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Original Article

Breathing pattern and thoracoabdominal motion in healthy individuals: influence of age and sex

Padrão respiratório e movimento toracoabdominal em indivíduos saudáveis: influência da idade e do sexo

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Abstract

Objective: To describe the breathing pattern and thoracoabdominal motion of healthy individuals, taking age and sex into consideration. **Methods:** The study included 104 individuals aged 20 to 39, 40 to 59, and 60 to 80 years (41 males and 63 females), with normal body mass index and spirometric values. Participants were evaluated at rest in the supine position, by means of respiratory inductive plethysmography. The following variables were measured: tidal volume (Vt), respiratory frequency (*f*), minute ventilation (VE), inspiratory duty cycle (Ti/Ttot), mean inspiratory flow (Vt/Ti), rib cage motion (%RC), inspiratory phase relation (PhRIB), expiratory phase relation (PhREB), and phase angle (PhaseAng). Comparisons between the age groups were performed using one-way ANOVA or Kruskal-Wallis H, while comparisons between the sexes were performed using Student's t test or the Mann-Whitney U test, depending on the data distribution; $p<0.05$ was taken to be significant. **Results:** Comparison between the sexes showed that, in the age groups 20 to 39 and 60 to 80 years, women presented significantly lower values for Vt, VE, and Ti/Ttot than men, and there was no significant difference in the age group 40 to 59 years. Comparisons between the age groups showed that participants aged 60 to 80 presented significantly greater PhRIB and PhaseAng than participants aged 20 to 39 years, without significant differences in the breathing pattern. **Conclusion:** The data suggest that breathing pattern is influenced by sex whereas thoracoabdominal motion is influenced by age.

Key words: respiratory physical therapy; assessment; breathing pattern; thoracoabdominal motion; healthy individuals.

Resumo

Objetivo: Descrever o padrão respiratório e o movimento toracoabdominal de indivíduos saudáveis considerando a idade e o sexo. **Métodos:** Foram estudados 104 indivíduos com idades entre 20-39, 40-59 e 60-80 anos, 41 homens e 63 mulheres, com índice de massa corporal e valores espirométricos normais. A pletismografia respiratória por indutância foi utilizada para mensurar, durante o repouso e em decúbito dorsal, as seguintes variáveis: volume corrente (Vc), frequência respiratória (*f*), ventilação minuto (VE), razão entre o tempo inspiratório e o tempo total do ciclo respiratório (Ti/Ttot) e fluxo inspiratório médio (Vc/Ti), deslocamento da caixa torácica (%CT), relação de fase inspiratória (PhRIB), relação de fase expiratória (PhREB) e ângulo de fase (AngFase). As comparações entre as faixas etárias foram realizadas por meio da ANOVA *one-way* ou *Kruskal-Wallis H,* comparações entre os sexos foram realizadas por meio dos testes *t* de *Student* para amostras independentes ou *Mann-Withney U,* de acordo com a distribuição dos dados, considerando significativo $p<0,05$. **Resultados:** Na comparação entre os sexos, mulheres apresentaram valores significativamente menores em relação aos homens nas variáveis Vc, VE e Ti/Ttot nas faixas etárias de 20 a 39 e de 60 a 80 anos, sem nenhuma diferença na faixa etária de 40 a 59 anos. Na comparação entre as faixas etárias, indivíduos com 60 a 80 anos apresentaram PhRIB e AngFase significativamente maiores em relação aos adultos entre 20 e 39 anos, sem diferenças significativas nas variáveis do padrão respiratório. **Conclusão:** Os dados encontrados sugerem influência do sexo sobre o padrão respiratório e da idade sobre o movimento toracoabdominal.

Palavras-chave: fisioterapia respiratória; avaliação; padrão respiratório; movimento toracoabdominal; indivíduos saudáveis.

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Introduction

The respiratory system consists primarily of the lungs, whose main function is to ensure gas exchanges with the environment, and the thoracic wall, which moves as a result of continual muscle action[1]. The thoracic wall represents the thoracoabdominal area composed of the rib cage and the abdomen, separated by the diaphragm[2,3]. Thus, normal thoracoabdominal motion consists of expansion and retraction of these compartments during inspiration and expiration, respectively[4,5]. Although the rib cage and abdomen move in unison, each of the compartments has independence of movement[6]. When the displacement between the compartments ceases to be harmonious, the thoracoabdominal motion becomes asynchronous[4,5,7]. Healthy men and women in different age groups present symmetry between the movements on the right and left sides of the chest and abdomen[8].

