ISSN 1413-3555
Rev Bras Fisioter, São Carlos, v. 13, n. 4, p. 294-300, July/Aug. 2009

Study on pulmonary volumes and thoracoabdominal mobility in morbidly obese women undergoing bariatric surgery, treated with two different physical therapy methods

Estudo dos volumes pulmonares e da mobilidade toracoabdominal de portadoras de obesidade mórbida, submetidas à cirurgia bariátrica, tratadas com duas diferentes técnicas de fisioterapia

Costa D[1,2], Forti EMP[3], Barbalho-Moulim MC[2], Rasera-Junior I[4]

Abstract

Objective: To compare the effects of conventional respiratory physical therapy (CRP) and CRP associated with transcutaneous electrical diaphragmatic stimulation (TEDS) on the pulmonary volumes and the thoracoabdominal mobility of patients undergoing bariatric surgery. **Methods:** This randomized prospective study evaluated 44 female candidates for bariatric surgery (age 37.4±8.1 years; body mass index 47.4±6.1 kg/m^2), before surgery and 15 and 30 days after surgery. The candidates were evaluated with regard to measurements of inspiratory reserve volume (IRV), expiratory reserve volume (ERV), inspiratory capacity (IC) and thoracoabdominal mobility, by means of spirometry and cirtometry, respectively. CRP consisted of diaphragmatic respiratory exercises, deep fractionated inspiration and respiratory exercises associated with upper limb movement. One set of 10 repetitions of each exercise was carried out twice daily while hospitalized. For TEDS, two electrodes were placed on the parasternal region, next to the xiphoid process, and another two between the sixth and seventh intercostal spaces, bilaterally on the anterior axillary lines. Friedman's test was used to compare repeated measures within groups, and the Mann-Whitney test for comparisons between groups. P values <0.05 were taken to be statistically significant. **Results:** The IRV, ERV and thoracoabdominal mobility measurements increased significantly in the CRP+TEDS group. In contrast, the IC measurements decreased significantly both in the CRP and in the CRP+TEDS groups. **Conclusion:** The obese women who underwent bariatric surgery and received postoperative CRP+TEDS presented greater gains in some of the pulmonary volumes and improvements in the amplitude of respiratory movements.

Key words: physical therapy, electrical stimulation, bariatric surgery, morbid obesity, cirtometry, spirometry.

Resumo

Objetivo: Comparar os efeitos da fisioterapia respiratória convencional (FRC) e FRC associada à estimulação diafragmática elétrica transcutânea (EDET) nos volumes pulmonares e mobilidade toracoabdominal em pacientes submetidas à cirurgia bariátrica. **Métodos:** Este estudo prospectivo randomizado avaliou 44 mulheres candidatas a cirurgia bariátrica com 37,4±8,1 anos, índice de massa corpórea de 47,4±6,1 Kg/m^2, no pré-operatório, 15^0 e 30^0 dias pós-operatório em relação às medidas do volume de reserva inspiratório (VRI), volume de reserva expiratório (VRE), e capacidade inspiratória (CI) e da mobilidade toracoabdominal por meio da espirometria e da cirtometria, respectivamente. A FRC consistiu de exercícios respiratórios diafragmáticos, inspirações profundas, fracionadas e exercícios respiratórios associados à movimentação dos membros superiores. Foi realizada uma série de 10 repetições cada exercício, duas vezes ao dia, durante a internação. Para a EDET, foram posicionados 2 eletrodos na região paraesternal ao lado do processo xifoide e outros 2, entre o 6º e 7º espaços intercostais, nas linhas axilares anteriores bilateralmente. O teste de Friedman foi utilizado para comparação de amostras repetidas intragrupos e o de Mann-Whitney para a comparação intergrupos. Um valor de p<0,05 foi considerado estatísticamente significativo. **Resultados:** No grupo FRC+EDET, as medidas de VRI e VRE e mobilidade toracoabdominal apresentaram aumento significativo. Por outro lado, a CI evidenciou declínio significativo tanto no grupo FRC como no grupo FRC+EDET. **Conclusões:** As obesas submetidas à cirurgia bariátrica que receberam FRC+EDET no pós-operatório apresentaram maior ganho de alguns dos volumes pulmonares e melhora na amplitude de movimentos respiratórios.

