Comparison of distinct incentive spirometers on chest wall volumes, inspiratory muscular activity and thoracoabdominal synchrony in the elderly

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ABSTRACT

The aging process is characterized by physiological and functional modifications that impair pulmonary function. Incentive spirometry (IS) has been widely used in clinical practice for lung expansion; however, the effects of volumetric IS (VIS) and flow-oriented IS (FIS) on chest wall volumes, inspiratory muscular activity and thoracoabdominal synchrony in elderly are poorly understood. **Objective:** To compare the effects of VIS and FIS on chest wall volumes and thoracoabdominal synchrony, as well as on inspiratory muscular activity, in elderly subjects and in normal healthy adult subjects. **Methods:** Sixteen elderly subjects (9 women, 70.6 ± 3.9 yrs, 23.8 ± 2.5 kg/m^2) and sixteen normal healthy adults (8 women, 25.9 ± 4.3 yrs, 23.6 ± 2.4 kg/m^2) performed quiet breathing, VIS and FIS (randomized sequence). Chest wall kinematics (optoelectronic plethysmography) and inspiratory muscular activity (surface electromyography) were assessed simultaneously. Synchrony between the superior thorax and abdominal motion was calculated (phase angle). ANOVA with the post hoc test of Holm-Sidak was used, and the significance level was set at 5%. **Results:** In the elderly, both types of IS increased chest wall volumes similarly while in normal healthy adult subjects VIS induced greater chest wall volume than FIS. In addition, FIS and VIS triggered similar lower thoracoabdominal synchrony in elderly while in normal healthy adults FIS induced lower synchrony than VIS. At last, FIS required augmented muscular activity in elderly subjects to promote an increase in chest wall volumes. **Conclusion**: We conclude that performance during the use of incentive spirometer is influenced by age. We also present differences between elderly

and normal healthy adult subjects in response to this therapy that should be considered in clinical practice.

INTRODUCTION

The aging process is associated with a progressive reduction in physiological capacity, which can compromise several organs and systems, thus resulting in impairment of their functions. In the respiratory system, age-related functional changes result from a decrease in the static elastic recoil of the lungs, chest wall compliance and respiratory muscle strength [1-3]. This decrease in the static elastic recoil of the lungs is related to changes in the quantity and composition of the supporting structures within the lung parenchyma [4].

The reduced physiological capacity of the respiratory system with aging can predispose vulnerable individuals to an increased risk for respiratory diseases, such as respiratory insufficiency, atelectasis and respiratory infections [5,6]. Some breathing exercises are commonly used in the treatment and prevention of these patterns related to the physiological aging processes that affect respiratory performance.

Incentive spirometry (IS) is a type of deep breathing exercise and it is widely used in clinical practice for lung expansion and the prevention of pulmonary complications in children, adults and the elderly [7,8]. Two types of IS are commercially available, volume- (VIS) and flow (FIS)-oriented incentive spirometers, and they are used to encourage subjects to breathe as nearly as possible of their total lung capacity through maximal inspiration aided with visual feedback. These maneuvers lead to an increase in transpulmonary pressure and, therefore, an increase in chest wall volume [9].

Parreira et al (2005)[10] and Paisani et al (2013)[11] showed that VIS promotes a greater chest wall volume with a larger abdominal contribution

compared to FIS in healthy adult subjects. In addition, Chang et al (2010)[7] and Parreira et al (2005)[10] suggested that the inspiratory flow rate rather than the type of IS determines the breathing pattern and the respiratory muscle activation in this population [7,10]. However, to the best of our knowledge, the effects of VIS and FIS in the elderly subjects have not been evaluated and remain unknown.

The aim of this study was to compare the effects of VIS and FIS on chest wall volume and thoracoabdominal synchrony, as well as on inspiratory muscular activity, in the elderly.

METHODS

Design: We conducted a randomized controlled clinical trial. The study was approved by the Hospital Research Ethics Committee (protocol number 606/11), and all of the subjects provided written informed consent.

Participants: We recruited 22 healthy elderly (aged >65 years) and 18 normal healthy adult (aged <40 years), matched by body mass index (BMI) and height, from a university population. The exclusion criteria were deformities of the chest wall or spine, the presence of pulmonary (FEV_1 or FVC <80% predicted or $FEF_{25-75\%}$ < 60% predicted) [11], any respiratory symptoms (dyspnea, coughing, breathlessness) or cardiac disease and current smoking (Figure 1).

