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Analysis of expiratory muscle strength and spontaneous breathing of individuals on mechanical ventilation: a cross-sectional study

Análise da força muscular expiratória e respiração espontânea de indivíduos em ventilação mecânica: estudo transversal

El análisis de la fuerza muscular espiratoria y la respiración espontánea de los individuos en ventilación mecánica: el estudio transversal

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ABSTRACT | The expiratory muscles have functions throughout the respiratory cycle, but they are not often evaluated in the weaning from mechanical ventilation. Thus, reviews and consensus do not mention the maximal expiratory pressure (MEP) and the expiratory training. The aim of this study was to investigate the relationship of expiratory muscle strength with the spontaneous breathing of individuals on mechanical ventilation. This is a cross-sectional study with participants aged between 18 and 79 years. The groups satisfactory MEP (SMEPG) and low MEP (LMEPG) were formed according to the cut-off point of 55 cmH_2O and compared to weaning parameters. The SMEPG (n=9) had better performance than LMEPG (n=21) in the rapid shallow breathing index (RSBI) (40.6±17.6 bpm/L and 75.3±44.1 bpm/L, respectively; p=0.022) and in the respiratory rate (RR) (19.1±6.2 bpm and 26.1±9.4 bpm; p=0.044). Prevalence of satisfactory MEP was low, as observed in the size of groups. In addition, although the MEP percentage of the predicted value was lower in LMEPG, as expected (67.2±15.4% vs. 45.8±14.7%; p=0.001), the percentage for maximal inspiratory pressure was not significantly different (82.4±21.8% vs. 67.8±18.4%; p=0.077). The MEP was moderately correlated with the RSBI (r=−0.406; p=0.026) and with the RR (r=−0.426; p=0.017). It was concluded that MEP≥55 cmH_2O was associated with better values in RSBI and RR and that the reduction of expiratory muscle strength was more prevalent and severe than that of inspiratory muscle strength.

Keywords | Abdominal Muscles; Muscle Weakness; Ventilator Weaning; Physical Therapy Modalities; Critical Care.

RESUMO | Os músculos da expiração têm funções em todo o ciclo respiratório, mas não são frequentemente avaliados no desmame da ventilação mecânica. Assim, revisões e consensos não mencionam a pressão expiratória máxima ($PE_{máx}$) e o treino expiratório. Objetivou-se investigar a relação da força muscular expiratória com a respiração espontânea de indivíduos ventilados mecanicamente. Trata-se de um estudo transversal com participantes de 18 a 79 anos de idade. Foram formados os grupos $PE_{máx}$ satisfatória (GPES) e $PE_{máx}$ baixa (GPEB) conforme o ponto de corte de 55cmH2O e comparados a parâmetros de desmame. O GPES (n=9) teve desempenho superior ao do GPEB (n=21) no índice de respiração rápida e superficial (IRRS) (40,6±17,6rpm/L e 75,3±44,1rpm/L, respectivamente; p=0,022) e na frequência respiratória (*f*) (19,1±6,2rpm e 26,1±9,4rpm; p=0,044). A prevalência de $PE_{máx}$ satisfatória foi pequena, observada no tamanho dos grupos. Além disso, embora a $PE_{máx}$ percentual do valor predito tenha sido menor no GPEB, como esperado

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(67,2±15,4% vs. 45,8±14,7%; p=0,001), a pressão inspiratória máxima percentual não diferiu significantemente (82,4±21,8% vs. 67,8±18,4%; p=0,077). A $PE_{máx}$ se correlacionou moderadamente com o IRRS (r=−0,406; p=0,026) e com a *f* (r=−0,426; p=0,017). Conclui-se que a $PE_{máx}$≥55cmH_2O esteve associada à melhores valores no IRRS e na *f*, e que a redução da força muscular expiratória foi mais prevalente e severa que a da força muscular inspiratória.
Descritores | Músculos Abdominais; Debilidade Muscular; Desmame do Respirador; Modalidades de Fisioterapia; Cuidados Críticos.

