ORIGINAL ARTICLE

Ventilatory and muscular assessment in healthy subjects during an activity of daily living with unsupported arm elevation

Avaliação ventilatória e muscular de indivíduos saudáveis durante atividade de vida diária com os braços elevados e sem apoio

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Abstract

Introduction: Patients with chronic obstructive pulmonary disease (COPD) report dyspnea when performing activities of daily living (ADLs) with elevated upper limbs. To elucidate the determinants of dyspnea, it is important to study the changes in the respiratory pattern of these patients and the electromyographic activity of their accessory muscles of respiration during ADLs. In the literature, there are no reports of a normative parameter, therefore it is necessary to study how these variables behave in healthy subjects. **Objectives:** To verify, in healthy subjects, the existence of changes in the respiratory pattern and activation of the sternocleidomastoid (SCM) muscle during an ADL with unsupported arm elevation. **Methods:** Thirteen male subjects, 60.57 (±6.42) years old, with normal spirometry values for age and sex, were evaluated using surface electromyography (EMG) and respiratory inductive plethysmography (RIP) collected at rest and during the activity of combing their hair with elevated and unsupported upper limbs. The data distribution was assessed using Shapiro-Wilk's test. ANOVA was used to compare the phases, and when the difference was significant (p<0.05), Tukey's test was applied. **Results:** The RIP during the ADL showed a significant increase in tidal volume, minute ventilation, respiratory frequency and mean inspiratory flow. Thoracoabdominal asynchrony was identified in percentage of asynchrony in inspiration, expiration, and Phase Angle (p<0.05). The EMG showed an increase in SMC muscle recruitment (p<0.05). **Conclusions:** Healthy subjects increased their SCM muscle activation and changed their breathing pattern when performing the ADL with unsupported arm elevation, resulting in thoracoabdominal asynchrony.

Key Words: Physical therapy; upper limbs; activities of daily living.

Resumo

Introdução: Pacientes com doença pulmonar obstrutiva crônica (DPOC) relatam dispneia quando realizam atividades da vida diária (AVD) com membros superiores (MMSS) elevados. Estudar as alterações do padrão respiratório e a atividade eletromiográfica dos músculos acessórios da respiração desses pacientes nas AVD pode contribuir para esclarecer os determinantes de dispneia. Entretanto, não se encontrou, na literatura, um padrão de normalidade, fazendo-se necessário estudar, primeiramente, o comportamento dessas variáveis em saudáveis. **Objetivos:** Verificar, em indivíduos saudáveis, a existência de mudanças no padrão respiratório e na ativação do músculo esternocleidomastoideo (ECM) durante a realização de uma AVD com os MMSS elevados e sem apoio. **Métodos:** Treze voluntários masculinos, com média de idade 60,57 (6,42) anos, com valores espirométricos normais para idade e sexo foram avaliados com eletromiografia (EMG) de superfície e pletismografia respiratória por indutância (PRI), coletadas durante o repouso e na atividade de pentear cabelos com MMSS elevados sem apoio. A distribuição dos dados foi analisada pelo teste Shapiro-Wilk. Para a comparação entre as fases avaliadas, utilizou-se ANOVA e, quando a diferença foi considerada significativa (p<0,05), aplicou-se o teste de Tuckey. **Resultados:** A PRI, durante a AVD, mostrou aumentos significativos do volume corrente, do volume minuto, da frequência respiratória e do fluxo inspiratório médio. Observou-se assincronia toracoabdominal tanto em porcentagem de assincronia na inspiração e na expiração quanto na análise do Ângulo de Fase (p<0,05). A EMG mostrou aumento no recrutamento do ECM (p<0,05). **Conclusões:** Indivíduos saudáveis apresentam maior ativação do músculo ECM e modificam o padrão respiratório durante AVD com MMSS elevados sem apoio, gerando assincronia toracoabdominal.

Palavras-chaves: Fisioterapia; membro superior; atividades cotidianas.

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Introduction ::::

In healthy subjects[1] and in patients with chronic obstructive pulmonary disease (COPD), arm elevation results in changes in the pattern of respiratory muscle recruitment and in an increase in metabolic demand, the latter being more marked in subjects with airflow obstruction[2-9]. This could be explained by an efficiency reduction in the respiratory mechanics, by a dual activity of shoulder girdle muscles in COPD and by an increase in dead space[2].