Study protocol: The assessment of thoracoabdominal kinematics and inspiratory muscle activity was performed during quiet breathing followed by either VIS or FIS, guided by a respiratory therapist. The order of use (VIS or FIS) was randomly determined and was placed in sealed envelopes that were numbered sequentially by an independent researcher. All of the subjects performed 8 quiet breaths followed by 8 deep breaths, using FIS and VIS in the order specified by the randomization, with an interval of at least 2 minutes between the devices. During IS the subject was asked to perform 8 breaths with a slow inhalation to raise the ball (FIS) or the piston plate (VIS) and to sustain the inflation for at least five seconds, followed by normal exhalation [12,13]; an average of 6 homogeneous respiratory cycles was considered for the data analysis performed by a bioengineer. The chest wall volumes and inspiratory muscular activity outcomes were assessed concurrently.

Respiratory therapy resources: Respiron® (NCS, Brazil) and Voldyne 5000® (Hudson RCI, USA) were used to evaluate FIS and VIS, respectively. This choice was influenced by the fact that these devices are commonly used in clinical practice. Respiron is a flow-oriented incentive spirometer. During inspiration, the subject makes the ball in the column of the instrument rise and keeps it suspended by sustained inspiratory flow; this process serves as visible feedback of the inspiratory flow. Voldyne is a volume-oriented incentive spirometer. During inspiration, the subject makes the piston plate rise and keeps it suspended, which serves as visible feedback of the inspiratory volume. All subjects were instructed to perform slow inhalation to raise the ball (FIS) or

the piston plate (VIS) and to sustain the inflation for at least five seconds, followed by normal exhalation [12].

Measurements:

1. Thoracoabdominal Kinematics

Thoracoabdominal kinematics were evaluated using optoelectronic plethysmography (OEP System, BTS, Italy), as previously described [12]. This equipment is based on eight special video cameras (solid-state charge-coupled devices) operating at 100 frames per second and synchronized with a flashing infrared light-emitting diode. Four cameras were positioned in front of the subject and four behind. Eighty-nine retro-reflective markers were placed on the anterior and posterior sides of the trunk, according to the protocol previously described by Aliverti et al (2009) [14]. Three-dimensional calibration of the equipment was performed, based on the manufacturer's recommendations. Next, to evaluate the thoracoabdominal kinematics around the chest wall, the assessment was performed with the subject seated on a wheelchair without back support. The following variables were measured.

  - *Total chest wall (CW) and compartmental volumes:* The OEP software (SMART) reconstructed the three-dimensional position of each marker during the experiment and computed by the mean the chest wall volumes with high accuracy. Algorithms computed the volume variations of the whole chest wall and the thoracic and abdominal compartments: the values for the upper and lower ribcage and abdomen were expressed as absolute values and percentages.

- *Inspiratory Flow rate:* The mean value of the inspiratory flow rate was quantified dividing the total chest wall volumes by the total inspiratory time.

- *Time variables:* The mean values of the inspiratory time (Ti) and total time (Ttot), as well as the inspiratory duty cycle (Ti/Ttot), were quantified based on each respiratory cycle.

- *Thoracoabdominal asynchrony (θ):* This value was obtained using a calculation of the upper ribcage to the abdominal phase angle, according to Agostoni et al (1966) [15]. The phase angle was calculated as the lag time between the peaks of the upper ribcage and the abdominal signals divided by the total cycle time multiplied by 360 degrees.

2. <u>Respiratory muscle activity</u>

The activity of the sternocleidomastoid and external superior and inferior intercostal muscles was assessed using electromyography signals (EMG BTS, Italy), which were obtained simultaneously with the thoracoabdominal kinematics.

a) *Electrode position*: Each probe was attached to two reusable bipolar superficial electrodes, consisting of Ag/AgCl material and a conductive adhesive hydrogel (Maxicor®, Brazil). The inter-electrode distance was 20 mm. To place the electrode, the skin was cleaned with an alcohol swab at the sites of attachment to remove oils from the contact surface, thus decreasing the impedance of the skin. Superficial electrodes were fixed on the muscle belly, away from the motor point and parallel to the direction of the muscle fibers, in

accordance with the European standards for surface EMG of the non-invasive assessment of muscles [16]. The right sternocleidomastoid (RSL) electrode was placed on the muscular body, 5 cm from the mastoid process[17]. For the external intercostal muscle of the right upper ribcage (RIC), the electrode was placed on the 2nd anterior intercostal space [18]. For the external intercostal muscle of the left lower ribcage (LIC), electrodes were placed on the 7th and 8th anterior intercostal spaces[18]. All of the electrode positions were determined in accordance with the best signal capture, and the EMG analyses were performed as recommended by Hermens et al (2000)[16]. (Figure 2)