RESUMEN | Los músculos de la espiración tienen funciones en todo el ciclo respiratorio, sin embargo, no son frecuentemente evaluados en el desmame de la ventilación mecánica. Así, revisiones y consensos no mencionan la tensión espiratoria máxima ($PE_{máx}$) y el entreno espiratorio. Se ha objetivado investigar la relación de la fuerza muscular espiratoria con la respiración espontánea de los individuos ventilados mecánicamente. Se trata de un estudio transversal con participantes de 18 a 79 años de edad. Han sido hechos los grupos PEmáx satisfactoria (GPES) y PEmáx baja (GPEB) de acuerdo con el punto de corte de 55cmH2O y han sido comparados a parámetros de destete. El GPES (n=9) ha tenido el desempeño superior al del GPEB (n=21) en el índice de respiración rápida y superficial (IRRS) (40,6±17,6rpm/L y 75,3±44,1rpm/L, respectivamente; p=0,022) y en la frecuencia respiratoria (f) (19,1±6,2rpm y 26,1±9,4rpm; p=0,044). La prevalencia de PEmáx satisfactoria ha sido pequeña, ha sido observada en el tamaño de los grupos. Además de eso, aunque la PEmáx porcentual del valor predicho haya sido menor en el GPEB, como ha sido esperado (67,2±15,4% vs. 45,8±14,7%; p=0,001), la presión inspiratoria máxima porcentual no ha diferido significantemente (82,4±21,8% vs. 67,8±18,4%; p=0,077). La $PE_{máx}$ se ha correlacionado moderadamente con el IRRS (r=−0,406; p=0,026) y con la f (r=−0,426; p=0,017). Se concluye que la $PE_{máx}$≥55cmH2O ha estado asociada a los mejores valores en el IRRS y en la f, y que la reducción de la fuerza muscular espiratoria ha sido más prevalente y severa que la de la fuerza muscular inspiratoria.
Palabras clave | Músculos Abdominales; Debilidad Muscular; Desconexión del Ventilador; Modalidades de Fisioterapia; Cuidados Críticos.

INTRODUCTION

Abdominal muscles (AM) are the main organs responsible for the forced expiration[1] and have other respiratory functions. In inspiration, the tension of rest of AM limits the visceral expansion, allowing the diaphragm to raise the intra-abdominal pressure, which is transferred to the zone of apposition, thus expanding the thoracic diameter. In addition, the abdominal tone assists in the maintenance of the functional residual capacity (FRC) and of the shape of the dome of the diaphragm, which is crucial in the performance of such[2].

The transverse abdominal muscle (TVM) is connected with the diaphragm in the last six ribs and, with other passive and contractile structures, stabilizes the rib cage[3,4]. The TVM contracts at the end of the calm expiration and reduces the lung volume below the FRC, causing sudden diaphragmatic stretching that facilitates the subsequent inspiration. The AM can sustain the ventilation when keeping the expiration active, compensating the overload on inspiratory muscles[5,6].

The fatigue of the AM decreases the exercise tolerance and their strengthening increases the lung volume and the stability of the torso[7,4]. Muscle inhibition caused by abdominal surgery makes the cough little effective and favors the accumulation of secretions in the airways[8]. In the study by McCaughey et al.[9], the electrostimulation of the AM in tetraplegic patients improved lung function and reduced the time of weaning from mechanical ventilation (WMV).

The fault in the DVM has as one of the main causes the respiratory muscle weakness[10-12], commonly evaluated by the maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP)[13]; however, there are only a few studies focusing on the function of expiratory muscles at weaning, whose focus in generally on the inspiratory ones, in particular on the diaphragm[14-16]. Thus, reviews and guidelines do not mention the MEP and the expiratory muscle training[10,12,17]. On the other hand, recently the MEP, the rapid shallow breathing index (RSBI) and the test of airway patency were the only independent predictors of success in 6,583 endotracheal extubation processes[18].