Breathing pattern and thoracoabdominal motion may be influenced by several factors, such as the individual's positioning[9,10], age[10,11], sex[10], respiratory overload[12], neuromuscular diseases[13], lung diseases associated with increased airway resistance[4,14,15], and chronic obstructive pulmonary disease (COPD)[5,16-18]. Higher rates of asynchrony may be related to worse prognosis and significantly greater mortality[16].

Among the factors that may influence the respiratory system in healthy individuals, age and sex can be highlighted. In the elderly, the structural changes to the respiratory system encompass modifications that occur in the lungs, rib cage, respiratory muscles, and respiratory drive. The main change relating to the rib cage is its reduction in compliance. Among healthy individuals, these changes are more evident after the age of 80, although they are present from the age of 50 onwards[11]. Studies using plethysmography have demonstrated that the mean values of the components of the breathing pattern of healthy elderly individuals do not differ significantly from what is found among non-elderly adults[7,10,11]. This suggests that, in the populations studied, the process of aging of the respiratory system did not cause a great impact on the parameters analyzed.

In relation to sex, a study that made comparisons between men and women showed that there were differences in respiratory times[3]. The inspiratory time, expiratory time, and total time of the respiratory cycle were shorter among the women. In addition, the women presented higher respiratory frequency, thus suggesting that they tended to breathe more rapidly than the men[3]. In the analysis of thoracoabdominal motion during quiet breathing, men and women presented the same response[3,10].

Data on breathing pattern and thoracoabdominal asynchrony are important sources of information on respiratory function[10,11,14,19] and represent an important tool in physical therapy evaluations of patients with acute and chronic respiratory dysfunctions. Its importance starts in primary healthcare as the patient enters the public healthcare system and goes up to high-complexity environments such as intensive care units. Data relating to breathing pattern, e.g. tidal volume and respiratory frequency, are useful for follow-ups within different types of respiratory physical therapy interventions. Examples would include pulmonary rehabilitation and patient care before and after chest and abdominal surgery, among other clinical situations, thus making it possible to observe whether different parameters have evolved favorably or not. One instrument frequently used in studies evaluating breathing pattern and thoracoabdominal motion is the inductive plethysmography, which measures displacement of thoracoabdominal compartments and changes in time and pulmonary volume[3,7,10].

To the best of our knowledge, studies on breathing pattern and thoracoabdominal motion among healthy adults have either evaluated few individuals[3], very different numbers of individuals in different age groups[7], or a limited number of variables[10]. Given the importance of evaluating breathing pattern and thoracoabdominal motion for clinical practice, it would be of interest to obtain data on different variables from a significant number of Brazilian individuals. Within this context, the aim of this study was to describe the breathing pattern and thoracoabdominal motion of healthy Brazilian individuals according to sex and age.

Methods

Sample

For this study, 109 participants were recruited. Data were gathered at the Laboratório de Avaliação e Pesquisa em Desempenho Cardiorrespiratório. The inclusion criteria were: age between 20 and 80 years; body mass index (BMI) without indication of excess weight (18.5 and 29.9 kg/m^2)[20]; non-smoker; absence of ventilatory disorders of any kind in pulmonary function tests, in accordance with the values predicted by Pereira[21]; absence of evident chest or abdominal deformity; absence of cardiac or neuromuscular diseases; and absence of previous chest or abdominal surgery. The exclusion criterion was inability to understand and/or undergo any of the procedures. The study was approved by the Research Ethics Committee of Universidade Federal de Minas Gerais (UFMG), Belo Horizonte (MG), Brazil (Approval ETIC 148/07), and all participants signed an informed consent form.

Procedures and measurement instruments

After the participants had read and signed the consent form, their weight and height were measured using a calibrated scale (Filizola Ind. Ltda, São Paulo, SP, Brazil) to calculate the BMI, and the pulmonary function test was performed by means of a forced maneuver, using spirometry (Vitalograph 2120, Buckingham, England). To evaluate the breathing pattern and thoracoabdominal motion, respiratory inductive plethysmography was used (Respitrace®, Nims, Miami, FL, USA). This is a noninvasive method that requires little exertion by the participant; it has been shown to be accurate[22-24] and has been used in previous studies[3,5,7,10-12,14-17,25-32]. Respiratory inductive plethysmography measurements are based on changes to the cross-sectional area detected by two inductance bands. Each band is composed of two thin, adhered elastic bands around a plastic-coated transducer wire that is arranged in a sinusoidal pattern. One of the strips was positioned on the axilla and the other, on the umbilical line. The bands were given a slight stretch to fit tightly around the participant and minimize signal distortion, but without limiting chest movement or causing discomfort.

