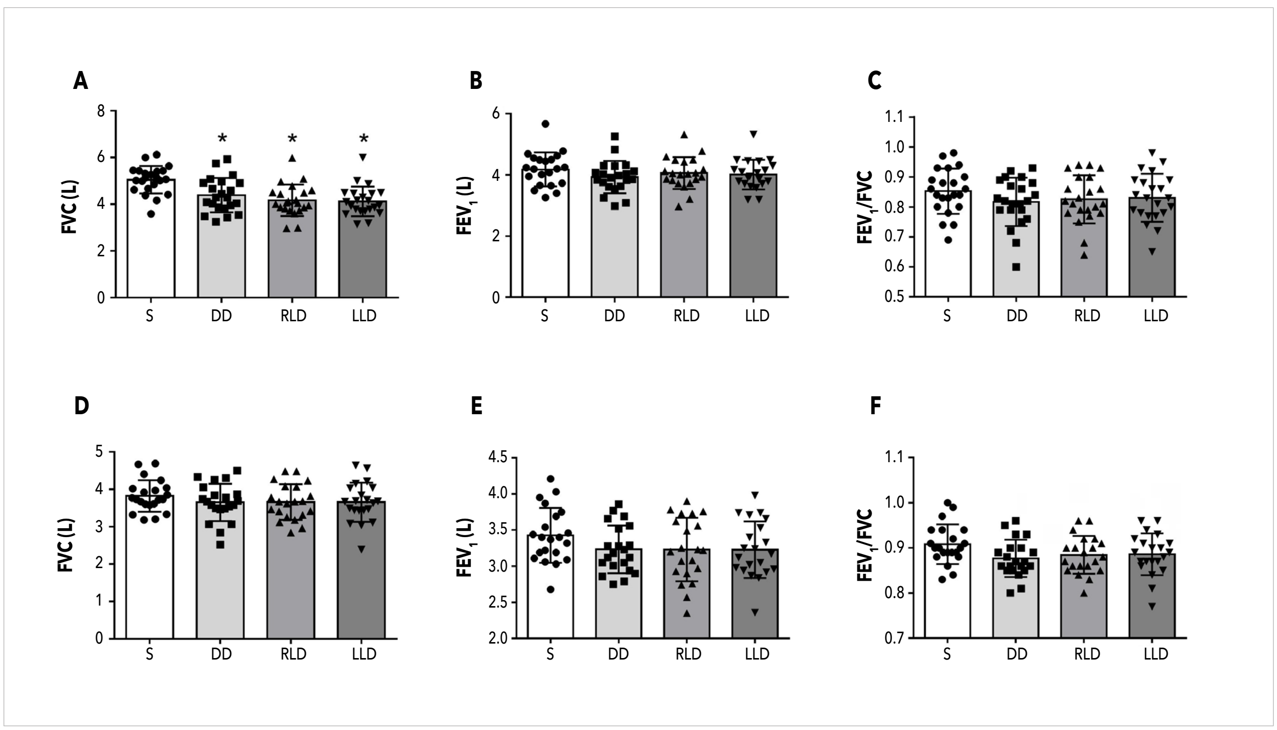

Figure 1 - Respiratory function analysis of male and female participants. A - Forced vital capacity (FVC) in male; B - Forced expiratory volume in 1 second (FEV_1) in male; C - Tiffeneau index (FEV_1/FVC) in male; D - FVC in female; E - FEV_1 in female; F - FEV_1/FVC in female. S = sitting position; DD = dorsal decubitus; RLD = right lateral decubitus; LLD = left lateral decubitus. *It represents significant difference between groups when compared to group S. Data expressed as mean ± standard deviation and were analyzed by One-way ANOVA followed by Tukey's post-test ($p < 0.05$) n = 21.

The association between the values in the S position was also evaluated in comparison to the other positions. In the male group, there was a strong, positive correlation between FVC values (S) compared to those for the DD, RLD and LLD positions (Figure 2A). The FEV_1 values for the S position were compared to those of DD, RLD and LLD (Figure 2B). Regarding the Tiffeneau index values, there was a strong correlation in the S position compared to DD, RLD, and RLE positions (Figure 2C).