Given this context, this study aimed to investigate the relationship of expiratory muscle strength with the spontaneous respiration of individuals on invasive mechanical ventilation (IMV).

METHODOLOGY

This is a cross-sectional study with convenience sampling conducted in an intensive care unit (ICU) of the Hospital

Getúlio Vargas, PE/Brazil. The sample calculation was conducted based on a finite population of known size. With an average of 64 admissions in 60 days (duration of data collection), half of this value (32 individuals) was considered the population, deducting losses and exclusions according to sectoral data. By assuming a 50% proportion, 95% reliability and 5% error, the calculation resulted in n=30. All patients already hospitalized or admitted in the period were assessed for inclusion. The study was approved by the Research Ethics Committee of the Universidade de Pernambuco (CAAE 60149516.5.0000.5192). Informed consent was obtained from patients or relatives.

For being an ICU of general scope, the inclusion criteria were: any ongoing clinical decompensation of non-traumatic origin with acute respiratory insufficiency; age between 18 and 79 years; and less than 48 hours on IMV. Exclusion criteria were: decompensated heart failure; acute cranial or thoracic injury; intolerance to the pressure support ventilation (PSV); respiratory rate (RR) equal to or higher than 35 bpm; SpO_2 lower than 90% with positive-end expiratory pressure (PEEP) higher than 55 cmH_2O or FiO_2 equal to or higher than 0.5; heart rate higher than 140 bpm; and systolic blood pressure equal to or higher than 180 or equal to or lower than 90[19].

The groups *satisfactory MEP* (SMEPG) and *low MEP* (LMEPG) were formed and compared considering the parameters MEP and MIP (percentages of values predicted[20]), RSBI, volume minute (VM), RR, absolute (ATV) and relative (RTV) tidal volume, and absolute (AVC) and relative (RVC) vital capacity. MEP, MIP and RSBI were considered satisfactory if ≥55 cmH_2O, <−40 cmH_2O and <68 rpm/L, respectively[20].

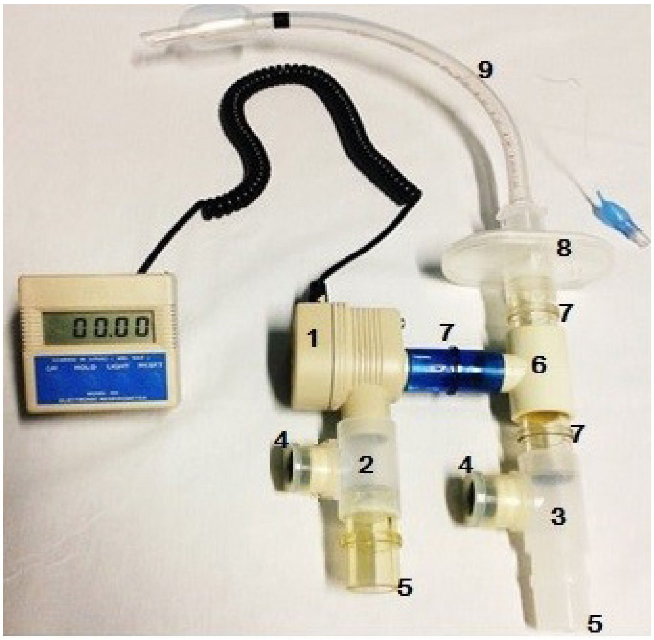
Characterization of groups was determined by the variables: age, sex, type of artificial airway (AAW), time of hospitalization (T-Hosp), time in ICU (T-ICU), time on IMV (T-IMV), sepsis, comorbidities and postoperative care after abdominal and other surgeries.

Two physiotherapists, blind on the allocation, were trained in preestablished functions. Procedures were preceded by placement of individuals in semi decubitus position from 30° to 45°, adjustment of cuff pressure in 30 cmH_2O[21] and aspiration of airways. The protocol began with a spontaneous breathing test (PEEP=5 cmH_2O and pressure support=7 cmH_2O) interspersed with disconnection of the ventilator for respiratory assessment.