Patients with COPD report fatigue and dyspnea when performing activities of daily living (ADLs) with unsupported arm elevation[9], such as combing their hair[4] and brushing their teeth. In contrast, they find it less difficult to perform more demanding activities involving their legs[1,10]. It is likely that these patients' ability to sustain unsupported arm elevation is not determined by the endurance and strength of the shoulder girdle muscles alone. A number of studies suggest that this limitation in respiratory mechanics is influenced by arm positioning, with changes being observed in the respiratory breathing pattern and thoracoabdominal asynchrony during unsupported arm elevation[8,10,11].

According to Epstein et al.[6], when COPD patients sustain arm elevation, two factors become determinants of the altered respiratory pattern: lung hyperinflation and, to a small degree, diaphragm reserve strength. During inspiration due to dynamic hyperinflation, the respiratory muscles are placed in an unfavorable position of their length-tension curve, reducing the strength generation capacity[12]. Therefore, unsupported arm elevation may force the shoulder girdle muscles and the upper torso to participate simultaneously in the ventilatory and non-ventilatory activities[1,4,6]. Simultaneous afferent inputs and outputs of the central nervous system (CNS), responsible for the respiratory and tonic functions of these muscles, can result in a significant lack of coordination of respiratory muscle action and can result in an increase in dyspnea, with thoracoabdominal asynchrony being observed during unsupported arm exercise[6].

Based on the literature on the possible reasons for dyspnea and changes in the respiratory pattern and respiratory muscle recruitment in COPD patients during ADL with unsupported arm elevation, it is necessary to establish parameters for healthy subjects for further comparison studies involving COPD patients. The findings of these studies will contribute to the development of future interventions and/or improvements in the existing ones, providing more functional independence and, consequently, better quality of life for these individuals. Also, the findings of the present study will be used in another study, currently underway by our group, comparing the results of healthy subjects with COPD patients using the same protocol during an ADL with unsupported upper limbs. Therefore, the current data will also be part of a more comprehensive research. The aim of the present study was to assess, in healthy subjects, the breathing pattern, thoracoabdominal motion and electromyographic activity of the sternocleidomastoid (SCM) muscle at rest and during an ADL with unsupported arm elevation.

Methods ::::

The Ethics Research Committee of Universidade Federal de Minas Gerais, Belo Horizonte (MG), Brazil, approved the protocol (ETIC 551/06), and all subjects gave their informed consent. The sample calculation was accomplished after a pilot study with the first ten subjects, using all respiratory pattern variables, thoracoabdominal motion and electromyography (EMG) to a power of 80% and a significance level of 0.05 (non-directional). The calculation resulted in a value of 13.8 healthy subjects. The sample consisted of 13 healthy subjects selected from the community. The inclusion criteria were: male subjects, age between 50 and 80 years, absence of bone and joint impairment in the shoulder girdle and normal lung function tests according to Brazilian standards of normality[13]. The exclusion criteria were: inability to maintain overhead arm elevation for the five minutes of data collection and inability to perform any of the steps determined in the protocol. A signed informed consent form was obtained from all subjects.

The subjects underwent a functional analysis of lung volume and capacity. A portable spirometer (Vitalograph 2120®, Vitalograph, Buckingham, England) was used to ensure normal lung function according to the recommendations of the Brazilian Society of Pneumology[13]. The values of the spirometric variables were compared to predicted values according to Pereira et al.[14]. The breathing pattern was accessed by respiratory inductive plethysmography (RIP) based on the principle first described by Konno and Mead[15], and the electromyographic activity of the SCM muscle was accessed by surface EMG.