b) Data acquisition and processing: Signals were obtained using an eight-channel EMG module with wireless probes, which had an acquisition frequency of 1000 Hz. Each probe consisted of a mother electrode and a satellite electrode connected via a flexible cable, with each fitted with a clip. The mother electrode contained an A/D converter with a resolution of 16 bits, an antenna and a battery. The satellite electrode contained a signal-conditioning low-pass filter with a frequency of 500 Hz and an amplifier with a gain range of ±1.62 mV. All of the data were processed using dedicated software for acquisition and analysis (SMART).

In the post-processing stage, we applied a Butterworth high-pass filter with a cut-off frequency of 20 Hz; thus, the frequency range of the signal was set at 20-500 Hz. To detect the linear envelope of the EMG signal, the signal was full-wave rectified and low-pass filtered. The electrical activity of the sternocleidomastoid muscle and of the upper and lower intercostal muscles was measured using root mean square (RMS) values, and these values were expressed recorded in 10^{-3}mV.

Statistical analysis: The sample size calculation was performed considering the average difference in pulmonary volume generated by the VIS compared to FIS of 475 ml, with an average standard deviation of 15% (71 ml) and a power of 80% as the primary variables [10]. The sample size estimated was 16 subjects per group. The normality was tested with the Shapiro-Wilk test. The homoscedasticity between normal healthy adults and the elderly was tested using the t test. The analyses of differences between quiet breathing and breathing using IS within the groups were performed using ANOVA with the Holm-Sidak method post hoc. The significance level was set to 5%.

RESULTS

Sixteen elderly subjects and sixteen normal healthy adult subjects were evaluated, and all of the subjects presented normal lung function (Table 1).

Thoracoabdominal volumes

In elderly and normal healthy adult subjects, both FIS and VIS induced similar increases in the volume of the chest wall, superior and inferior thorax and abdominal compartments, compared to quiet breathing. However, in elderly subjects, both devices had the same effect, while in normal healthy adult subjects, VIS promoted a greater increase in the chest wall and abdominal compartments compared to FIS (Table 2). Percentage increase values of VIS and FIS in normal healthy adult and elderly subjects are presented in Figure 3.

Respiratory cycles, thoracoabdominal synchrony and inspiratory flow rate

In the elderly, the use of FIS or VIS did not promote any significant changes in the inspiratory time (Ti) or total cycle time (Ttot), compared to quiet breathing; however, in normal healthy adult subjects, the use of VIS promoted a higher inspiratory time and total cycle time, compared to FIS and quiet breathing (Table 2). In relation of the inspiratory flow rate, both groups presented higher rates during use of IS than during quiet breath but without difference between devices or groups (Table 2).

In the elderly, both IS types induced lower thoracoabdominal synchrony (higher values) compared to quiet breathing; however, in normal healthy adult subjects, only FIS promoted changes in thoracoabdominal synchrony (Table 2).

Inspiratory muscle activity

In elderly and normal healthy adult subjects, the electromyographic analysis of inspiratory muscles (sternocleidomastoid and superior and inferior intercostal muscles) did not show differences in the electrical activity of the intercostal muscles during the use of FIS and VIS (Table 2). However, the inspiratory muscles activity per chest wall volume was higher in the elderly during the use of FIS than in normal healthy adult subjects (Figure 4).

DISCUSSION

VIS and FIS have been widely used in clinical practice to reverse or prevent reductions in chest wall volumes, and the use of IS has been employed for normal healthy adult subjects and for the elderly as if the effect would be similarly independent of subject´s age. In normal healthy adults, previous

studies have reported that VIS induces greater chest wall expansion and abdominal displacement [10,11,19] and reduces inspiratory muscular activity [9,11,20] and breathing work [21,22], compared to FIS; however, to the best of our knowledge, the advice to use incentive spirometry has never been investigated in elderly subjects. This difference seems quite relevant because it is well known that aging leads to a reduction in chest wall compliance and decreases in the size and number of respiratory muscle fibers, as well as changes in thoracoabdominal motion [23] that can alter performance during the use of these devices.