Measurements of respiratory pressures lasted from 40 to 60 seconds, having as subjective basis the patients' comfort (adapted from Guimarães et al.[22]) and were only repeated if deemed necessary. On MEP, a manovacuometer (Comercial Médica – SP/Brazil, ±120 cmH_2O) with one-way valve that allowed only the inspiration necessary for the Valsalva maneuver was attached to the AAW: maximal expiratory effort in total lung capacity (TLC) with occlusive AAW. The reverse process was conducted for MIP (Muller's maneuver): maximal inspiratory effort in residual volume (RV)[13,23].

A ventilometer (AINCA-USA, model 00-295) recorded the VM, which was divided by RR, obtaining the mean ATV in mL, whose division by the predicted weight resulted in the RTV. The RSBI was obtained by dividing RR by ATV in liters[24]. As for the vital capacity (VC), it was estimated by adapting the method of Marini et al.[25], arranging two one-way valves, a T-tube and a ventilometer (Figure 1). The inspiratory valve was manually occluded and the patient exhaled until reaching the RV. Subsequently, only the expiratory valve was occluded and the volumes of consecutive inspiratory efforts were added up until ceasing the alterations in the ventilometer, indicating that the TLC had been achieved. The value resulting from this procedure was the AVC (RVC=AVC/predicted weight).

The height estimated was twice the distance from the center of the sternal furcula to the extremity of the middle finger, with the upper limb in elbow extension and 90° of shoulder abduction[26]. Equations for predicted weight were: men: 50+0.91 (height: 152.4); women: 45.5+0.91 (height: 152.4)[27].



1. Ventilometer; 2. One-way inspiratory valve; 3. One-way expiratory valve; 4. Permanent occlusion; 5. Manual occlusion; 6. T-Tube; 7. Adapter; 8. Barrier filter; 9. Orotracheal tube.

Figure 1. Instrument for evaluation of vital capacity

Data were stored in the software Epi-info 7.2. The software SPSS 20.0 was used in descriptive analysis (mean, standard deviation, median, 25% and 75% percentile and 95% confidence interval). The Shapiro-Wilk test was used to evaluate the normality of data. The analysis of the heterogeneity between groups was obtained by the Student's t-test for two independent samples (parametric) or by the Mann-Whitney U test (non-parametric). Contingency tables were evaluated by the Fisher's exact test. Correlations were established through the Pearson's (parametric) or Spearman's rank (nonparametric) correlation coefficient. Associations were significant when $p<0.05$.

RESULTS

From the 68 admissions in the collection period (including those already hospitalized at the beginning), 8 exclusions occurred due to intolerance to the PSV and 30 others were not included due to: absence of AAW (12), extubation in less than 48 hours (10), and age above 79 years (8). Thus, 30 individuals were included: 9 (30%) allocated into the SMEPG and 21 (70%) into the LMEPG, depending on the cut-off point of 55 cmH_2O for MEP.

As expected, the MEP percentage (%MEP) of the SMEPG was greater than that of LMEPG ($p=0.001$), but there was no difference in MIP percentage (%MIP) (0.077). In the intra-group subanalysis, the %MEP was lower than the %MIP in LMEPG ($p<0.0001$), which did not occur in the SMEPG ($p=0.145$). From the entire sample, only one patient presented unsatisfactory MIP (<40 cmH_2O).

The SMEPG had superior performance than that of LMEPG in RSBI ($p=0.022$) and RR ($p=0.044$). The difference favoring the SMEPG on ATV ($p=0.044$) was not maintained in the RTV (0.312), a result similar to that of AVC ($p=0.035$) and RVC ($p=0.227$). The VM did not differ among groups ($p=0.586$). Table 1 shows the descriptive and analytical statistics of quantitative data.