Respiratory variables were obtained by RIP (Respitrace®, Nims, Miami, FL, USA). Teflon-coated inductance coils of appropriate size were placed around the rib cage (RC) and abdomen (AB); the upper edge of the RC band was placed at the level of the axilla and the AB band at the level of the umbilicus. The signals were calibrated using qualitative diagnostic calibration (QDC)[16] during five minutes of natural breathing; this is a two-step procedure whereby the RC and AB electrical gains of the RIP amplifiers are correctly partitioned during tidal breathing and subsequently compared to the output of a spirometer to attain equivalence. The subject then breathed into a spirometer via a mouthpiece (Vitatrace, Pro Médico, Rio de Janeiro, RJ, Brazil) with the nose clipped, for 30 to 60 s, and the electrical

spirometer output was recorded with a computer and used to calibrate the RIP sum signal for absolute volume in mL[17]. The spirometer was calibrated with a one-liter syringe (Vitalograph, Ennis, Ireland). The entire procedure was performed using a computer software (RespiPanel 4.0, Nims Miami, FL, USA)[18,19] that allows a tidal volume (V_T) variation ≤5% during calibration process.

The following variables were measured by a digital acquisition system on a breath-by-breath basis (RespiEvents®, Nims, Miami, FL, USA): tidal volume (V_T), respiratory frequency (f), minute ventilation (V_E), inspiratory time (Ti), inspiratory duty cycle (Ti/Ttot), mean inspiratory flow (V_T/Ti), RC motion contribution to V_T (RC/V_T), phase angle (PhAng; 0° for complete RC-AB synchrony and 180° for complete asynchrony)[20], inspiratory RC-AB synchrony (PhRIB), expiratory RC-AB synchrony (PhREB), inspiratory and expiratory synchrony (PhRTB), variables that represent the time percentage during a respiratory cycle in which the RC and AB move in opposite directions. When the RC and AB are moving in perfect synchrony, the values are equivalent to 0%, and when there is paradoxical movement, they are equivalent to 100%[20]. The contribution of abdominal motion to V_T (AB/V_T) was calculated as AB/V_T = 100 - RC/V_T.

The surface EMG device (EMG System do Brasil LTDA, São Paulo, SP, Brazil) was used to record the electromyographic activity of the SCM muscle. After the skin was cleansed, ECG bipolar surface electrodes (Mini Medi Trace 100, Kendall – LTP/Tyco, Canada) were placed on the lower third of the left sternal portion of the SCM muscle belly. The electrodes were positioned 2.5 cm apart over this area[21,22]. The EMG signals were recorded using one of the eight channels of the biological signal acquisition system consisting of a signal conditioner with a gain of 1000, a high-pass filter of 20 Hz, and a low-pass filter of 500 Hz, a specific software for data acquisition and analysis (Aqdados, São José dos Campos, SP, Brazil) and a 12-bit analog-to-digital converter, with a sample frequency of 2000 Hz for the channel and an entry band of 5 mV. The mean amplitude of the signal was estimated by its root mean square (RMS) value. In the present study, the data were normalized by rest, given that the objective was to compare the analyzed variables at rest and at different moments of an ADL with unsupported arm elevation. The subject was his own control group.

There was a simultaneous collection for the surface EMG and for the RIP data, there were two different collections. In the first collection, the data were collected with the subject in a seated position and arms resting along the body during five minutes. For the statistical analyses, the last regular minute of the RIP was considered. Next, the second data collection was conducted with the subject in a seated position and combing their hair with unsupported arm elevation for five minutes. The subjects were instructed to perform the combing movement on the top of the head, alternating both arms with the dominant hand holding the comb while the other followed the movement. The activity had to be constant and uninterrupted for the entire period and at a minimum of 90° arm elevation. The last 30 seconds of the 1st, 3rd and 5th minute were considered for analyses.

Data are reported as mean and standard deviation (SD). The data distribution for each variable was assessed using Shapiro-Wilk's test. The comparisons between the four analyzed phases (rest, 1st, 3rd and 5th minute of exercise) were performed with ANOVA for repeated measures. When the difference was considered significant, Tukey's test was performed to identify the difference between pairs. The level of significance (α) was set at 0.05 for all tests. Data were analyzed with the Statistical Package for the Social Sciences software (SPSS 15.0, Chicago, IL, USA).

Results ⁙

Demographic data of the 13 subjects are presented in Table 1. The values for the variables during rest, 1st, 3rd, and 5th minutes of exercise with unsupported arm elevation and the respective analysis are presented in Table 2.