Palavras-chave: fisioterapia; estimulação elétrica; cirurgia bariátrica; obesidade mórbida; cirtometria; espirometria.

Received: 22/06/2008 – **Revised:** 26/11/2008 – **Accepted:** 10/03/2009

[1] Department of Physical Therapy, Universidade Nove de Julho (UNINOVE), São Paulo (SP), Brazil
[2] Graduate Program in Physical Therapy, Universidade Federal de São Carlos (UFSCar), São Carlos (SP), Brazil
[3] Undergraduate Physical Therapy Course, School of Health Sciences, Universidade Metodista de Piracicaba (UNIMEP), Piracicaba (SP), Brazil
[4] Doctor, Gastroenterologist, Surgeon
Correspondence to: Eli Maria Pazzianotto Forti, UNIMEP, Rodovia do Açúcar, Km 156, CEP 13400-911, Piracicaba (SP), Brazil, e-mail: empforti@unimep.br

Introduction

The excessive fat stored in the abdominal cavity of individuals with morbid obesity has a direct mechanical effect on the thoracic cage and the diaphragm muscle, restricting thoracic expandability and leading to a subsequent reduction in pulmonary volumes[1-3], even in a respiratory system without pathologic changes[4,5]. In obese individuals, this restriction in chest wall expansion in the seated position is 70% of the total resistance and, in the supine position, it increases to 80% of the total resistance of the respiratory system[6]. This leads to muscle overload for ventilation and results in respiratory muscle dysfunction[5,7].

Abdominal surgery can affect the respiratory muscles through different mechanisms, such as pain and loss of the abdominal muscle integrity due to the incision and use of neuromuscular blockers for anesthesia which interfere in the muscular contraction and contribute to inadequate performance of the respiratory muscles after the surgery[8]. There is evidence that diaphragmatic dysfunction is the main factor in the etiology of postoperative pulmonary complications, possibly due to the manipulation of the viscera during surgery, causing reflex inhibition of the phrenic nerve and subsequent temporary paresis of the diaphragm muscle[9]. This fact may contribute to the occurrence of atelectases and infections in the lung bases, which depend heavily on the movement of the diaphragm muscle for ventilation[10-12], justifying the physical therapy intervention in those patients.

The transcutaneous electrical diaphragmatic stimulation (TEDS) is one of the available resources in respiratory physical therapy and it aims to prevent hypotrophy or reduction in respiratory muscle strength and of the pulmonary volumes by triggering muscle contractions with electrical stimuli[13]. It can also be combined with conventional respiratory techniques[14] in order to contribute towards mobility changes of the thoracoabdominal movements during breathing. Therefore, the aim of this study was to compare the effects of conventional respiratory physical therapy (CRP) and CRP associated to TEDS in the pulmonary volumes and thoracoabdominal mobility of patients undergoing bariatric surgery.

Methods

During the period from February 2006 to April 2007, 44 patients who underwent bariatric surgery were studied. The inclusion criteria were: morbidly obese women who underwent open, silastic ring Roux-en-Y gastric bypass performed by the same surgical team; who evolved without complications; who had duration of surgery within the expected time (approximately 70 minutes); who did not smoke; who did not exercise more than once a week; who did not have acute or chronic pulmonary disease; who were able to accomplish the evaluation test protocol and available to take part in the study. During the preoperative period, before being admitted to the hospital, the patients received instructions on the test procedures and the physical therapy treatments they would undergo after surgery. All of the patients included in this study were informed about the objectives of the study and signed an informed consent form. The experimental protocol was approved by the Human Research Ethics Committee of Universidade Metodista de Piracicaba (UNIMEP), protocol number 08/05.