The %MEP showed moderate correlation with RSBI ($r=-0.406$; $p=0.026$), RR ($r=-0.426$; $p=0.017$), T-IMV ($r=-0.408$; $p=0.025$) and T-ICU ($r=-0.426$; $p=0.019$). The %MIP was only correlated with the %MEP ($r=0.676$; $p<0.001$). As for the values measured, without considering the percentage, there was correlation of MEP ($r=0.369$; $p=0.045$) and MIP ($r=-406$; $p=0.026$) with the AVC; however, this phenomenon did not occur with the RVC, which had association with the RSBI ($r=-0.640$; $p<0.001$), RTV ($r=0.673$; $p<0.001$) and RR ($r=-0.542$; $p=0.002$).

There were more women in the LMEPG (71.4%) than in the SMEPG (22.2%, $p=0.020$). The satisfactory RSBI (<68 bpm/L) prevailed in SMEPG (88,89%) in relation to the LMEPG (47.62%, $p=0.049$). There were no differences in the other categorical variables (Table 2).

Table 1. Descriptive data of quantitative variables and the result of comparisons according to Student's t- or Mann-Whitney U test

Variable	Group	Mean ± SD	Median	Percentile 25%	Percentile 75%	95% CI Inferior	95% CI Superior	P
Demography and anthropometry								
Age (years)	SMEPG	55.11±10.85	56.0	44.0	65.50	46.70	63.45	0.213
	LMEPG	59.19±17.80	65.0	55.0	76.80	51.08	67.29	
Estimated height (cm)	SMEPG	170.66±10.75	172.0	162.0	178.5	162.39	178.93	0.399 (T)
	LMEPG	165.23±8.73	166.0	156.5	180.0	161.26	169.21	
Predicted weight (kg)	SMEPG	65.61±11.02	67.83	56.47	73.74	57.13	74.09	0.275 (T)
	LMEPG	58.47±9.59	57.87	49.22	75.11	54.10	62.83	
Condition in hospital (days)								
T-Hosp	SMEPG	10.88±4.75	10.0	7.50	12.50	7.23	14.54	0.389
	LMEPG	19.14±15.22	14	6.50	46.20	12.21	26.07	
T-ICU	SMEPG	6.44±2.96	6.0	4.0	9.0	4.16	8.72	0.219
	LMEPG	10.47±8.07	8.0	4.50	26.0	6.79	14.15	
T-IMV	SMEPG	7.0±4.15	8.0	2.50	10.0	3.80	10.19	0.229
	LMEPG	12.90±11.51	8.0	4.50	32.8	7.66	18.14	
Respiratory pressures (cmH_2O)								
MEP measured	SMEPG	74.66±20.27	64.0	58.0	94.50	59.07	90.25	<0.001*
	LMEPG	39.42±8.89	40.0	35.0	49.60	35.37	43.47	

(continues)