Breathing pattern

The V_T increased significantly from the 3rd minute; its value was 31% higher than the rest value. At the 5th minute, a slight increase in V_T was observed when compared with the 3rd minute corresponding to a value 33% higher than rest. There was a statistically significant difference between rest and the 3rd minute (P=0.008), rest and the 5th minute (P=0.033) and between the 1st and the 3rd minute (P=0.048) of activity (Table 2).

The f increased between rest and the 1st minute of activity, which was 21% higher than the baseline value, and then remained stable during the course of the exercise. There was a statistically significant difference between rest and the 1st minute

Table 1. Characteristics of the 13 subjects.

Variables	Mean	SD	Range
Age (yr)	60.6	6.42	51-71
Weight (Kg)	72.1	11.14	56-90
Height (m)	1.7	0.06	1.6-1.8
BMI (Kg/m²)	25.6	3.63	19.2-30.9
FVC % pred	105.2	20.41	86.7-162.7
FEV₁ % pred	101.4	23.45	73.6-118.8
FEV₁/FVC (%)	76.7	0.05	70.0-83.1

SD=standard deviation; Kg=kilogram; m=meters; BMI=body mass index; FVC=forced vital capacity; VEF₁=forced expiratory volume in one second.

Table 2. The analyzed variables during rest, 1st, 3rd, and 5th minutes of exercise with unsupported arm elevation. The values of p, f and Power of ANOVA for repeated measures are also presented.

Variable	Rest	1st	3rd	5th	p	f	Power
V_T (mL)	461.42 (199.08)	530.21 (205.66)	603.57 (254.88)*†	612.48 (204.18)*	0.010	4.39	0.83
V_E (l/min)	5.82 (1.64)	8.41 (2.66)*	9.74 (3.05)*†	9.79 (2.75)*†	0.000	18.48	0.99
f (bpm)	14.15 (4.46)	17.17 (4.64)*	17.47 (5.06)*	17.37 (4.74)*	0.001	6.91	0.96
Ti (s)	1.81 (0.83)	1.54 (0.47)	1.53 (0.58)	1.56 (0.48)	0.105	2.27	0.40
Ti/Ttot	0.37 (0.04)	0.40 (0.05)	0.40 (0.04)	0.41 (0.04)	0.103	2.22	0.51
V_T/Ti (mL/s)	265.71 (82.62)	361.38 (109.76)*	419.62 (139.67)*	419.52 (146.26)*	0.001	11.19	0.99
% RC/V_T	52.27 (15.40)	48.54 (14.79)	46.73 (15.23)	48.04 (16.36)	0.479	0.74	0.16

Data expressed as mean (standard deviation). Significant difference was considered when p<0.05; * Statistically different in comparison to rest; † Statistically different in comparison to the 1st minute.
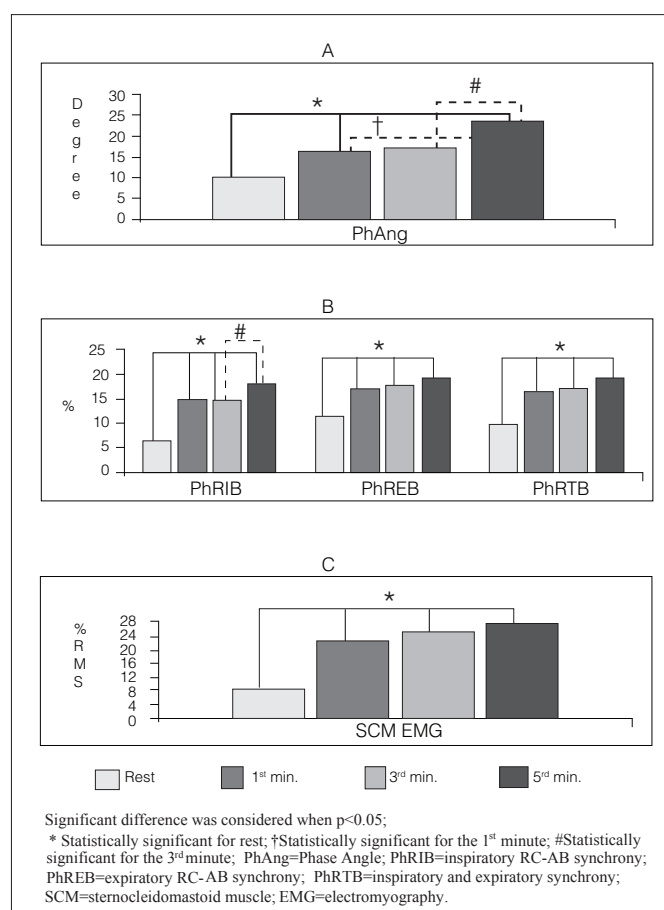