The 44 participants were randomly divided, by draw, into two groups of 22 women each. One group received CRP, and the other received CRP+TEDS. The participants were submitted to three evaluations, the first being preoperative, the second, 15 days postoperative and the third, 30 days postoperative. The first evaluation consisted of clinical history, pulmonary function assessment through the spirometry and thoracoabdominal mobility assessment through cyrtometry. In the other evaluations, the pulmonary function measurements and the thoracoabdominal mobility measurements were repeated. These two postoperative evaluations were only carried out 15 days after hospital discharge, so that the immediate effects of the surgery, such as pain and paresis, would not interfere in the mechanical variables.

To measure pulmonary volumes, we used the Swiss-made, Easy One computerized ultrasound spirometer with a flow sensor and internal Winspiro Software upgrade, version, 1.04 for computer connection. Slow Vital Capacity (SVC), Forced Vital Capacity (FVC) and Maximum Voluntary Ventilation (MVV) measures were carried out in accordance with American Thoracic Society[15] recommendations and the guidelines for pulmonary function tests[16]. Thoracoabdominal mobility was measured by cyrtometry with the use of a conventional tape measure in centimeters. The thoracic and abdominal circumferences were measured by placing the zero end of the tape measure on the anterior area of the chest, wrapping the tape around the chest and placing the other end of the tape on the same spot at the end of the respiratory movement. To minimize any possible interference of the excess soft tissue, the examiners held the tape measure with the same amount of pressure for all participants and in a constant way during the maximum inspiratory and expiratory movements. The tape measure was placed at the axillary, xiphoid process and abdominal lines, with the participants in the standing position. These measures were taken three times at each line, and the highest value during inspiration and the lowest value during expiration were recorded. The absolute difference between these values was considered the thoracic or abdominal mobility value for each one of the three lines[17].

To apply TEDS, the Phrenix Dualpex equipment was used with the following parameters: pulse width of 1.2 m, rise time (ramp) of 0.7 second, respiratory frequency of 14 rpm, pulse frequency of 30 Hz, and sufficient intensity to promote a palpable contraction of the diaphragm muscle[3,14]. Two pairs of carbon electrodes were used. One pair was placed on the parasternal region, next to the xiphoid process, and the other pair between the sixth and seventh intercostal spaces, bilaterally on the anterior axillary lines[18]. The electrodes were fixed with micropore tape to the skin, which was previously cleaned with alcohol. The TEDS application time was 30 minutes per session. For the application, the participants were in supine position, with the headboard tilted to 30º, knees semiflexed, feet supported, arms along the body and with the head on a pillow.

CRP consisted of diaphragm respiratory exercises, deep inspiration, interval-based (two and three) inspiratory training and respiratory exercises associated with shoulder flexion and upper limb extension movements. One set of 10 repetitions of each exercise was carried out. Exercises for the prevention of deep vein thrombosis and ambulation were also carried out. The CRP and CRP+TEDS sessions were applied from the first to the third day postoperative, morning and afternoon, with a total of five sessions. All evaluated participants spent four days in the hospital and received physical therapy treatment until hospital discharge.

The software GraphPad InStat for Windows version 3.05 was used for statistical analysis. Initially, the Kolmogorov-Smirnov normality test was used, followed by the Friedman non-parametric test to compare repeated measures within groups, and the Mann-Whitney test for comparisons between groups. The α level considered for all analyses was set at 0.05. The software GraphPad StatMate version 1.01i was used for the sample size calculation. The variable axillary cyrtometry was considered for this calculation as it is a reliable parameter for determining thoracoabdominal mobility. The confidence level was set at 95%, and the power was set at 95% for a total of 44 individuals. The Student *t* test was used to compare the anthropometric characteristics and age between groups at the three moments of evaluation.

