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Respiratory muscles stretching acutely increases expansion in hemiparetic chest wall

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ABSTRACT

Individuals post-stroke may present restrictive ventilatory pattern generated from changes in the functionality of respiratory system due to muscle spasticity and contractures.

Objective was to assess the acute effects after respiratory muscle stretching on the ventilatory pattern and volume distribution of the chest wall in stroke subjects. Ten volunteers with right hemiparesis after stroke and a mean age of 60 ± 5.7 years were randomised into the following interventions: respiratory muscle stretching and at rest (control). The ventilatory pattern and chest wall volume distribution were evaluated through optoelectronic plethysmography before and immediately after each intervention. Respiratory muscle stretching promoted a significant acute increase of 120 mL in tidal volume, with an increase in minute ventilation, mean inspiratory flow and mean expiratory flow compared with the control group. Pulmonary ribcage increased 50 mL after stretching, with 30 mL of contribution to the right pulmonary rib cage (hemiparetic side) in comparison to the control group. Respiratory muscle stretching in patients with right hemiparesis post-stroke demonstrated that acute effects improve the expansion of the respiratory system during tidal breathing.

Clinical Trial Registration: NCT02416349 (URL: https://clinicaltrials.gov/ct2/show/ NCT02416349).

1. Introduction

Hemiplegia/hemiparesis represents the most common disability and the main indication of rehabilitation after stroke (Gordon et al., 2004). Fatigue, lack of balance, contractures and spasticity are some of specific disadvantages in these patients, interfering in functions of the whole body and could compromise the respiratory system (Billinger et al., 2012).

Respiratory changes depend on the central structures affected by stroke and could be related to trunk postural dysfunctions caused by hemiplegia/hemiparesis (Billinger et al., 2012; Jandt et al., 2011), leading to an impairment of respiratory mechanics, reduction in respiratory muscle pressure, asymmetry and reduction in chest wall displacement and ventilation. Thus, individuals presenting pulmonary function injury with a restrictive ventilatory pattern may experience respiratory complications and require recurrent hospital intervention (Billinger et al., 2012; Fernandes et al., 2007; Jandt et al., 2011; Lanini et al., 2003).

Muscle stretching has been commonly used in clinical practice because it increases tissue extensibility through mechanisms involving deformation and structural adaptations of the muscles, and it allows increases in soft tissue extensibility, such as connective, vascular, cutaneous and neural tissues (Galea, 2012; Smania et al., 2010). Respiratory muscle stretching (RMS) has been suggested as an intervention that is able to reduce chest wall rigidity, consequently increasing its expansion and improving ventilatory patterns in patients with chronic obstructive pulmonary disease (Da Cunha et al., 2005; Ito et al., 1999; Minoguchi et al., 2002).

Currently, rehabilitation programs for post-stroke patients do not include specific actions aiming to improve respiratory muscle and chest wall compliance. For this reason, we have investigated the use of RMS to improve respiratory function in these patients.

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We hypothesized that RMS allows for better expansion of the chest wall due to both increased muscle length and chest wall compliance.

Therefore, the specific aim of this study was to evaluate the acute effects of respiratory muscle stretching on the ventilatory pattern and total and compartmental chest wall volumes in post-stroke patients with right hemiparesis.

2. Material and methods

2.1. Study design and sample

A randomised crossover clinical trial with allocation concealment and blind was performed at the Cardiopulmonary Physiotherapy Laboratory. The Human Ethics Committee approved the study protocol, and all participants gave written informed consent after being fully informed of the protocol. The study was conducted according to Consort Statement (Schulz et al., 2010).

Inclusion criteria for the study were post-stroke patients with right hemiparesis for more than three months, of both sexes, older than 20 years old, with scores between 1 and 3 according to the Ashworth Scale for the elbow flexor muscle group (Bohannon and Smith, 1987), scores above 85 for the Barthel Index (Sulter and Steen, 1999), and a minimum score of 18 on the Mini Mental State Examination (Bertolucci et al., 1994).