Our data show that FIS required greater inspiratory muscle activity to generate similar volumes in the elderly compared to VIS, while in normal healthy adult subjects there was no difference in the effort using both devices (Figure 3). Our findings suggest that the subject's age must be considered when the use of an incentive spirometer is required. This information should be considered during clinical practice mainly when elderly subjects present any symptom or signal of respiratory muscle wasting. Interestingly, this increase in respiratory muscular activity was observed even in "healthy" elderly subjects, and it could be explained by the elderly having a reduced lung volumes and chest wall capacities [23,24], placing the diaphragm at a mechanical disadvantage in generating effective contraction [1,25].

We also showed that both types of incentive spirometry induced similar volumes and displacement in all thoracoabdominal compartments in the elderly, while in normal healthy adult subjects, VIS induced greater abdominal displacement than FIS [10,11]. Contrary to the findings of previous studies, normal healthy adult subjects did not present higher sternocleidomastoid muscle

activity during use of FIS [10,11]. A possible difference between the study results could be probably due to either difference in how the subjects were advised to perform IS or by different position for the electrodes electromyography. In our study, this was standardized and the same researcher oriented all subjects similarly and also positioned the electrodes. In addition, electrodes positioning was performed as previously described in the literature[17,18] and EMG signal capture analyses were performed according international guidelines[16].

We also observed that, contrary to what has been previously shown in normal healthy adult subjects[9,26], VIS and FIS induced similar inspiratory flow rate and reduced similarly thoracoabdominal synchrony in the elderly. Interestingly, we also observed that the elderly displayed a shorter inspiratory total time than normal healthy adult subjects that can be explained by physiological changes in the lung and respiratory system related to aging requiring greater inspiratory muscle activity that can lead to reduced thoracoabdominal synchrony (higher values). Our hypothesis is supported by the findings that the total inspiratory time in normal healthy adult subjects was twice than those observed in the elderly (Table 2), and as a consequence, the elderly cannot expand their chest wall using VIS as much as normal healthy adult subjects can.

Our study had some limitations. First, the effects of IS were evaluated in subjects with normal lung function; however, our research group is conducting studies in different populations to increase the practical applicability of IS. Second, muscular activity was evaluated using surface electromyography, and there is no consensus about electrode positioning for the respiratory muscles; in our study, the electrodes were placed according to previous studies performed

by experts in this field. In contrast, we used novel technology in the present study for thoracoabdominal analysis, and it is the only available equipment that allows for the simultaneous measurement of volume displacement and respiratory muscular activity.

Our results provide important information using IS in clinical practice, despite the prevention and treatment of respiratory complications using these devices as mono therapy remains poorly understood[27]. In addition, it might be also important for future studies to evaluate the use of IS either as unique therapy or associated with other respiratory care techniques in different clinical situations in order to properly recommend the appropriate therapy for elderly.

Conclusions: We conclude that both incentive spirometers have similar effects in increasing chest wall and compartmental volumes in the elderly, but the flow-oriented spirometer requires greater inspiratory muscular activity. Therefore, the proper use of better IS for these individuals should consider the age and clinical condition of the subject, as well as the goal of therapy.

REFERENCES

1. Janssens JP, Pache JC, Nicod LP. Physiological changes in respiratory function associated with age. European Respiratory Journal 1999;13(1):197-205.

2. Watsford ML, Mark L, Murphy AJ, Pine MJ. The effects of ageing on respiratory muscle function and performance in older adults. Journal of Science and Medicine in Sport 2007;10(1):36-44.

3. Fragoso CAV, Gill TM, McAay G, Yaggi HK, Van Ness PH, Concato J. Respiratory impairment and mortality in older persons: A novel spirometric approach. Journal of Investigative Medicine 2011;59(7):1089-95.

4. Meyer FJ, Lossnitzer D, Kristen AV, Schoene AM, Kubler W, Katus HA, Borst MM. Respiratory muscle dysfunction in idiopathic pulmonary arterial hypertension. European Respiratory Journal 2005;25(1):125-30.

5. Sprung J, Gajic O, Warner DO. Review article: age related alterations in respiratory function - anesthetic considerations. Canadian Journal of Anesthesia 2006;53(12):1244-57.

6. Fernandes CR, Ruiz Neto PP. The respiratory system and the elderly: anesthetic implications. Revista Brasileira de Anestesiologia 2002;52(4):461-70.

7. Chang AT, Palmer KR, McNaught J, Thomas PJ. Inspiratory flow rate, not type of incentive spirometry device, influences chest wall motion in healthy individuals. Physiotherapy: Theory and Practice 2010;26(6):385-92.