Table 1. Continuation

Variable	Group	Mean ± SD	Median	Percentile		95% CI		P
				25%	75%	Inferior	Superior	
MIP measured	SMEPG	−86.28±22.70	−80.0	−69.0	−108.0	−68.77	−103.67	<0.001* (t)
	LMEPG	−59.76±15.60	−58.0	−46.0	−81.60	−52.65	−66.86	
MEP predicted	SMEPG	112.74±22.34	119.94	111.84	128.42	98.14	127.35	0.021*
	LMEPG	90.68±23.96	79.0	72.90	102.18	80.06	101.30	
MIP predicted	SMEPG	105.74±17.18	110.50	102.50	116.90	94.51	116.97	0.021*
	LMEPG	89.56±18.82	81.0	76.10	99.62	81.22	97.89	
MEP predicted (%)	SMEPG	67.21±15.47	69.03	50.07	81.26	57.10	77.33	0.001* (t)
	LMEPG	45.88±14.77	44.30	34.23	58.50	39.33	52.42	
MIP predicted (%)	SMEPG	82.43±21.81	81.44	69.48	94.07	67.17	96.69	0.077 (t)
	LMEPG	67.87±18.46	63.89	58.95	74.07	59.69	76.05	
Ventilometry								
RSBI (bpm)	SMEPG	40.68±17.65	41.22	26.46	54.34	27.11	54.25	0.022*
	LMEPG	75.37±44.09	69.23	40.27	152.29	55.29	95.44	
ATV (mL)	SMEPG	503.77±114.35	440.64	420.40	622.21	415.87	591.67	0.044*
	LMEPG	398.02±123.80	400.0	306.36	572.08	341.66	454.37	
RTV (mL/kg)	SMEPG	7.83±2.09	7.74	6.42	8.66	6.45	9.20	0.312 (t)
	LMEPG	6.91±2.28	6.64	5.54	8.28	5.90	7.92	
RR (bpm)	SMEPG	19.11±6.27	18	15.0	23.50	14.28	23.93	0.044*
	LMEPG	26.14±9.46	24	19.50	42.20	21.83	30.44	
VM (mL)	SMEPG	9,273.3±2,499.9	8,900	7,020	11,430	7,351.7	11,194.9	0.586 (t)
	LMEPG	10,097.1±4,151.1	9,440	7,470	17,002	8,207.5	11,986.7	
AVC (mL)	SMEPG	1,917.22±610.21	1,865	1,425	2,370	1,448.1	2,386.2	0.035* (t)
	LMEPG	1,446.42±503.18	1,435	1,015	2,292	1,217.3	1,675.4	
RVC (mL/kg)	SMEPG	29.61±7.94	29.99	22.63	36.42	23.51	35.72	0.227 (t)
	LMEPG	24.85±10.31	25.24	17.61	37.78	20.15	29.54	

SD: Standard deviation; 95% CI: 95% confidence interval; T-IMV: Time on invasive mechanical ventilation; T-Hosp: Time of hospitalization; T-ICU: Time in intensive care unit; MEP: Maximal expiratory pressure; MIP: Maximal inspiratory pressure; RSBI: Rapid shallow breathing index; ATV: Absolute tidal volume; RTV: Relative tidal volume; RR: Respiratory rate; bpm: breaths per minutesize of groups.; VM: Volume minute; AVC: Absolute vital capacity; RVC: Relative vital capacity; SMEPG: Satisfying maximal expiratory pressure group; LMEPG: Low maximal expiratory pressure group; (t): Normal data evaluated by the Student's t-test; * p<0.05.

Table 2. Descriptive data of categorical variables and results of comparisons according to Fisher's exact test.

Variables	Options	SMEPG n (%)	LMEPG n (%)	P
Sex	Male	7 (77.8%)	6 (28.6%)	0.020*
	Female	2 (22.2%)	15 (71.4%)	
Type of AAW	OTT	8 (88.9%)	15 (71.4%)	0.393
	TST	1 (11.1%)	6 (28.6%)	
Sepsis	Yes	3 (33.3%)	12 (57.1%)	0.427
	No	6 (66.7%)	9 (42.9%)	
Abdominal surgery	Yes	4 (44.4%)	7 (33.3%)	0.687
	No	5 (55.6%)	14 (66.7%)	
DM	Yes	0 (0.0%)	8 (38.1%)	0.067
	No	9 (100%)	13 (61.9%)	
SAP	Yes	5 (55.6)	5 (23.8%)	0.115
	No	4 (44.4%)	16 (76.2%)	

(continues)

Table 2. Continuation

Variables	Options	SMEPG n (%)	LMEPG n (%)	P
Respiratory disease	Yes	1 (11.1%)	9 (42.9%)	0.204
	No	8 (88.9%)	12 (57.1%)	
Cardiovascular disease	Yes	0 (0.0%)	2 (9.5%)	1.0
	No	9 (100%)	19 (90.5%)	
CNS diseases	Yes	2 (22.2%)	7 (33.3%)	0.681
	No	7 (77.8%)	14 (66.7%)	
History of HA	Yes	1 (11.1%)	1 (4.8%)	0.517
	No	8 (88.9%)	20 (95.3%)	
Renal insufficiency	Yes	3 (33.3%)	7 (33.3%)	1.0
	No	6 (66.7%)	14 (66.7%)	
GIT disease	Yes	3 (33.3%)	6 (28.6%)	1.0
	No	6 (66.7%)	15 (71.4%)	
Other surgeries	Yes	3 (33.3%)	6 (28.6%)	1.0
	No	6 (66.7%)	15 (71.4%)	
Satisfactory RSBI (<68 bpm/L)	Yes	8 (88.89%)	10 (47.62%)	0.049*
	No	1 (11.1%)	11 (52.38%)	