The following exclusion criteria were considered: facial paralysis, rheumatic or orthopaedic diseases, spinal abnormalities or deformities that compromise respiratory mechanics, spirometry with forced expired volume in the first second (FEV_1) < 80% predict and FEV_1/forced vital capacity (FVC) ≤ 0.7 according to predicted values (Duarte et al., 2006), respiratory comorbidities, recent history of thoracic or abdominal surgery, hemodynamic instability or pregnancy.

2.2. Study protocol

All patients underwent two types of intervention: respiratory muscle stretching (RMS) and maintaining resting conditions for a similar period to that of the RMS (control group). The sequence to start the interventions was randomly performed using a computer program available on the internet (www.randomization.com), and it was coded by another auxiliary researcher; allocation concealment was done using numbered opaque envelopes containing the patient's selection. Those envelopes were sent to the therapist researcher responsible for intervention, and who was blinded to the intervention type used on the patients. A minimum period of one day was used between the two interventions.

The whole study protocol was performed over three different days. On the first day, all participants underwent the general assessment consisting of anamnesis and anthropometric measurements: weight, height and body mass index using a digital scale (Welmy W300, São Paulo, Brazil). Then, all participants were submitted to spirometry (Micro Medical Microloop MK8, Kent, England) and respiratory muscle maximal pressure assessment using a manovacuometer (MV-300 Globalmed, São Paulo, Brazil) according to the American Thoracic Society/European Respiratory Society Statement (Costa et al., 2010; Moore, 2012).

2.3. Intervention

The study protocol was preliminarily tested to obtain greater participation of the patients with the lowest possible postural compensation. After this preliminary analysis, active-assisted stretching was selected with patients positioned sitting with their backs supported and they were asked to avoid postural compensations during stretching.

The following stretching exercises were then performed (Fig. 1):

- Neck (Fig. 1A): The patient sat with their back supported, straight trunk and head flexion toward the left side using his/her left hand, with the therapist supporting the stretching, displacing patient's right shoulder in the craniocaudal direction. Similarly, head extension toward the right side was performed using patient's right hand, but with greater participation by the therapist due to patient's limitation on this side.
- Upper chest (Fig. 1B): The patient was positioned sitting with their back supported, straight trunk and was asked to interlace fingers of both hands and put them in the upper thorax region. Stretching was performed after requesting the patient to pull down the chest using both hands while lifting their chin and exhaling slowly. In situations where it was not possible to interlace their fingers on their chest due to spasticity, stretching was promoted by the therapist standing behind the patient, interlacing his/her own fingers on the patient's chest and performing chest wall deflation synchronized to the patient's expiration while lifting their chin.
- Pectoralis major (Fig. 1C): The patient was positioned sitting with their back supported, with the arm to be stretched abducted, forearm flexed and hand kept on the occipital region, with one the therapist's hands supporting the upper third of the arm and the other hand in the lateral region of the upper chest, displacing the hand in the craniocaudal direction, following the muscle fibers direction. A higher level of support was given by therapist in situations where the right shoulder presented limitations in joint mobility due to spasticity or pain.
- Lateral chest (Fig. 1D): The patient was positioned in lateral and dorsal decubitus using a half-moon-shaped foam roller placed in the lateral region, the supra-lateral forearm flexed with the hand placed in the occipital region with the therapist supporting rib mobilization in the craniocaudal direction and displacing the supra-lateral arm of the patient to perform shoulder abduction with the other hand.

All of the interventions were done by respecting joint limitations and any pain complaints from the patients.

The exercises were explained to the patients before a stretching session by providing a demonstration to them performed by the therapist. The patients were also instructed to exhale slowly (Da Cunha et al., 2005). The stretching occurred throughout the expiratory phase allowing inspiratory muscles to reach their maximum length during the relaxation time. Two sets of 10 consecutive stretches were performed for each muscle, with a 30-s interval between the series. Only lateral chest stretching was performed in lateral decubitus, allowing for stretching of the lateral chain muscles at the moment of inspiration and accompanying the ribs during expiration (Postiaux, 2000).

The control intervention was assisted in a resting period of approximately 20 min (the average estimation of the stretching exercise) with patients sitting in a comfortable chair.