8. Qaseem A, Snow V, Fitterman N, Hornbake ER, Lawrence VA, Smetana GW, Weiss K, Owens DK, Aronson M, Barry P, Casey DE Jr, Cross JT Jr, Fitterman N, Sherif KD, Weiss KB. Risk assessment for and strategies to

reduce perioperative pulmonary complications for patients undergoing noncardiothoracic surgery: a guideline from the American College of Physicians. Annals of Internal Medicine 2006;144(8):575-80.

9. Tomich GM, França DC, Diório ACM, Brito RR, Sampaio RF, Parreira VF. Breathing pattern, thoracoabdominal motion and muscular activity during three breathing exercises. Brazilian Journal of Medical Biological Research 2007;40(10):1409-17.

10. Parreira VF, Tomich GM, Brito RR, Sampaio RF. Assesment of tidal volume and thoracoabdominal motion using volume and flow-oriented incentive spirometers in healthy subjects. Brazilian Journal of Medical and Biological Research 2005;38(7):1105-11.

11. Paisani DM, Lunardi AC, Marques da Silva CCB, Porras DC, Tanaka C, Carvalho CRF. Volume rather than flow incentive spirometry is effective in improving chest wall expansion and abdominal displacement using optoelectronic plethysmography. Respiratory Care 2013 (in press).

12. Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, et al. ATS/ERS Task Force. Standardisation of spirometry. European Respiratory Journal 2005;26(2):319-38.

13. Restrepo RD, Wettstein R, Wittnebel L, Tracy M. Incentive Spirometry: 2011. Respiratory Care 2011;56(10):1600-4.

14. Aliverti A, Carlesso E, Raffaele Dellacà R, Pelosi P, Chiumello D, Pedotti A, Gattinoni L. Chest wall mechanics during pressure support ventilation. Critical Care 2006;10(2):1-10.

15. Aliverti A, Quaranta M, Chakrabarti B, Albuquerque ALP, Calverley PM. Paradoxical movement of the lower ribcage at rest and during exercise in COPD patients. European Respiratory Journal 2009;33(1):49-60.

16. Agostoni E, Mognoni P. Deformation of the chest wall during breathing efforts. Journal of Applied Physiology 1966; 21(6):1827-32.

17. Hermens HJ, Freriks B, Disselhorst-Klug C, Rau G. Development of recommendations for SEMG sensors and sensor placement procedures. Journal of Electromyography Kinesiology 2000;10(5):361-74.

18. Kallenberg LA, Preece S, Nester C, Hermens HJ. Reproductibility of MUAP properties in array surface EMG recordings of the upper trapezius and sternocleidomastoid muscle. Journal of Electromyography and Kinesiology 2009;19(6):536-42.

19. Maarsingh EJ, van Eykern LA, Sprikkelman AB, Hoekstra MO, van Aalderen WM. Respiratory muscle activity measured with a noninvasive EMG technique: technical aspects and reproducibility. Journal of Applied Physiology 2000;88(6):1955-61.

20. Ho SC, Chiang LL, Cheng HF, Lin HC, Sheng DF, Kuo HP, Lin HC. The effect of incentive spirometry on chest expansion and breathing work in patients with chronic obstructive airway diseases: comparison of two methods. Chang Gung Medicine Journal 2000;23(2):73-9.

21. Weindler J, Kiefer RT. The efficacy of postoperative incentive spirometry is influenced by the device-specific imposed work of breathing. Chest 2001;119(6):1858-64.

22. Mang H, Obermayer A. Imposed work of breathing during sustained maximal inspiration: Comparison of six incentive spirometers. Respiratory Care 1989;34:1122-8.

23. Verschakelen JA, Demedts MG. Normal thoracoabdominal motions. Influence of sex, age, posture, and breath size. American Journal of Respiratory and Critical Care Medicine 1995;151(2 Pt 1):399-405.

24. Kim J, Sapienza CM. Implications of expiratory muscle strength training for rehabilitation of the elderly: Tutorial. Journal of Rehabilitation Research and Development 2005;42(2):211-24.

25. Sharma G, Goodwin J. Effect of aging on respiratory system physiology and immunology. Journal of Clinical Interventions in Aging 2006;1(3):253-60.

26. Chan ED, Welsch CH. Geriatric respiratory medicine. Chest 1998;114(6):1704-33.

27. Carvalho CRF, Paisani DM, Lunardi AC. Incentive spirometry in major surgeries: a systematic review. Brazilian Journal of Physical Therapy 2011;15(5):343-50.

FIGURE LEGENDS

Figure 1. Flow diagram of elderly and normal healthy adults subjects recruitment.