On the other hand, in the FG there was a positive correlation between the S position regarding FVC values compared to the DD, RLD and LLD positions (Figure 3 A). Therefore, the FEV_1 values in the S position were compared to DD, RLD, and LLD positions (Figure 3 B). Similarly, the Tiffeneau index values showed a strong association in the S position between the DD, RLD, and LLD positions (Figure 3 C).

We observed a positive correlation for the evaluated data in both men and women for body position and the pulmonary function test; but, in Bland-Altman's analysis, we found that for the forced vital capacity the data does not present a good degree of agreement. For the women, however, in all the evaluated parameters the accordance of the data was found. The cut-off point adopted to determine the clinical relevance of our result was the pulmonary function test, based on the ATS/ERS and the Brazilian Guidelines for Pulmonary Function Tests of the Brazilian Thoracic Association (Table 2).

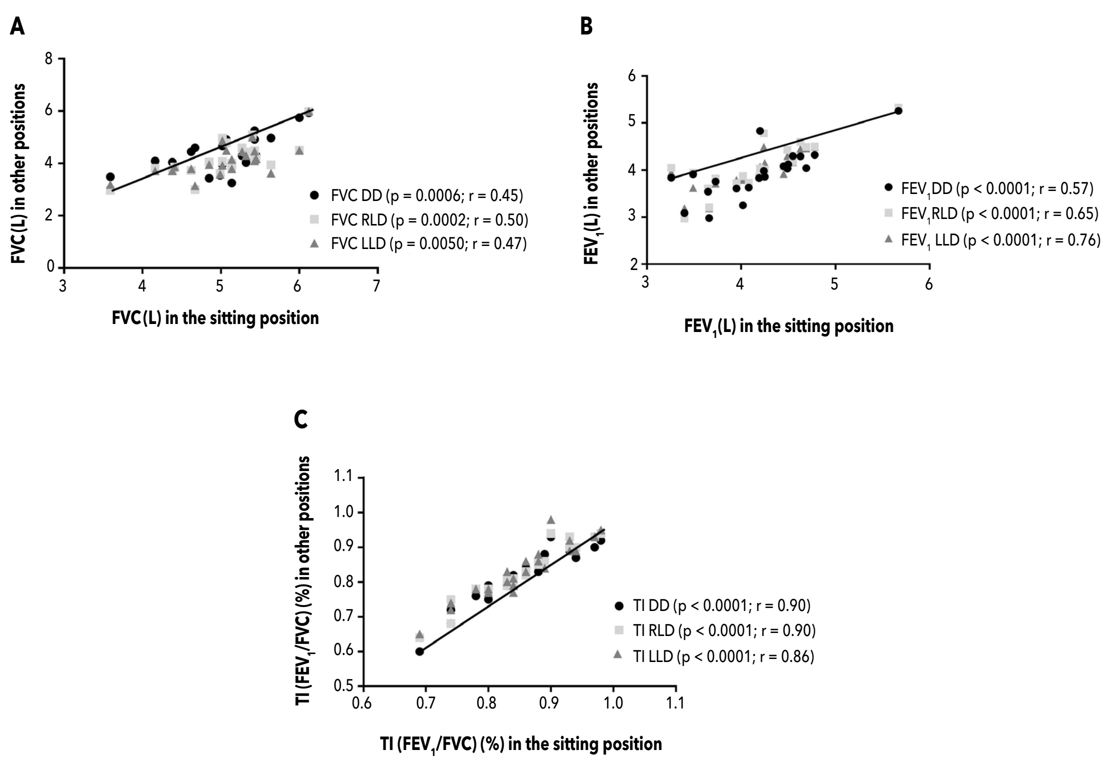

Figure 2 - Correlations between sitting position and other positions in male participants. A - Relationship between forced vital capacity (FVC) in the sitting position (S) and dorsal decubitus (DD); right lateral decubitus (RLD) and left lateral decubitus (LLD). B - Relationship between forced expiratory volume in 1 second (FEV_1) in the sitting position and DD, RLD, LLD. C - Relationship between Tiffeneau index (TI) (FEV_1/FVC) in S and DD, RLD, LLD. Data were expressed as mean ± standard deviation and were analyzed by Pearson's correlation (r) n = 21.