2.4. Optoelectronic plethysmography

An analysis of the ventilatory pattern and chest wall compartmental volumes was performed through optoelectronic plethysmography (OEP – BTS Bioengineering, Milan, Italy) with eight cameras; four positioned anterior and four posterior to the patient. According to the protocol of Aliverti and Pedotti (2003), 89 reflective markers were positioned by hypoallergenic adhesives on the anterior, lateral and posterior thoraco-abdominal wall.

Patients were positioned sitting with their feet kept on the floor, knees and hips at 90°, straight trunk, arms supported on an adapted pad and asked to spontaneously breathe without speaking or changing their posture during OEP data acquisition. After an adaptation period, data were recorded during 3 min of spontaneous quiet breathing and three slow vital capacity maneuvers, each composed by an inspiratory capacity (IC, from functional residual capacity to total lung capacity – TLC) followed by a full expiration from TLC to residual volume. The same protocol was applied before and after each intervention (control or RMS) on two different days.

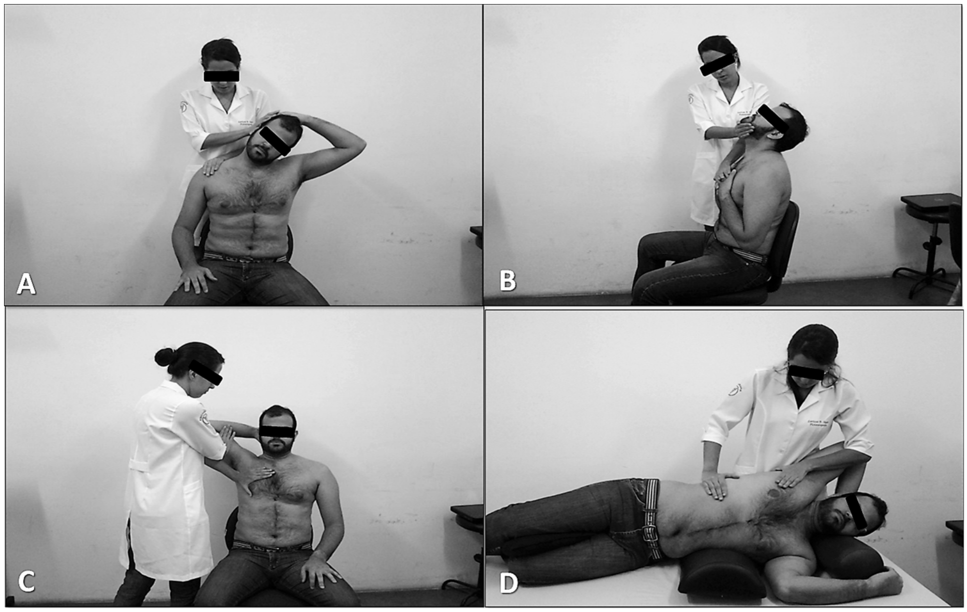

Fig. 1. Set of stretching exercises performed by the post-stroke patients with right hemiparesis.
A: Pattern 1: Neck stretching; B: Pattern 2: Upper chest stretching; C: Pattern 3: Pectoralis major stretching; and D: Pattern 4: Lateral chest stretching.

Tidal volumes of the different compartments (Vt,rcp- pulmonary rib cage, Vt,rca–abdominal rib cage, Vt,ab – abdomen), as well as their respective subdivisions in the right (Vt,rcp,r, Vt,rca,r and Vt,ab,r) and left (Vt,rcp,l, Vt,rca,l and Vt,ab,l) sides were determined as the difference between end-inspiratory volume and end-expiratory volume during quiet breathing. Total tidal volume (Vt,cw) was calculated as a sum of Vt,rcp + Vt,rca + Vt,ab. Tidal volumes of the right (Vt,cw,r) and left (Vt,cw,l) hemithorax were computed as Vt,cw,r = Vt,rcp,r + Vt,rca,r + Vt,ab,r and Vt,cw,l = Vt,rcp,l + Vt,rca,l + Vt,ab,l., respectively.