Table 1. Anthropometric characteristics and age of the patients under study in the CRP and CRP+TEDS groups, pre-operative and 15 and 30 days post-operative.

	CRP	CRP+TEDS
Number of patients	22	22
Age (years)	37.6±7.3	37.2±9.0
Height (m)	1.6±0.1	1.6±0.1
Pre-operative		
Weight (Kg)	122.5±18.3	121.3±15.9
Ideal weight (kg)	58.5±3.3	58.0±3.5
Initial BMI (kg/m²)	47.4±6.6	47.5±5.8
Ideal BMI (kg/m²)	22.7±0.5	22.7±0.6
15 days Postoperative		
BMI at 15 days (kg/m²)	43.9±6.2	43.9±5.5
Weight at 15 days (kg)	113.5±17.3	112.1±15.1
30 days Postoperative		
Weight at 30 days (Kg)	111.3±16.8	109.7±15.6
BMI at 30 days (kg/m²)	43.1±5.9	42.9±5.7

There was no significant statistical difference for any of the variables ($p<0.05$); CRP=Conventional respiratory physical therapy; CRP+TEDS=CRP associated with transcutaneous electrical diaphragmatic stimulation, BMI=Body Mass Index.

Results

As there was no sample loss, the 44 participants had a mean age of 37.4±8.1 yrs, mean height of 1.6±0.1 m, initial weight of 121.9±16.9 Kg and BMI of 47.4±6.1 Kg/m^2. The characteristics which composed the profile of the studied sample were not significantly different ($p<0.05$) for the anthropometric variables (weigh, height and BMI), as well as age, when comparing the three moments of evaluation both in the CRP group and the CRP+TEDS group. This indicates a homogeneous distribution of the groups as described in Table 1. None of the participants had changes in the preoperative pulmonary function tests, therefore no presence of restrictive or obstructive pulmonary disease.

Given the absence of any kind of change in pulmonary volumes and flow, except in the compartments which compose the vital capacity (VC), only the following spirometry variables were analyzed in this study: inspiratory reserve volume (IRV), expiratory reserve volume (ERV) and tidal volume, through inspiratory capacity (IC). In the CRP+TEDS group, there were significant increases in the IRV values when comparing the first evaluation to the second evaluation ($p<0.05$) and in the ERV values when comparing the first evaluation to the third evaluation ($p<0.05$). In the CRP group, there were no significant differences in the IRV values or the EVR values, as shown in Table 2.

There was a significant decrease in IC ($p<0.05$) between the first and the third evaluation in the CRP group, and between the first and the second evaluation and between the first and the third evaluation in the CRP+TEDS group, which characterizes a postoperative decrease in the IC of both groups (Table 2). With regard to thoracoabdominal mobility, the CRP group had no postoperative differences (p<0.05) in any of the variables after 15 and 30 days. However, in the CRP+TEDS group, the differences were significant between the evaluations in the three lines (axillary, xiphoid and abdominal), showing a significant increase in thoracoabdominal mobility in the participants after the bariatric surgery as demonstrated in Table 3.

Discussion

According to the literature, obese individuals have decreased ERV and functional residual capacity (FRC) especially in the vertical position, and tidal volume can decrease according to the occlusion capacity of the airways, causing changes in pulmonary ventilation and perfusion or even areas of pulmonary shunt with subsequent hypoxemia[19]. Therefore, the application of TEDS in the participants of this study may have prevented postoperative IRV and ERV reduction because this technique increases diaphragm contraction. This increase, combined with postoperative abdominal decompression due to the loss of excess fat, may have been decisive for such prevention and may have resulted in an increase in some volumes.