SMEPG: Satisfying maximal expiratory pressure group; LMEPG: Low maximal expiratory pressure group; AAW: Artificial airway; OTT: orotracheal tube; TST: tracheal tube; DM: Diabetes mellitus; SAH: Systemic arterial hypertension; CNS: Central nervous system; HA: Heart arrest; GIT: Gastrointestinal tract; RSBI: Rapid shallow breathing index; *p<0.05.

DISCUSION

The LMEPG had better performance in the RSBI and *RR*. There was no difference in RT_V, RV_C and VM. Prevalence of satisfactory ME_P was low, as observed in size of groups. The MIP did not vary statistically among groups and only one patient had unsatisfactory MIP. Among the correlations observed, those that outstand were observed only in $\%ME_P$ with the RSBI, *RR*, T-IMV and T-ICU and the correlations of RVC with the RSBI and its components.

The intra-group subanalysis of respiratory pressures shows that %MEP was lower than %MIP in both groups, with the significant difference in the LMEPG, suggesting that the expiratory weakness was more severe than the inspiratory one. This probably is an unprecedented finding on critical patients. However, changes of the complacency of the respiratory system are common in this population[28] and can culminate in lower TLC, reducing the MEP[13]. However, the muscle weakness acquired in ICU (MWA-ICU) may have influence on the phenomenon[29].

The satisfactory RSBI of the SMEPG, even though it can be attributed to the action of both muscle groups, may have had decisive contributions for the expiratory muscles, given that: they modulate the respiratory control, protecting the inspiratory muscles[30]; the AM ease the diaphragmatic contraction[2]; the suitable MEP may indicate greater effectiveness of cough and therefore greater airway permeability and less respiratory work[8,31]; the LMEPG had a MIP of −59.76±15.60, which is higher than the cut-off point of 40 cmH_2O, but did not reflect a good RSBI; only the %MEP was correlated with the RSBI; there was no correlation of the electrical activity of the diaphragm with the RR or RSBI[32]; and usually the inspiratory negativity of −5 cmH_2O in pleural pressure was sufficient for inhalation of 500 mL of air[33]. The RSBI is the predictive index most used in WMV[17], but the design of this study limits the interpretations. A longitudinal follow-up is required to verify the outcomes in WMV according to the MEP.

The similarity found in the VM was observed in other studies[18,30,32] and may have derived from the sample's tolerance to PSV. As the VM is the product of ATV by RR, the difference was found in those variables that tend to change inversely. Thus, the SMEPG had lower RR for presenting higher ATV as the LMEPG compensated the low ATV by increasing the RR. As the difference in the RTV was not significant, the largest contribution came from RR, agreeing with Sugiura et al.[30], in which the expiratory fatigue triggers the fast and shallow pattern and, to a certain level of effort, the change in the ATV is not significant.

The RVC did not vary statistically between groups, even when being correlated with the RSBI and its components in isolation, which, except for the RTV, showed difference in the comparison of SMEPG with the LMEPG, as well as the correlation with %MEP. It is possible that the use of one-way valves, aiming at leading individuals to exert greater efforts, promotes greater homogeneity even among those with difference of strength, since the volume of air is accumulated at each respiratory cycle. The findings may also result from improper activation of AM[1], since the VC may increase with training[3]. In addition, apart from relying on the neuromuscular respiratory function, the VC is influenced by the mechanical properties of the lung and thoracic system, which has similarities before distinct respiratory pressures[34]. The method used in the VC was validated[25], but its performance on individuals with AAW still remains necessary. In validation, the authors found in healthy participants and those with ambulatory pneumonia, AVC of 4.63 L and 3.02 L, respectively. The values in this study were 1.91 L (SMEPG) and 1.44 L (LMEPG), acceptable numbers due to the need of IMV. Furthermore, correlations observed in this study indicate that the method has produced reliable data.