The following variables were determined to analyze the ventilatory pattern: total respiratory cycle time (Ttot), inspiratory time (Tinsp), expiratory time (Texp), Tinsp/Ttot ratio (duty cycle), respiratory rate (RR), minute ventilation (VE), mean inspiratory flow (MIF = Vt/Tinsp) and mean expiratory flow (MEF = Vt/Texp). Inspiratory capacity (IC) was calculated as the difference between the volume at TLC and average of end-expiratory volume of the three breaths preceding the last one before the maneuver. Vital capacity (VC) was determined as the difference between volumes at TLC and RV. The highest values of IC and VC were considered for subsequent analysis.

2.5. Statistical analysis

The sample size calculation was performed considering tidal volume data obtained in a pilot study involving six patients and using free software available on the internet (http://hedwig.mgh.harvard.edu/sample_size/size.html) developed by MGH Mallinckrodt General Clinical Research Center (Boston, USA). We considered a significance level of 95% ($p < .05$), 80% power, standard deviation obtained from the individual mean difference of Vt,cw generated by the difference between post-control and post-RMS = 0.094, and a minimum calculated detected difference (Weir, 2005) of 0.107 L. The sample size was estimated as 9 subjects according to these data.

Statistical analysis was based on: SigmaPlot software for Windows, version 12.0. Shapiro-Wilk Test and Equal Variance Test were performed to verify normality and homogeneity of the sample data, respectively. Two Way Repeated Measures ANOVA with post-hoc Holm-Sidak was performed on OEP data for normal and equal distribution, with intervention (RMS/control) and time (before/after) as factors. Friedman Repeated Measures Analysis of Variance on Ranks with post-hoc Tukey was performed when OEP data failed on the normality and homogeneity tests. All statistical tests were two-tailed, and data were expressed as the mean and standard deviation, mean change and confidence interval for differences between post-intervention data, considering $p < .05$ as significant.

3. Results

Ten post-stroke patients with right hemiparesis were analyzed; the anthropometric, clinical, pulmonary function and respiratory maximal pressure data are reported in Table 1. Two women and eight men with mean age of 60 ± 5.7 years completed the study protocol (Fig. 2). The patients presented FVC (pred%) = 74 ± 16, and FEV_1/FVC (pred %) = 106 ± 4.74, showing restrictive pulmonary disorder in some patients.

3.1. Ventilatory pattern

As shown in Table 2, RMS caused a significant increase in the VE (2.90 L/min, $p = .001$) due to the increase in Vt,cw (120 mL, $p = .029$) compared with the control intervention. RMS also showed a significant rise in Tinsp/Ttot ratio, Mean Inspiratory Flow and Mean Expiratory Flow (3.78, $p = .031$; 0.08 L/s, $p = .007$; and .13 L/s, $p = .002$, respectively).

No significant differences were found in Ttot, Tinsp, Texp or respiratory rate during quiet breathing. The control intervention did not show any significant alteration in ventilatory pattern (Table 2).

3.2. Chest wall volume distribution

The chest wall tidal volume analysis of the different compartments is shown in Table 3. A significant increase of 60 mL in the right hemithorax (with hemiparesis) was found ($p = .006$) after RMS intervention compared with the control intervention. Pulmonary rib cage presented a significant increase of 50 mL after RMS, 30 mL from the right pulmonary rib cage with hemiparesis ($p = .028$ and $p = .041$, respectively). No significant changes were found after the control intervention.

No significant differences in VC and IC were observed after either intervention (Fig. 3).

Table 1
Anthropometric, clinical, pulmonary function and respiratory muscle data.

Variables	Mean (SD)
Sex (F/M)	2/8
Age (years)	60 (5.7)
Height (m)	1.62 (.07)
Weight (Kg)	75 (10)
BMI (kg/m^2)	28 (3.0)
Stroke time from last (months)	62 (58)
Barthel Index	98 (3.5)
MEEM	27 (3.5)
Ashworth Scale (shoulder, n)	
1	3
+1	3
2	1
3	3
VC (L)	2.90 (.65)
IC (L)	2.47 (.61)
FEV_1(L)	2.51 (.49)
FEV_1 ($\%_{pred}$)	82 (13)
FVC (L)	2.93 (.56)
FVC ($\%_{pred}$)	74 (16)
FEV_1/FVC	86 (3.33)
FEV_1/FVC ($\%_{pred}$)	106 (4.74)
PEF (L/s)	5.12 (1.69)
PEF ($\%_{pred}$)	53 (13)
MIP (cmH_2O)	80 (30)
MIP ($\%_{pred}$)	78 (25)
MEP (cmH_2O)	93 (40)
MEP ($\%_{pred}$)	84 (30)