Figure 2. Diagram of the electrode placement. RSL= right sternocleidomastoid muscle; LIC=external superior intercostal muscle; RIC= external inferior intercostal muscle.

Figure 3. Comparison of total lung volume and thoracoabdominal compartments during the use of volume- (VIS) and flow-oriented (FIS) incentive spirometer in normal healthy adults (Adu) and elderly (Eld) subjects. QB=quiet breathing; STX=superior thorax; ITX=inferior thorax; ABD=abdomen; CW=chest wall; *$p<0.05$ when comparing VIS to FIS in normal healthy adult subjects.

Figure 4: Muscular activity per inspired chest wall volume. The results represent the ratio of total respiratory muscular activity to total inspired lung volume in elderly and normal healthy adult subjects; QB=quiet breathing; FIS=flow-oriented incentive spirometry; VIS=volumetric-oriented incentive spirometry; RMS=sum of inspiratory muscle activity; CW=chest wall volume; [&]$p<0.05$=compared to QB and VIS; *$p<0.05$=compared to FIS and VIS in elderly subjects.

Table 1: Characterization of elderly and normal healthy adult subjects evaluated (n=32)

Variables	Elderly (n=16)	Adult (n=16)	P
Male	7 (44%)	8 (50%)	0.78
Age, years	70.6 ± 2.3	25.9 ± 4.7	<0.001
BMI, kg/m²	23.8 ± 2.5	23.6 ± 2.4	0.82
Height, cm	1.67 ± 0.05	1.67 ± 0.10	0.99
FVC %predicted	101 ± 19	105 ± 12	0.48
FEV_1 %predicted	113 ± 21	104 ± 10	0.13
FEV_1/FVC	88 ± 9	85 ± 5	0.25

Legend: data are presented as means ± SDs or as percentages; BMI=body index mass, FEV_1=forced expiratory volume after one second; FVC=forced vital capacity

Table 2: Respiratory variables and muscular activity during quiet breathing and during the use of FIS and VIS by normal healthy adult and elderly subjects.

	Elderly (n=16)			Adult (n=16)		
	QB	FIS	VIS	QB	FIS	VIS
Volume (*L*)						
CW	0.50 ± 0.26	1.23 ± 0.61*	1.38 ± 0.74*	0.66 ± 0.20	2.25 ± 1.04#	2.84 ± 1.20# &
STX	0.14 ± 0.10	0.35 ± 0.19*	0.39 ± 0.21*	0.24 ± 0.12	0.89 ± 0.45#	1.07 ± 0.63#
ITX	0.08 ± 0.05	0.29 ± 0.19*	0.29 ± 0.20*	0.14 ± 0.07	0.55 ± 0.28#	0.68 ± 0.36#
ABD	0.29 ± 0.18	0.60 ± 0.36*	0.71 ± 0.46*	0.28 ± 0.09	0.82 ± 0.48#	1.09 ± 0.14# &
Time (*s*)						
Inspiratory	1.61 ± 0.57	1.66 ± 0.82	1.93 ± 1.24	2.12 ± 0.92	2.37 ± 1.15	3.55 ± 2.57# &
Total	3.61 ± 0.87	3.50 ± 2.21	4.30 ± 2.24	4.95 ± 1.21	5.51 ± 2.72	8.32 ± 4.16# &
Inspiratory/Total (%)	0.44 ± 0.07	0.49 ± 0.06	0.44 ± 0.10	0.43 ± 0.11	0.43 ± 0.07	0.39 ± 0.10
Inspiratory flow rate (L/*s*)						
CW/Inspiratory time	0.31 ± 0.10	0.78 ± 0.23*	0.80 ± 0.35*	0.34 ± 0.13	0.99 ± 0.28#	0.94 ± 0.45#
Synchrony (*θ*)						
STX x ABD	4.72 ± 3.73	17.65 ± 14.63*	10.63 ± 7.91*	7.25 ± 10.9	29.40 ± 29.9#	11.94 ± 12.4&
Muscular activity ($10^{-3}mV$)						
RSL	5.20 ± 1.8	48.64 ± 24.3*	33.9 ± 24.61* ⊤	4.45 ± 1.90	33.74 ± 32.1#	30.9 ± 25.4#
RIC	9.19 ± 7.3	19.36 ± 10.3*	15.82 ± 9.80*	5.59 ± 1.60	21.76 ± 22.7#	19.9 ± 25.4#
LIC	6.34 ± 2.6	11.57 ± 7.2*	11.69 ± 6.30*	6.79 ± 3.40	15.36 ± 8.9#	14.6 ± 8.5#