The participant was positioned in supine and asked to remain comfortably in this position while breathing quietly without raising the head (0º), speaking, sleeping, or moving any of the body segments until the data recording had finished. The signal was calibrated during spontaneous breathing, by means of a specific procedure (Qualitative Diagnostic Calibration) that was first described by Sackner et al.[34]. This procedure was carried out in two stages. Firstly, the participant breathed spontaneously to balance the electrical gain of the signals relating to the rib cage and abdomen. When correctly amplified and divided, these signals allow relative calibration, which lasts about five minutes. Next, after using a syringe of known volume, the participant breathed through a spirometer (Vitatrace, Pro Médico, Rio de Janeiro, RJ, Brazil) for 30 to 60 seconds using a nose clip. During this stage, the electrical signals from the rib cage and abdomen were used to obtain the tidal volume in ml.

The calibration was performed by means of a software program (RespiPanel, NIMS, Miami, FL, USA). A detailed description of the calibration has been published previously[28,35]. After the calibration, the plethysmographic data were recorded for around 10 minutes by means of specific software (RespiEvents 5.2, NIMS, Miami, FL, USA). To analyze the data, intervals of at least 30 seconds of stable tracing were selected. In addition, the sum of these intervals had to reach a minimum of five minutes of recording.

Variables analyzed

For the breathing pattern, the following volume and time variables were analyzed[11]: tidal volume (Vt); respiratory frequency (*f*); minute ventilation (VE); inspiratory duty cycle (Ti/Ttot); and mean inspiratory flow (Vt/Ti). In relation to thoracoabdominal motion, the following were analyzed: rib cage motion (%RC); phase angle (PhaseAng), which reflected the delay between rib cage and abdomen excursions[4,5,12,14,15,27,29,30]; inspiratory phase relation (PhRIB) and expiratory phase relation (PhREB), which reflected the percentage of time during one breath in which the rib cage and abdomen moved in opposite directions, respectively[29,30].

Statistical analysis

The data were presented as central tendency and dispersion. To analyze the data, the individuals were divided into three groups according to age: 20 to 39 years, 40 to 59 years, and 60 to 80 years. For the comparisons between the sexes, the age groups were divided into women and men.

The normality of the data was checked by means of the Shapiro-Wilk test. The comparisons between the sexes were made using Student's t test for independent samples or the Mann-Whitney U test, depending on the data distribution. The comparisons between the age groups were made using one-way ANOVA or Kruskal-Wallis H, according to the data distribution. The significance level was set at $p<0.05$. The analyses were performed using the Statistical Package for the Social Sciences, version 13.0.

Results

Of the 109 participants, five were excluded due to technical problems during the data collection. Thus, the data relate to 104 participants (48 between 20 and 39 years of age; 18 between 40 and 59, and 38 between 60 and 80 years). In all, 8667 respiratory cycles were analyzed, with a mean of 84 cycles per participant. Table 1 describes the anthropometric, demographic, and spirometric characteristics of the sample.

Table 2 presents the values of the breathing pattern and thoracoabdominal motion variables among the men and women in the three age groups. Comparisons between the sexes were made in each age group, and these showed that Vt, VE, and Ti/Ttot were significantly lower among the women in the age group 20 to 39, but without any significant differences in the other variables. There were no significant differences in the age group 40 to 59. Among the women in the elderly group, Vt, VE, and Vt/Ti were significantly lower, but without significant differences in the other variables.

Table 3 presents comparisons of breathing pattern and thoracoabdominal motion between the age groups. No significant differences were observed in any of the variables relating to the breathing pattern. In relation to thoracoabdominal motion, PhRIB and PhaseAng were significantly greater in individuals over the age of 60 than in adults between 20 and 39 years.

In addition, comparisons between the age groups were made for the men and women separately. No significant differences between the age groups were found among the women. Among the men, there was only a significant difference in the variable Ti/Ttot. Men aged 20 to 39 presented significantly lower values than did the men over 60 years.

Table 1. Anthropometric, spirometric, and demographic data of the sample.