F: females; M: males; BMI: body mass index; MIP: maximal inspiratory pressure; MEP: maximal expiratory pressure; MEEM: mini mental state examination; VC: vital capacity; IC: inspiratory capacity; FEV_1: forced expiratory volume in the first second; FVC: forced vital capacity; PEF: peak expiratory flow; % pred: percentage from the predicted value.

4. Discussion

Several abnormalities can be found in post-stroke subjects due to the presence of hemiplegia or hemiparesis; these include reduced chest wall expansion and pulmonary function alterations (Billinger et al., 2012; Lanini et al., 2003; Teixeira-Salmela et al., 2005). Previous studies have shown that a restrictive pulmonary pattern occurs in these patients, probably due to the limited respiratory movements that make the chest wall and abdominals expand (Marcucci et al., 2007; Parreira et al., 2003). This has been confirmed in our small sample of patients, who showed lower FEV_1 and FVC values, but not FEV_1/FVC, clearly suggesting a restrictive pattern (Miller, 2008).

In this study, we demonstrate that respiratory muscle stretching is able to promote changes in the ventilatory pattern, namely by augmenting tidal volume, minute ventilation, Tinsp/Ttot ratio, mean inspiratory and mean expiratory flows, and by increasing chest wall volume displacement, especially in the right hemiparetic side of the pulmonary rib cage.

These results can be explained by biomechanical improvements such as: 1) spasticity adequacy in the hemiparetic side through reduced motor neuronal excitability during muscle stretching (Smania et al., 2010), 2) muscle length increase due to the effective muscular contraction during breathing (Leelarungrayub, 2012), and 3) improvements in chest wall compliance resulting in a load reduction imposed on the respiratory system, also improving diaphragm action (Leelarungrayub, 2012).

The increase of tidal volume observed after RMS due to the increase of pulmonary rib cage can therefore be explained by improvements in the chest wall mobility, especially in the affected hemithorax (Da Cunha et al., 2005; Ito et al., 1999; Minoguchi et al., 2002; Smania et al., 2010).

Interestingly, the increase in minute ventilation, mean inspiratory and mean expiratory flows was only related to the higher tidal volume with no changes in respiratory rate or in the respiratory times (Tinsp,