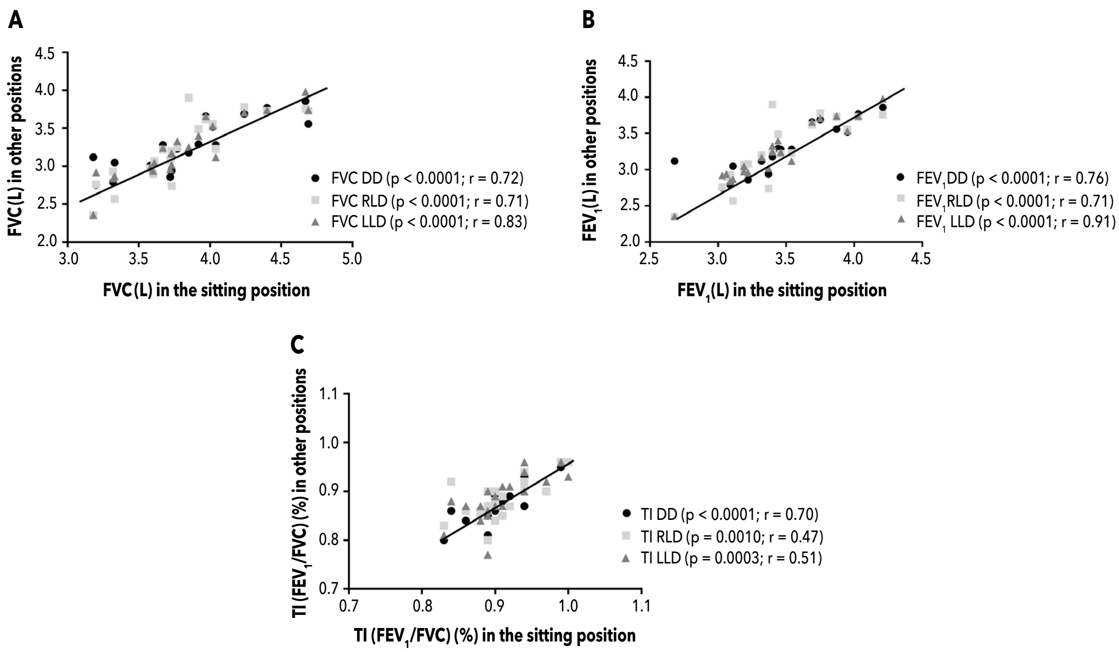

Figure 3 - Correlations between sitting position and other positions in female participants. A - Relationship between forced vital capacity (FVC) in the sitting position (S) and dorsal decubitus (DD); right lateral decubitus (RLD); left lateral decubitus (LLD). B - Relationship between Forced expiratory volume in 1 second (FEV_1) in the sitting position (S) and DD; RLD, LLD. C - Relationship between Tiffeneau index (TI) (FEV_1/FVC) in S and DD, RLD, LLD. Data were expressed as mean ± standard deviation and were analyzed by Pearson's correlation (r) n = 21.