Expiratory muscles can be evaluated dynamically through the cough[8]. Individuals with a peak of expiratory flow in cough below 60 L/min were five times more inclined to have unsuccessful extubation and 19 times more inclined to dye at the hospital[35]. There is interest on indexes that predict combined results of WMV and extubation[35,18]. Although the need for ventilatory support and AAW has different etiologies[18], the expiratory function seems useful in the evaluation of the discontinuity of these two factors and physical weakness.

Impairments in the diaphragm caused by critical illness polyneuromyopathy (CIPNM) are considered vital in the prolongation of IMV[36], but little is known about the involvement of AM and its impact. The comparison of the transdiaphragmatic pressure in subjects with success and failure in the WMV showed no difference in the establishment of fatigue in the diaphragm[37]. Results of this study do not show significant reduction in %MIP between groups, being possible that the CIPNM primarily affects the expiratory muscles. However, the mechanism lacks research, because the poor performance of the AM is also present on low back pain[38], chronic obstructive pulmonary disease[39], multiple sclerosis[40], and spinal cord injury[41].

CIPNM diagnosis requires invasive methods, of difficult interpretation and limited by conditions as low level of consciousness, edema and previous neuropathy[29]. The Medical Research Council Sum Score (MRC-SS) is used in the diagnostic hypothesis for identifying the MWA-ICU, but it also requires cooperation of the patient[29,42]. Tzanis et al.[43] found correlation between MIP and the MRC-SS, showing that this could be an alternative. Similarly, there was correlation between the MRC-SS and the respiratory pressures, with greater significance on MEP ($p<0.0001$) in relation to the MIP ($p=0.001$)[28].

The association between peripheral muscle weakness and duration of T-IMV is mediated by the concurrent respiratory weakness[28]. In the absence of mechanical disadvantage, the reduction of MEP may reflect a generalized muscle weakness[44]. During a maximal expiratory effort, the electrical activity of the AM is small compared to that recorded when the head and shoulders in dorsal positions stop touching a surface[45]. To understand the expiratory muscle function in the WMV is essential in the therapeutic approach.

The existing correlation between %MEP and %MIP generates a questioning of the current consensus on intensive therapy of only training inspiratory muscles. It becomes necessary to compare the expiratory and inspiratory muscle training, separately and combined, as well as to test other strategies. In the case of neuromuscular electrical stimulation, the TVM, for being the deepest and most active muscle in forced expiration, followed by the oblique and rectus abdominis muscles[1], such a basis can guide the arrangement of electrodes for effective neuromuscular stimulation and the monitoring of the AM recruitment through ultrasonic images[46]. In addition, active movements of the lower limbs may be beneficial because they are preceded by TVM activation[47] and it is possible that the increased VC is achieved by strengthening the inspiratory muscles on TLC and the expiratory ones in RV[40].

This study had limitations that should be considered. There was a high prevalence of women in LMPEG, which, associated with a series of nonsignificant changes in age and in other clinical variables, can interfere with main outcomes. It is necessary that in larger samples individuals are stratified by sex and age group for analysis of the influence of MEP in the different groups. Finally, apart from the pressures and volumes, this study does not bring new data on the association of these variables with others, such as muscle thickness and diaphragmatic mobility, which could significantly deepen the knowledge about the role of expiratory and inspiratory muscles in the weaning from mechanical ventilation.

CONCLUSION

The MEP≥55 cmH_2O was associated to better values in RSBI and RR. The reduction of expiratory muscle strength was more prevalent and severe than that of inspiratory muscle strength. There were no participants with normal MEP and low MIP at the same time, which limits the conclusions on the isolated function of expiratory muscles, but indicates that the inspiratory muscles are less affected and that the effects of expiratory muscle training must be investigated in the difficult weaning.

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