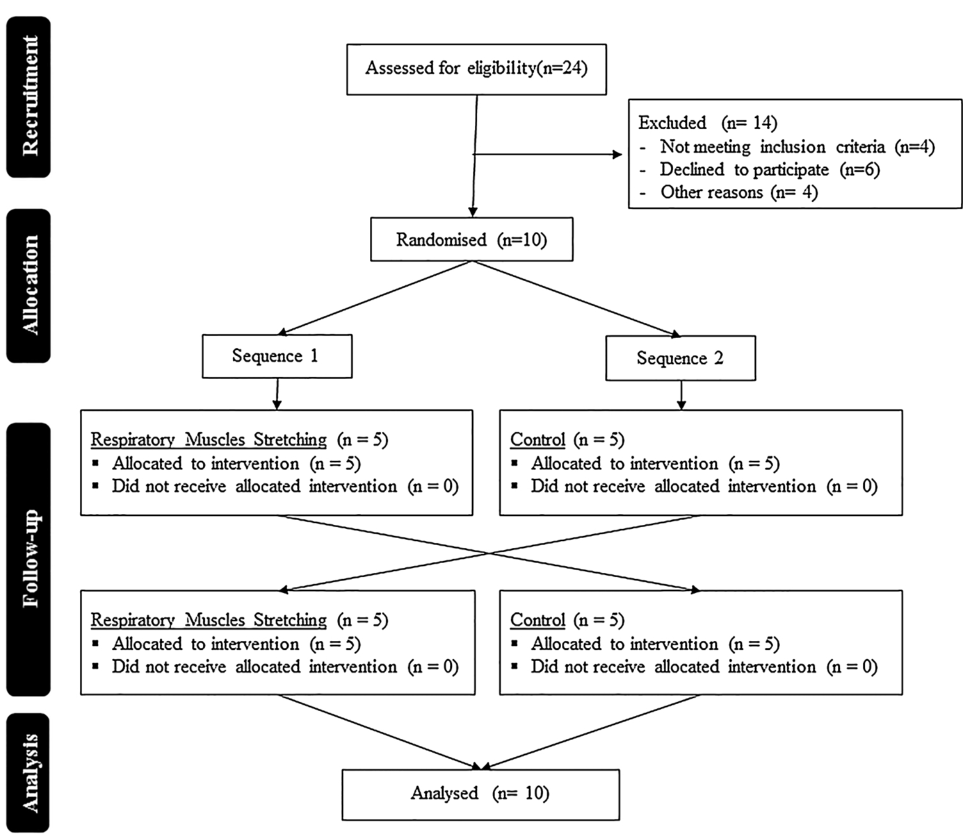

Fig. 2. Study flow chart.

Table 2
Ventilatory pattern during quiet breathing before and after interventions.

Variables	Interventions				Intra-intervention difference		Differences between interventions	Interventions X Time Effect *P* Value
	Before		After		After − Before		After − After	
	Control (n = 10)	RMS (n = 10)	Control (n = 10)	RMS (n = 10)	Control	RMS	RMS − Control	
V_T (L)	0.47 (0.09)	0.46 (0.09)	0.45 (0.11)	0.55 (0.14)	- 0.03 (0.06)	0.09 (0.09)	0.12 (0.06–0.18)	0.029
P Value	–	–	–	–		*< .05*	*< .05*	
Ttot	3.47 (0.87)	3.46 (0.85)	3.57 (1.02)	3.33 (0.88)	0.10 (0.55)	−0.13 (0.31)	- 0.23 (-0.65 to 0.19)	0.248
P Value	–	–	–	–				
Tinsp	1.46 (0.35)	1.46 (0.41)	1.54 (0.49)	1.53 (0.44)	0.07 (0.24)	0.06 (0.21)	-0.01 (-0.23 to 0.21)	0.916
P Value	–	–	–	–				
Texp	2.00 (0.58)	1.99 (0.47)	2.03 (0.57)	1.8 (0.53)	0.03 (0.42)	−0.19 (0.22)	-0.22 (-0.48 to 0.04)	0.088
P Value	–	–	–	–				
Tinsp/Ttot	43 (4.97)	43 (2.95)	43 (4.33)	46 (6.78)	0.29 (4.70)	4.07 (5.37)	3.78 (0.42–7.14)	0.031
P Value	–	–	–	–	*0.860*	*0.024*	*0.022*	
BR	18 (3.66)	18 (4.26)	18 (4.44)	19 (4.04)	- 0.29 (3.00)	0.73 (1.69)	1.02 (-1.18 to 3.21)	0.321
P Value	–	–	–	–				
VE	8.5 (1.82)	8.2 (1.5)	7.8 (2.10)	10.4 (3.5)	−0.72 (1.69)	2.18 (2.24)	2.90 (1.47–4.33)	0.001
P Value	–	–	–	–	*0.271*	*0.004*	*< .001*	
MIF	0.34 (0.07)	0.33 (0.05)	0.30 (0.07)	0.38 (0.10)	−0.03 (0.05)	0.05 (0.07)	0.08 (0.02–0.15)	0.007
P Value	–	–	–	–			*< .05*	
MEF	0.26 (0.07)	0.24 (0.05)	0.24 (0.08)	0.35 (0.17)	−0.02 (0.07)	0.10 (0.13)	0.13 (0.06–0.19)	0.002
P Value	–	–	–	–	*0.586*	*0.007*	*< .001*	

Data expressed as the mean (Standard Deviation) or Mean Change (Confidence Interval of 95%).; Vt: tidal volume; Ttot; total time; Tinsp: inspiratory time; Texp: expiratory time; Tinsp/Ttot: inspiratory time and duty cycle index; BR: breathing rate; VE: minute ventilation; MIF: mean inspiratory flow; MEF: mean expiratory flow. Interventions X Time Effect P Value: Two Way Repeated Measures ANOVA or Friedman Repeated Measures Analysis of Variance on Ranks. *P Value*: post-hoc Holm-Sidak Test or post-hoc Tukey Test.