Table 2 - Pearson's correlation and Bland-Altman analysis for the data collected

	Male			Female		
	Correlation Coefficient (CI95%)	Bland Altman		Correlation Coefficient (CI95%)	Bland Altman	
		Error	Limit of Agreement (95%)		Error	Limit of Agreement (95%)
FVC – S x DD	0.67 (0.34 to 0.58)	0.66	-0.42 to 1.74	0.84 (0.65 to 0.93)	0.17	-0.19 to 0.53
FVC – S x RLD	0.71 (0.41 to 0.87)	0.87	-0.07 to 1.83	0.84 (0.64 to 0.93)	0.16	-0.19 to 0.52
FVC – S x LLD	0.68 (0.36 to 0.85)	0.92	-0.03 to 1.88	0.90 (0.78 to 0.96)	0.16	-0.43 to 0.76
FEV_1 - S x DD	0.75 (0.48 to 0.89)	0.25	-0.46 to 0.98	0.87 (0.71 to 0.94)	0.19	-0,16 to 0.55
FEV_1 - S x RLD	0.80 (0.57 to 0.91)	0.13	-0.5 to 0.79	0.84 (0.65 to 0.93)	0.19	-0.26 to 0.65
FEV_1 - S x LLD	0.87 (0.70 to 0.94)	0.17	-0.34 to 0.69	0.95 (0.88 to 0.98)	0.19	-0.03 to 0.42
FEV_1/FVC - S x DD	0.94 (0.87 to 0.97)	0.03	-0.01 to 0.08	0.83 (0.63 to 0.93)	0.03	-0.01 to 0.07
FEV_1/FVC - S x RLD	0.95 (0.90 to 0.98)	0.02	-0.01 to 0.07	0.66 (0.33 to 0.85)	0.02	-0.04 to 0.09
FEV_1/FVC - S x LLD	0.92 (0.82 to 0.96)	0.02	-0.03 to 0.08	0.71 (0.40 to 0.87)	0.02	-0.04 to 0.08

Note: FVC = forced vital capacity; FEV1 = forced expiratory volume in 1 second; FEV_1/FVC = Tiffeneau index; S = sitting position; DD = dorsal decubitus; RLD = right lateral decubitus; LLD = left lateral decubitus.

Discussion

The data evaluated in this study show that the mean FVC values, in males, in the DD, RLD, and LLD positions were significantly lower when compared to the S position. Males present a more abdominal pulmonary ventilation pattern with predominant pulmonary expansion in the lower thorax regions;[16] this may explain the reduction of the parameter found in the present study because the abdominal volume in the decubitus could cause respiratory musculature work restriction. There is also a significant positive correlation comparing the S position with the decubitus position, showing that the variables are inter-dependent. The FEV_1 and Tiffeneau index values show no significant differences in this study, in either sex, when compared in the same positions. Body positioning, thus affecting volume, flow, and pulmonary pressure, can change the respiratory biomechanics of the musculature. Changes in the values of the spirometric data may occur when there is a change from orthostatic or seated positions to reclined or decubitus positions.[17-19] Regarding our results in the FG, we have to consider that there is sexual dimorphism in the human respiratory system between males and females about morphology, geometry in lungs, especially, in sex-related differences in the respiratory patterns.[20,21] Therefore, in healthy adults, ventilation, inspiratory peak, and expiratory flows are also lower in women than in men.[21,22]

Body position changes could directly interfere with lung mechanics, inducing restrictive ventilatory conditions and inhibiting phrenic nerve reflexes, consequently leading to diaphragmatic dysfunction. Ventilatory volume increases have been demonstrated, in previous studies, when diaphragm excursion is greater, thus showing a positive correlation between inspired volumes and diaphragm excursion.[23]

In a pioneering study, Townsend and collaborators found a reduction in the values of forced maneuvers in the S position when compared with the orthostatic position, likely due to slightly higher inspirations in this last position.[17] The effect of the dorsal decubitus on different variables of pulmonary function in healthy adults is already well established in the literature; there may be decreased FVC and FEV1 values in addition to increased airway resistance and decreased maximal expiratory pressure.[18,19,24,25] In the orthostatic position, the increase in lung volume appears to be correlated with an increase in the thoracic cavity. In this position, the abdominal volume suffers the action of gravity, triggering the diaphragm caudally, thus increasing the vertical diameter of the thorax; also, the heart does not compress the basal portions of the lungs. Finally, in the orthostatic position, the respiratory musculature is unrestricted in all directions, facilitating diaphragm contraction and triggering thoracic cavity caudally,[18] as observed in the present study. In the S position, there may be a limitation on thoracic expansion by the back of the chair; thus, the capacity of the thoracic cavity, limited in the S position, appears to result in lower lung volumes.[11]