	Participants n=104
Age (years)	46.24±19.57
Weight (kg)	67.12±14.45
Height (m)	1.65±0.09
BMI (kg/m^2)	24.66±5.36
FEV_1 (% predicted)	96.38±10.45
FVC (% predicted)	97.02±10.34
FEV_1/FVC	99.67±7.32
$FEF_{25-75\%}$ (% predicted)	90.7±25.96

Data are presented as mean ± standard deviation. BMI: body mass index; FVC: forced vital capacity; FEV_1: forced expiratory volume in the first second; FEV_1/FVC: ratio of FEV_1 to FVC; and $FEF_{25-75\%}$: forced expiratory flow at 25 and 75% of FVC.

Discussion

The main result from this study was that there were significant differences in some of the breathing pattern variables between the sexes and in the thoracoabdominal motion variables between the participants in the three age groups evaluated. Comparison between the sexes showed that women presented significantly lower values than men for the variables Vt, VE, and Ti/Tot in the age group between 20 and 39 years and for the variables Vt, VE, and Vt/Ti in the elderly group, but without significant differences in the variables related to thoracoabdominal motion. Comparison between the age groups showed that the participants over the age of 60 presented significantly greater PhRIB and PhaseAng, in relation to the participants aged 20 to 39, but without significant differences in the breathing pattern variables.

To the best of our knowledge, previous studies that evaluated breathing pattern and thoracoabdominal motion variables

Table 2. Respiratory pattern and thoracoabdominal motion data in age and sex subgroups.

	20 to 39 years		40 to 59 years		60 to 80 years	
	Women	Men	Women	Men	Women	Men
Vt (ml)	325±127	441±114 *	309±111	325±115	283±83	383±124 *
f (breaths/min)	15±2	13±4	14±2	16±3	15±2	15±3
VE (l/min)	4.69±1.34	5.61±1.13 *	4.43±1.51	4.65±2.08	4.26±1.29	5.98±1.76 *
Ti/Ttot	0.39±0.03	0.42±0.04 *	0.39±0.03	0.41±0.02	0.38±0.04	0.39±0.04
Vt/Ti(ml/s)	199±56	221±46	193±80	192±90	187±49	259±68 *
%RC	46±15	39±10	40±9	32±7	45±18	37±14
PhRIB (%)	7±3	8±3	7±3	11±6	10±4	12±6
PhREB (%)	15±6	12±6	13±6	16±6	16±9	18±8
PhaseAng (°)	11±5	10±6	12±4	17±9	13±7	17±9

Data are presented as mean ± standard deviation. Vt: tidal volume; *f*: respiratory frequency; VE: minute ventilation; Ti/Tot: inspiratory duty cycle; Vt/Ti: mean inspiratory flow; %RC: rib cage motion; PhRIB: inspiratory phase relation; PhREB: expiratory phase relation; PhaseAng: phase angle. * significant difference (p<0.05) for comparisons between women and men in each age subgroup.

Table 3. Comparison of respiratory pattern and thoracoabdominal motion variables between the three age subgroups.

	20 to 39 years	40 to 59 years	60 to 80 years	p
Vt (ml)	352±133	302±117	338±118	0.323
f (breaths/min)	15±3	15±3	16±3	0.532
VE (l/min)	4.9±1.3	4.6±1.7	5.2±1.8	0.370
Ti/Ttot	0.40±0.04	0.40±0.03	0.38±0.04	0.079
Vt/Ti(ml/s)	204±55	193±82	227±70	0.085
%RC	44±14	36±11	40±16	0.058
PhRIB (%)	8±3	9±5	11±5*	0.002
PhREB (%)	15±7	15±6	17±8	0.093
PhaseAng (°)	11±6	14±7	15±8*	0.032

Data are presented as mean ± standard-deviation. Vt: tidal volume; *f*: respiratory frequency; VE: minute ventilation; Ti/Tot: inspiratory duty cycle; Vt/Ti: mean inspiratory flow; %RC: rib cage motion; PhRIB: inspiratory phase relation; PhREB: expiratory phase relation; PhaseAng: phase angle. * significant difference (p<0.05) for comparisons between adult (20 to 39 years) and elderly (60 to 80 years) participants.

among healthy adults were conducted among populations in other countries and/or using limited numbers of variables or individuals[3,7,10]. The present study adds important information, considering that the values observed among individuals in different age groups can be used both in the evaluation process and physical therapy treatment of patients with acute or chronic respiratory dysfunctions. The participants were recruited as a convenience sample from residents of the city of Belo Horizonte, Minas Gerais, Brazil, which may be considered to be a limitation of this study. Nonetheless, the number of participants analyzed is similar to the numbers in other studies related to respiratory function parameters that have put forward reference values[36,37].