Figure 1. A) Comparison between PhAng during rest and during the analyzed moments of the hair-combing activity. B) Comparison between PhRIB, PhREB and PhRTB during rest and during the analyzed moments of the hair-combing activity. C) Comparison between SCM EMG during rest and during the analyzed moments of the hair-combing activity.

(P=0.013), rest and the 3rd minute (P=0.003) and between rest and the 5th minute (P=0.01) of activity (Table 2). Consequently, the changes in f in the 1st minute, in addition to the changes in V_T, led to a progressive increase in V_E until the 3rd minute, with a 67% higher value than rest that remained unchanged through the 5th minute. There was a significant difference between rest and the 1st minute (p=0.001), rest and the 3rd minute (p<0.001),

rest and the 5th minute (p<0.001), and between the 1st and the 3rd minute (p=0.013) and the 1st and the 5th minute of exercise (p=0.02; Table 2).

The V_T/Ti presented a 36% increase in the 1st minute when compared with rest, a 56% increase in the 3rd minute, stabilizing in the 5th minute of activity. There was a significant difference when comparing rest and the 1st minute (p<0.001), rest and the 3rd minute (p<0.001) and rest and the 5th minute of activity (p=0.003; Table 2).

Thoracoabdominal motion

No statistically significant difference was found for %RC/V_T and for %AB/V_T during the activity period, however it was observed that at rest %RC/V_T was 4.54% higher than %AB/V_T, and that during the exercise there was a shift to AB in which the %AB/VC increased its participation by 6.54% compared with %RC/V_T (Table 2). Considering the PhAng, we observed that the subjects presented a PhAng of 23.82º at the end of the activity, which corresponds to a 129% increase from rest. There was a significant difference when considering rest and the 1st minute (p=0.038), rest and the 5th minute (p=0.003), the 1st and the 5th minute (p=0.045) and the 3rd and the 5th minute of exercise (p=0.026; Figure 1 - A).

A progressive increase in PhRIB was observed during the activity, corresponding to 6.36% at rest, 14.77% in the 1st minute, 14.59% in the 3rd minute and 17.73% in the 5th minute, which represents a 79% increase between rest and the end of the exercise. There was a significant difference when considering rest and the 1st minute (p<0.001), rest and the 3rd minute (p<0.001), rest and the 5th minute (p<0.001) and the 3rd and the 5th minute of exercise (p=0.034; Figure 1 - B). Similarly, a progressive increase in PhREB was observed during the activity, corresponding to 11.63% at rest, 17.18% in the 1st minute, 18.07% in the 3rd minute and 19.05% in the 5th minute, which represents a 64% increase between rest and the end of the exercise. There was a significant difference when considering rest and the 1st minute (p=0.042), rest and the 3rd minute (0.021), and rest and the 5th

minute of exercise (p=0.001; Figure 1- B). When we consider the PhRTB, a progressive increase in synchrony between the two compartments was also observed during the activity, corresponding to 9.93% at rest, 16.61% in the 1st minute, 17.09% in the 3rd minute and 19.12% in the 5th minute, which represents a 92% increase between rest and the end of the exercise. There was a statistically significant difference when considering rest and the 1st minute (p=0.005), rest and the 3rd minute (p=0.002) and rest and the 5th minute of exercise (p<0.001; Figure 1 - B).

Electromyography activity

The subjects' SCM muscle activity between rest and the activity of combing hair with unsupported arm elevation ranged in the following magnitude compared with rest: 168% RMS in the 1st minute, 196% RMS in the 3rd minute and 224% RMS in the 5th minute. There was a statistically significant difference when comparing rest with the 1st (p=0.005), the 3rd (p=0.001) and the 5th minute of exercise (p=0.001; Figure 1 - C). No correlations were found between the respiratory pattern variables, thoracoabdominal motion and electromyographic activity of the SCM muscle.