Based on the present results, the IRV and ERV increases observed in the participants can be attributed to the respiratory physical therapy, especially to the CRP+TEDS treatment. Although it was not possible to evaluate the variables in a group without physical therapy intervention, such as a control group, these results can be attributed to the physical therapy intervention because, in most of the literature references, there is a postoperative reduction in the variables[6-8,11]. The changes in volume also indicate a relationship with the thoracic and abdominal mobility changes verified by cyrtometry, although it is not an appropriate form of measuring pulmonary volumes[20].

Cyrtometry or thoracoabdominal perimetry, which consists of a group of chest and abdominal circumference measurements, has the purpose of evaluating thoracic expandability and can be carried out in a simple and accessible way[21]. This technique is considered a valid measure for analyzing the dimensions and widths of thoracic and abdominal movements[20]. Although seldom referred to in the literature, this measuring technique is widely used in clinical physical therapy practice to evaluate abdominal and thoracic mobility during respiratory movements[22]. The results of the cyrtometry for the thoracoabdominal mobility of both groups, 15 and 30 days postoperative, demonstrated significant differences between the three moments of evaluation and the three evaluated areas (axillary, xiphoid and abdominal), which indicates a significant increase in the thoracoabdominal mobility of the CRP+TEDS group. In contrast, no significant differences were observed in the CRP group, except a greater tendency for increase in the range of abdominal movement between the first and the third evaluation, 30 days postoperative. The increased tendency for thoracic mobility found in both groups, although only significant in the CRP+TEDS group, may result from an improvement in thoracic cage mobility, which can also be attributed to the postoperative respiratory physical therapy. This result highlights the importance of these physical therapy techniques for respiratory muscle contraction,

Table 2. Mean and standard deviation and statistical results for the spirometry variables: RIV, REV, IC, pre-operative and 15 and 30 days post-operative for the CRP and CRP+TEDS groups.

		Pre-operative	15 days	30 days
RIV (L)	CRP	1.71±0.3	1.73±0.5	1.65±0.4
	CRP+TEDS	1.6±0.3	1.92±0.5*	1.76±0.4
REV (L)	CRP	0.67±0.3	0.72±0.3	0.82±0.4
	CRP+TEDS	0.67±0.3	0.81±0.3	0.88±0.4#
IC (L)	CRP	2.4±0.3#	2.34±0.4	2.21±0.5
	CRP+TEDS	2.59±0.5*#	2.32±0.4	2.41±0.4

*significant difference between the first and second evaluations (p<0.05); # significant difference between the first and third evaluations (p<0.05); CRP=Conventional respiratory physical therapy; CRP+TEDS=CRP combined with transcutaneous electrical diaphragmatic stimulation; RIV=reserve inspiratory volume; REV=reserve expiratory volume; IC=inspiratory capacity.

Table 3. Means, standard deviations and statistical results for the differences in value in axillary, xiphoid and abdominal cyrtometry for the conventional respiratory physical therapy (CRP) and conventional respiratory physical therapy combined with TEDS (CRP + TEDS) groups in the three evaluations.

Cyrtometry Thoracic-abdominal	(cm)	Pre	15 days	30 days
CRP	Axillary	8.4±2.1	7.9±2.0	8.8±1.6
	Xiphoid	4.9±2.0	5.8 ±1.8	6.2±1.5
	Abdominal	1.2±4.9	3.7±1.8	3.9±3.1
CRP+TEDS	Axillary	6.1±1.7	7.5±2.0*	7.8±2.0#
	Xiphoid	4.0±1.7	5.1±2.3	6.5±1.6#
	Abdominal	0.72±4.1	1.8±3.9	4.0±3.1#

*significant difference between the first and second evaluations (p<0.05); # significant difference between the first and third evaluations (p<0.05).

especially the diaphragm and the abdominal wall muscles which were stimulated by TEDS.

With regard to the normality values of cyrtometry or thoracoabdominal mobility, there is no consensus in the literature, especially for morbidly obese individuals. According to Jamami[17], in spite of the importance of thoracoabdominal mobility for good respiratory movements, it is necessary to consider the relative values, i.e. the differences related to each individual's physical structure. Nevertheless, there was a considerable increase in thoracoabdominal mobility in the participants, especially those who composed the CRP+TEDS group. It is possible that the respiratory physical therapy, especially with the electrical stimulus, contributed to this result.