Table 3
Distribution of tidal volume in the different compartments considering the hemithorax sides during quiet breathing before and after interventions.

Variables	Interventions				Intra-interventions difference		Differences between interventions	Interventions X Time Effect *P* Value
	Before		After		After − Before		After − after	
	Control (n = 10)	RMS (n = 10)	Control (n = 10)	RMS (n = 10)	Control	RMS	RMS − Control	
Vt. cw	0.47 (0.09)	0.46 (0.09)	0.45 (0.11)	0.55 (0.14)	−0.03 (0.06)	0.09 (0.09)	0.12 (0.06–0.18)	0.029
P value	–	–	–	–		*< .05*	*< .05*	
Vt.cw.r	0.25 (0.05)	0.24 (0.05)	0.24 (0.05)	0.28 (0.07)	−0.01 (0.04)	0.04 (0.06)	0.06 (0.01–0.10)	0.006
P value	–	–	–	–		*< .05*	*< .05*	
Vt.cw.l	0.22 (0.07)	0.22 (0.06)	0.21 (0.07)	0.27 (0.10)	−0.01 (0.04)	0.05 (0.09)	0.06 (0.01–0.12)	0.126
P value	–	–	–	–				
Vt. rcp	0.14 (0.04)	0.14 (0.07)	0.12 (0.03)	0.17 (0.08)	−0.02 (0.03)	0.03 (0.06)	0.05 (0.01–0.09)	0.028
P value	–	–	–	–	*0.299*	*0.037*	*0.032*	
Vt. rcp.r	0.07 (0.02)	0.07 (0.03)	0.07 (0.02)	0.09 (0.05)	−0.01 (0.02)	0.02 (0.04)	0.03 (0.00–0.06)	0.041
P value	–	–	–	–	*0.614*	*0.023*	*0.030*	
Vt. rcp.l	0.06 (0.03)	0.07 (0.04)	0.05 (0.02)	0.08 (0.04)	−0.01 (0.02)	0.01 (0.03)	0.02 (-0.00 to 0.04)	0.096
P value	–	–	–	–				
Vt.rca	0.06 (0.02)	0.07 (0.03)	0.06 (0.03)	0.08 (0.04)	0.01 (0.02)	0.00 (0.02)	-0.00 (-0.02 to 0.01)	0.761
P value	–	–	–	–				
Vt.rca.r	0.03 (0.01)	0.04 (0.02)	0.03 (0.01)	0.04 (0.02)	0.00 (0.01)	0.00 (0.01)	-0.00 (-0.01 to 0.01)	0.848
P value	–	–	–	–				
Vt.rca.l	0.03 (0.01)	0.03 (0.02)	0.03 (0.02)	0.04 (0.02)	0.01 (0.01)	0.00 (0.01)	-0.00 (-0.01 to 0.01)	0.888
P value	–	–	–	–				
Vt.ab	0.28 (0.10)	0.25 (0.08)	0.27 (0.09)	0.30 (0.11)	−0.01 (0.06)	0.05 (0.08)	0.07 (0.01–0.12)	0.058
P value	–	–	–	–				
Vt.ab.r	0.15 (0.06)	0.13 (0.05)	0.14 (0.05)	0.15 (0.05)	−0.01 (0.03)	0.02 (0.04)	0.03 (-0.00 to 0.06)	0.075
P value	–	–	–	–				
Vt.ab.l	0.13 (0.06)	0.12 (0.05)	0.13 (0.05)	0.15 (0.07)	−0.01 (0.03)	0.03 (0.06)	0.04 (0.01–0.08)	0.293
P value	–	–	–	–				