Discussion ::::.

The main results of this study were: increased f and V_T, followed by increased V_E, increased V_T/Ti and thoracoabdominal asynchrony demonstrated by PhAng, PhRIB, PhREB, PhRTB, and increase in SCM muscle activity during the unsupported arm elevation. In addition, a change was observed, though not statistically significant, in the predominance of the contribution of the RC and AB to V_T. There was a significant increase in V_T, followed by a slightly increased f, resulting in a significant increase in V_E during the activity time with unsupported arm elevation. The V_T and V_E absolute values during rest were comparable with those reported by Tobin et al.[23] using RIP in healthy subjects in the supine position. However, when comparing breathing patterns from different studies, body posture must also be taken into account[23,24].

In the sitting position, Couser, Martinez and Celli[3] and Baarends et al.[2] measured V_E and V_T using other methods, and the results were markedly higher than those recorded for healthy subjects during rest in the present study. This difference probably relates to direct measuring techniques which employ breathing through a mouthpiece with the nose clipped[23]. As a consequence of the small variation in f (21%) and especially in V_T in the 3rd minute (31%), there was a progressive increase in V_E until the 3rd minute, achieving 67% of the rest value, remaining stable until the 5th minute. These results are partially comparable with those reported by Couser, Martinez and Celli[3] and by Baarends et al.[2], who analyzed healthy subjects with static elevated arms for 2 minutes and observed a V_E increase due to an increase in V_T while the f remained unchanged. The difference in f variation may be due to the type of exercise performed by our subjects, i.e. combing hair with alternating unsupported arm elevation, which is more difficult than static arm elevation. Younes and Kivinen[25] also reported that, at low levels of exercise, ventilation increases primarily due to increases in V_T and, at higher levels of exercise, the changes occur through changes in f. Tobin et al.[23] reported that mean inspiratory flow reflects respiratory center drive input, which explains the increase in the V_T/Ti ratio during unsupported arm elevation and its stabilization by the 3rd minute with 58% of rest value.

When we analyzed the PhAng, we observed that the subject presented a value of 23.82° at the end of the activity that corresponds to a 129% increase when compared with rest. This demonstrates an increase in RC-AB asynchrony. To our knowledge, there are no reports in the literature of PhAng values for healthy adults during unsupported arm elevation. With regard to rest values, our results were comparable with those found by Tobin et al.[26] and Bloch et al.[27] with healthy subjects during quiet breathing.

The variables PhRIB, PhREB and PhRTB represent the time percentage during a respiratory cycle in which the RC and the AB move in opposite directions. If both compartments move in the same direction along a respiratory phase (inspiratory, expiratory or both), a 0% value is computed. If the compartments move in opposite directions, a 100% value is computed[20]. In the present study, there was a progressive increase in PhRIB, PhREB and PhRTB, representing an increase of approximately 18% when comparing rest and the last minute of activity.

In healthy subjects, arm elevation leads to increased ventilatory and metabolic demands similar to mild exercise. At rest, the diaphragm is the dominant active inspiratory muscle, displacing the abdomen. During exercise, the inspiratory accessories are progressively recruited to assist the diaphragm and elevate the RC. During arm elevation, some of the upper torso muscles become involved in arm positioning, their participation in ventilation is decreased, and there is a shift of ventilatory work to the diaphragm. This disproportionate increase in diaphragmatic work contributes to the generation of ventilatory pressures[3]. These changes in RC and/or AB mechanics may be the cause of the increase in asynchrony in COPD patients and, to a small degree, in healthy subjects. However, COPD patients have insufficient diaphragmatic function, leading to considerable thoracoabdominal asynchrony.

In a study that assessed healthy subjects, Tobin et al.[26] concluded that thoracoabdominal asynchrony and paradox in compartmental contribution to V_T are predominantly due to

increases in respiratory load rather than muscle fatigue. In the present study, the RC and AB movements at rest were similar to those reported by Tobin et al.[23]. It appears that the slight increase in the AB contribution in activity in exchange for RC contribution at rest is related to the arm elevation and to a greater participation of the diaphragm in ventilation. According to Goldman et al.[28], abdominal wall displacement is intimately related to diaphragm displacement, however the same cannot be said for RC displacement.