Legend: data are presented as the means ± SDs; QB=quiet breathing; FIS=flow-oriented incentive spirometry; VIS=volumetric-oriented incentive spirometry; CW=chest wall; STX=superior thorax; ITX=inferior thorax; ABD=abdomen; s=seconds; θ=phase angle;

RSL=right sternocleidomastoid; RIC=right intercostal; LIC=left intercostal; RMS=root mean square; *$p < 0.05$ compared with quiet breathing in the elderly group; ^{T} $p < 0.05$ compared with FIS in the elderly group; #$p < 0.05$ compared with quiet breathing in the normal healthy adult group; &$p < 0.05$ compared with FIS in the normal healthy adult group.
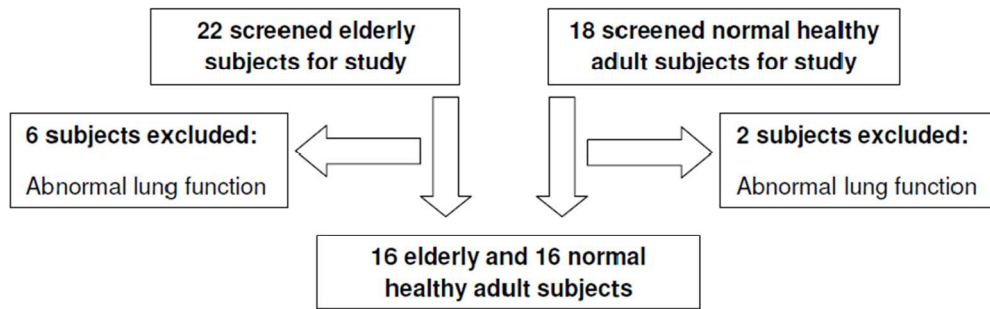
Figure 1. Flow diagram of elderly and normal healthy adults subjects recruitment.
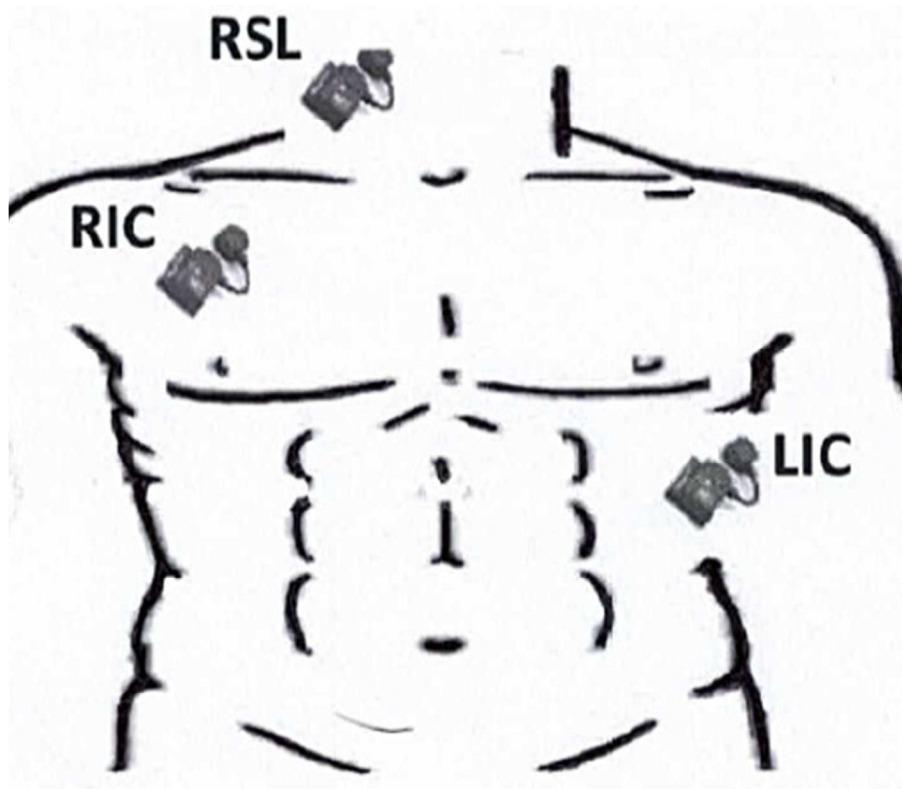236x78mm (96 x 96 DPI)