Data expressed as the mean (Standard Deviation) or Mean Change (Confidence Interval of 95%). Vt,cw: total tidal volume; Vt,cw,r: volume of right chest wall; Vt,cw,l: volume of left chest wall; Vt,rcp: volume of pulmonary rib cage; Vt,rcp,r: volume of right pulmonary rib cage; Vt,rcp,l: volume of left pulmonary rib cage; Vt,rca: volume of abdominal rib cage; Vt,rca,r: volume of right abdominal rib cage; Vt,rca,l: volume of left abdominal rib cage; Vt,ab: volume of abdomen compartment; Vt,ab,r: volume of right abdominal compartment; Vt,ab,l: volume of left abdominal compartment. Interventions X Time Effect P Value: Two Way Repeated Measures ANOVA or Friedman Repeated Measures Analysis of Variance on Ranks. *P Value*: post-hoc Holm-Sidak Test or post-hoc Tukey Test.

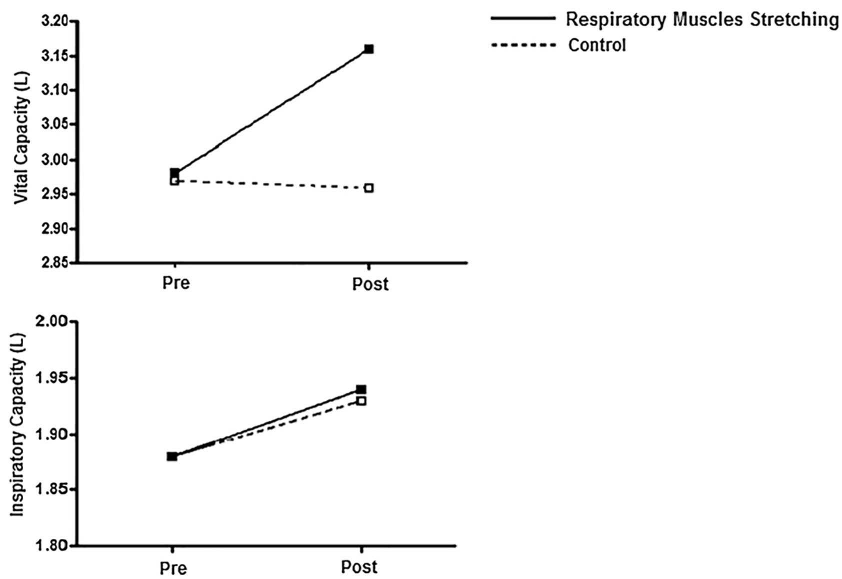

Fig. 3. Values of vital capacity and inspiratory capacity before and after intervention.

Texp and Ttot) (Da Cunha et al., 2005). The acute effects of RMS found in the present study involve spontaneous breathing, but not IC or VC; thus, RMS is presumably able to affect chest wall compliance only in the range of volumes occurring just above Functional residual capacity, but not in the range below TLC. To the best of our knowledge, no studies have been performed investigating IC and VC variations due to RMS in post-stroke patients.

However, there are studies which used different strategies to stretch the respiratory muscles in chronic obstructive pulmonary disease patients that demonstrated beneficial effects of RMS on the respiratory system, namely increased chest wall mobility, reduced pulmonary hyperinflation, reduced accessory muscle tension, a reduction in dyspnea sensation and overall improvement in pulmonary function (Da Cunha et al., 2005; Leelarungrayub, 2012; Leelarungrayub et al., 2009; Minoguchi et al., 2002; Putt et al., 2008; Yamada et al., 1996). These studies only suggest that this type of intervention should be considered during the rehabilitation program for those patients, but do not propose a standard intervention.

A limitation of the present study is the small number of patients due to the difficulty in selecting patients in accordance with the strict limitations of the inclusion criteria necessary to have a homogeneous group to study.

In conclusion, respiratory muscle stretching is able to promote acute increases in the tidal volume and hemiparetic rib cage expansion in post-stroke subjects with right hemiparesis, and should be considered in the rehabilitation programs of these patients.

Summary conflict of interest statements

There is no conflict of interest for all authors.

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