The changes in the respiratory pattern mentioned above seem to be related to the hypothesis raised by many authors[1,3,4,6] when referring to an increase in diaphragm activity in tasks involving unsupported arms, which may suggest an increase in diaphragmatic work to generate a V_T due to a decrease in participation of the accessory muscles needed to stabilize the shoulder girdle during unsupported arm movements. Tobin et al.[23] reported that, although there was a slight predominance of AB contribution to V_T compared to RC contribution in healthy subjects in the supine position, there was a large individual variation in the respiratory pattern at rest. Sharp et al.[29], in their study on the sitting position at rest, reported that the RC was responsible for about 70% of V_T whereas, in the supine position, its contribution was only about 25%. Grimby, Bunn and Mead[30] also reported a 25% contribution of AB to V_T in individuals sitting on a cycle ergometer without exercising. These findings were attributed to the position of the legs with a tonic contraction of the muscles in the torso and abdominal wall that could effectively reduce abdominal compliance.

Grimby, Bunn and Mead[30] noted the variability of V_T during exercise and the need for caution when analyzing the estimated changes to RC and AB contribution to V_T. However, they reported that, although there is a large individual variation, there appears to be a consistent pattern of changes in relative RC and AB movements with an increase in V_T between rest and moderate exercise with a tendency toward a greater AB contribution to V_T. In contrast, when exercise intensity increases, there is an increase in RC contribution.

In the present study, for the calibration of RIP, the QDC was used during natural breathing, a procedure first described by Sackner et al.[16] in 1989. This method computes the calibration factor (K) by considering breaths of constant V_T[31]. In 2001, De Groote, Paiva and Verbandt[31] criticized the QDC calibration method for the possibility of error when there is a variation in V_T during the procedure. It should be noted that, in the present study, there was variation in V_T, but this occurred mainly during the exercise. During the calibration performed at rest, there was a slight variation in V_T in 13 evaluated subjects, with maximum standard deviation of 12.2 mL (1.98% V_T variation).

Furthermore, this is the current method employed by various studies that used RIP to assess the respiratory pattern[18,19,32-35].

Regarding surface EMG, we observed a steady increase in the amplitude of SCM muscle recruitment between rest and activity. These changes suggest an increase in SCM muscle participation in upper limb support during activities with unsupported arm elevation, reducing its respiratory function. This would lead to an increase in AB contribution to V_T during exercise.

Our findings are comparable with those reported by Martinez, Couser and Celli[8], who observed changes in respiratory muscle recruitment pattern indicating a more effective contraction of the diaphragm and an increase in SCM muscle amplitude of activation in EMG during activities with unsupported arm elevation. This suggests that some RC muscles are recruited during arm elevation. The present study also shows that there was an increase in V_T and f with a subsequent increase in V_E during the activity with unsupported arm elevation, and there was an increase in V_T/Ti as the activity progressed, which shows a greater neural activation during exercise. We also observed an increase in thoracoabdominal asynchrony during unsupported arm elevation as well as an abrupt increase in SCM muscle amplitude of activation in the beginning of the exercise, showing a steady increase until the 5th minute of activity.

The changes detected in the respiratory pattern and the EMG activity of the respiratory accessory muscle of the healthy subjects during the studied ADL can contribute to elucidate the determinants of dyspnea in patients with COPD. However, no reports of a normative parameter were found in the literature. Therefore, it was necessary to study how these variables behave in healthy subjects. Considering the findings of the present study, it is possible to use this data as normality parameters for clinical application to assess upper limb ADLs in patients with COPD.

Study limitations

Although the sample number was calculated in the pilot study to find significant differences between the moments (rest and activity), the number of subjects was insufficient for the correlations between respiratory pattern variables, thoracoabdominal motion and SCM muscle EMG. For the variables RC/V_T and AB/V_T, although the sample calculated to a power of 80% was small (eight), after the statistical analysis, the power found by ANOVA was low.

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