Figure 2. Diagram of the electrode placement. RSL= right sternocleidomastoid muscle; LIC=external superior intercostal muscle; RIC= external inferior intercostal muscle.
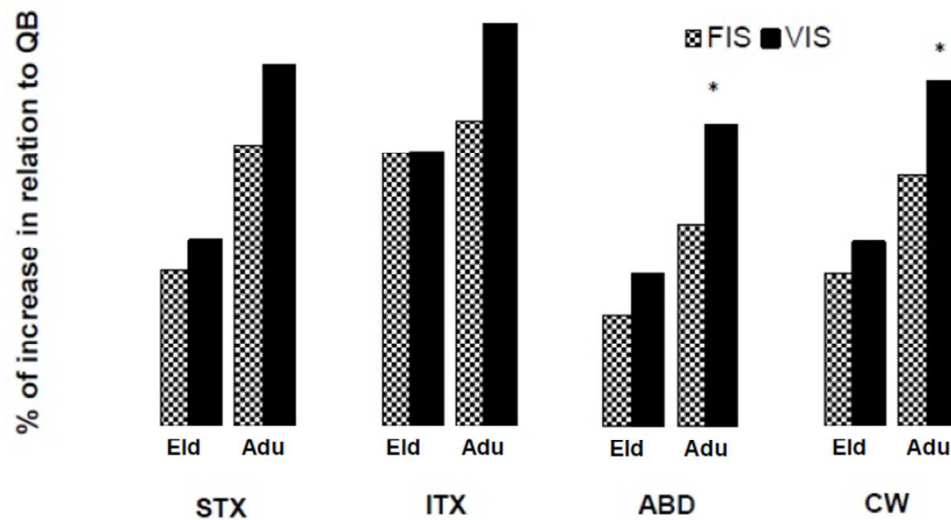120x105mm (96 x 96 DPI)

Figure 3. Comparison of total lung volume and thoracoabdominal compartments during the use of flow-(FIS) and volume-oriented (VIS) incentive spirometer in normal healthy adults (Adu) and elderly (Eld) subjects. QB=quiet breathing; STX=superior thorax; ITX=inferior thorax; ABD=abdomen; CW=chest wall; *p<0.05 when comparing VIS to FIS in normal healthy adult subjects.
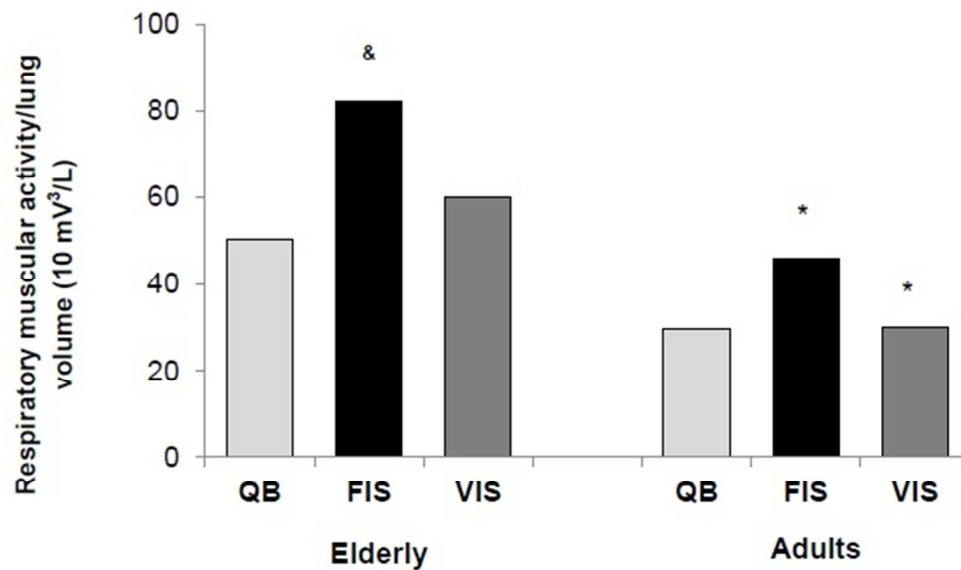202x115mm (96 x 96 DPI)

Figure 4: Muscular activity per inspired chest wall volume. The results represent the ratio of total respiratory muscular activity to total inspired lung volume in elderly and normal healthy adult subjects; QB=quiet breathing; FIS=flow-oriented incentive spirometry; VIS=volumetric-oriented incentive spirometry; RMS=sum of inspiratory muscle activity; CW=chest wall volume; &p<0.05=compared to QB and VIS; *p<0.05=compared to FIS and VIS in elderly subjects.
165x100mm (96 x 96 DPI)