Regarding the measurement instrument used, it should be emphasized that respiratory inductive plethysmography is an appropriate method for evaluating breathing pattern and thoracoabdominal motion, as proposed in the present study. It is also worth noting that there is a new method for obtaining information that gives greater detail about the operational volumes of the thoracic wall. The main innovation of this method is that it provides greater accuracy of analysis during exercise, given that it can produce a three-dimensional analysis that takes into consideration three compartments of the thoracic wall (pulmonary rib cage, abdominal rib cage, and abdomen), thus differing from the respiratory inductive plethysmography that analyzes two compartments. This point is particularly important in the presence of dynamic hyperinflation[38,39]. It is unlikely that there was any hyperinflation among the participants in the present study, given that the evaluation was performed on healthy individuals at rest.

Regarding comparisons between the sexes, significant differences in the breathing pattern variables were observed. In relation to the men, the women in the age group 20 to 39 presented significantly lower Vt, VE, and Ti/Ttot. To the best of our knowledge, only one other study made a comparison of breathing patterns between men and women, in which individuals aged between 20 and 45 years were evaluated[3]. Our data corroborate what was observed previously in relation to Vt, which was significantly lower among females. This result can be attributed to the difference in physical constitution between men and women. However, this difference was insufficient to significantly influence VE, which did not present any difference between women and men in these two studies. Regarding the time components of the breathing pattern, Feltrim[3] found a lower inspiratory time in the female group. This result may help to explain the significantly lower Ti/Ttot among the women in the present study. In the elderly group, the significant differences observed in Vt and VE were similar to those observed among adults aged 20 to 39, and the difference in Vt/Ti seemed to result from the change in Vt, given that no change in Ti/Ttot was observed. In relation to participants aged 40 to 59, no significant difference was observed.

In relation to the comparison between the sexes, the only difference was in the Ti/Ttot among the men over 60 years, compared with those aged 20 to 39. Despite the difference observed, the values were within the normal range[7]. Verschakelen and Demedts[10] evaluated the influence of sex on individuals in this age group, but only in relation to the variables of thoracoabdominal motion.

Comparison of the variables relating to thoracoabdominal motion between the sexes in the present study did not show any significant difference between men and women. This result corroborates the findings in the literature. The influence of sex on thoracoabdominal motion was previously evaluated in two studies[3,10], none of which found any significant difference in the percentage displacement of the chest and abdominal compartments between men and women in the supine position at rest. Thus, it seems to be well established that displacement of the abdominal compartment is proportionally greater in both men and women in the supine position.

Regarding thoracoabdominal asynchrony, no significant differences were found between men and women. To the best of our knowledge, the influence of sex on thoracoabdominal asynchrony has not been evaluated in any studies. The values observed in the present study are close to those described in the literature for healthy individuals at rest[26].

Comparison between the three age groups did not show any significant differences in the breathing pattern variables. These results are in agreement with other studies that compared breathing pattern variables between healthy adults and elderly individuals. No significant differences were observed in the parameters analyzed at rest in these studies[7,11]. Recently, Britto et al.[40] evaluated two groups of elderly people, one aged 60 to 69 and one over 69 years, also without significant differences in the respiratory pattern.

In relation to thoracoabdominal motion in the present study, the elderly participants presented significantly greater PhRIB and PhaseAng than the participants aged 20 to 39. The presence of greater thoracoabdominal asynchrony observed among the elderly participants may have been due to structural modifications to the rib cage, weakness of the respiratory muscles, and changes to the respiratory drive[41], given that these factors may increase respiratory overload[25]. The influence of age on thoracoabdominal asynchrony was previously evaluated among 18 elderly individuals[7]. This study evaluated the ratio of maximum compartmental amplitude to Vt, which is a parameter measuring thoracoabdominal asynchrony, and did not observe any significant difference. It is possible that the limited number of individuals may have influenced the results.

In conclusion, the present study made it possible to describe values for variables relating to breathing pattern and thoracoabdominal motion in men and women of different age groups. The data found in this study suggest that the breathing pattern is influenced by sex whereas the thoracoabdominal motion is influenced by age.

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