It is known that with aging, the parameters of pulmonary function undergo a physiological reduction due to the decrease in tensile function in the lung parenchyma, mass reduction, diminished intercostal musculature strength, and reduced rib cage and lung parenchyma compliance.[26] In the present study, the average age of the volunteers was homogeneous, precluding potential age-related bias. Recently, Kim et al.[27] showed a 38% reduction in airway pressure, a 41% increase in pulmonary complications and a 35-50% alteration in airway mechanics in 50-year-olds. Computational simulations were used for the coupled analysis of solid fluid for geometric models of bronchioles and alveolar sacs in mechanically ventilated patients to estimate airflow and pulmonary function characteristics. These findings may correspond to a reduction in the elasticity and in the lung tissue and rib cage compliance that occurs at advanced ages. [27]

In obese patients, there is a reduction in lung volumes and thoracic-pulmonary compliance in addition to increased airway resistance due to the consequent increase in the impedance of these pathways because the increase in thoracic and abdominal fat causes a reduction in respiratory system compliance.[28] In patients with a BMI below normal values, there may be reductions in pulmonary flows and pressures due to the reduced strength and amount of active muscle fibers responsible for the ventilation process.[29] In our study, the values of the anthropometric variables, such as height and weight, were homogeneous, reflected in the BMI calculations.

Furthermore, the upper limb positioning with the shoulder at 90° of adduction and external rotation associated with 90° flexion of the elbows, for example, revealed an improvement in tidal volume and minute volume in young, healthy individuals.[30] Badr et al.[18]

showed a significant reduction in the mean PEF values when the S and decubitus positions were compared to the orthostatic position. The justification presented by the authors is that the dependent hemithorax may have had its expansibility reduced. Naitoh et al.[31] also showed a significant reduction in the mean CV and FEV_1 values in six different positions, not including the prone and retroversion positions at 45°, when compared to the S position in healthy adult patients. Other comparisons related to position should be considered regarding the prone position that causes abdominal restriction and elevated PEF values, a situation comparable to patients with difficulties in the elimination maneuvers of pulmonary secretions.[19]

Since there is a significant difference in the pulmonary function parameters in decubitus positions in this study, there is an incentive for spirometry to become widely used in clinical practice. Using high lung volumes and sustained maximal inspirations, it can be possible to increase tidal volume, time, and inspiratory flow, effectively influencing pulmonary expansion, especially postoperatively and in patients with compromised mobility.[32]

This study presents some limitations that must be taken into account when interpreting the results. The first limitation concerns the small number of participants. Students enrolled at the UFOP were invited, however, our study depended on the availability of students to participate, for this reason sampling was used for convenience. This type of sampling presents some biases and may underestimate or overestimate the characteristics of the population, which reinforces the need for studies with a larger number of participants. The second limitation is the characteristic of the study. Since this is a descriptive cross-sectional study, only one collection of pulmonary function data was made; in order to better understand the influence of body positioning on the studied population, it would be necessary to carry out other measures over a longer period of time. The third limitation refers to the characteristic of the population evaluated; in this study we used a healthy population that did not present previous pneumopathies or comorbidities. In order to understand how body positioning can influence the results of the pulmonary function test, other studies conducted in a hospital environment and in patients requiring outpatient evaluation and follow-up are necessary.

Conclusion

This study demonstrates that body positioning alters pulmonary function test parameters in healthy adult men, but not in healthy adult women. These findings contribute to a better understanding of pulmonary physiology in different positions and can lead to the development of informed spirometry guidelines for patients with different conditions.

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Authors' contribution

KGS, OMPAB and FSB conceived and designed the research. KGS was responsible for the data collection, and KGS, NAM, TFC and FSB for analyzing it. KGS, NAM, TFC and FSB interpreted the results of the experiments; TFC and ABFS prepared the tables. KGS, NAM and ABFS drafted the manuscript, while NAM, ABFS, OMPAB and FSB edited and revised it.

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