It is worth noting that abdominal mobility varied the most between the three studied lines. According to Tribastone[23], thoracoabdominal mobility varies according to the anatomy of the individual's ribs. Physiologically, however, the lower ribs are more oblique than the upper ribs and, the more oblique they are, the greater the movement that the individual can accomplish. In addition to this physiological aspect, which is common in individuals with normal BMI, it should be taken into account that the participants lost weight, and this resulted in a decrease in abdominal fat. According to Sue[24], the abdominal content of obese individuals compresses the thoracic and abdominal areas, restricting chest movement.

Obese patients can also have significant changes in ventilatory mechanics. There is a general notion that total respiratory compliance is reduced due to compromised thoracic and pulmonary function, especially thoracic function given the presence of fat around the ribs and thorax[19]. Pelosi et al.[2] investigated the effects of BMI on ventilatory mechanics (compliance and resistance) in a group of anesthetized obese patients, and they found that the reduction in respiratory compliance related to BMI increase is caused mainly by the pulmonary component, while thoracic wall compliance was only weakly dependent on BMI and had a minimal contribution to the variation in total pulmonary compliance.

The decrease in pulmonary compliance is also attributed to alveolar collapse. This condition is frequent in morbidly obese individuals and makes the lungs more rigid and more difficult to insufflate, promoting an increase in respiratory work[25]. To promote the same percentage of ventilation of a healthy individual in obese individuals, more diaphragmatic activity is needed to overcome pulmonary elastance which generates a greater need for blood flow to the diaphragm. The muscles of obese individuals do twice as much work as those of non-obese individuals[4].

Although the objective was not to evaluate pulmonary or thoracic compliance as there were no adequate instruments for such measurement, the increase in thoracic mobility in the CRP+TEDS group was attributed to the preservation of the respiratory muscles, which may have promoted greater chest mobility as a consequence of less respiratory work due to weight loss. This aspect leads to the conclusion that TEDS has an important role in the mechanical recovery of thoracic and abdominal movement after bariatric surgery. Auler Jr, Giannini and Saragiotto[26], in their study with anesthetized morbidly obese patients, showed that the main factor in compliance reduction may be the pulmonary factor, as thoracic compliance is little affected in obese patients compared to normal patients and does not show variations during laparotomy. Besides low ventilatory compliance, the patients studied by those authors showed increased airway resistance, which was determined mainly by the pulmonary factor. However, the authors accepted the claim that intra-abdominal pressure can play an important role in the decrease in compliance and the increase in pulmonary resistance. These findings reinforce the theory of cranial displacement of the diaphragm during anesthesia, reducing FRC, pulmonary compliance and, consequently, total compliance[26].

Clearly the literature has so far presented a great discrepancy in the subject, and the controversies over it remain. In conscious patients, the investigations using different methods report a decrease in thoracic compliance[4,27]. In contrast, Suratt et al.[28] compared obese and non-obese conscious patients and did not find any correlation between BMI and thoracic wall compliance. According to Nguyen and Wolfe[29], the decrease in respiratory compliance in the intraoperative period of open bariatric surgeries is due to the rigid mechanical retractors placed in the abdominal wall, while in laparoscopic bariatric surgeries, the reduction in compliance is even greater and due to increased intra-abdominal pressure.

In the present study, there was no specific intention of studying compliance to find answers to the main component that changes it. The intention was to understand and to evaluate thoracic compliance as the ability to change chest mobility during the respiratory cycle. However, there was an increase in chest mobility, i.e. in thoracic expandability, in the three moments of evaluation and a significant increase in the group which had the contraction of diaphragm muscle intensified through electrical stimulus. At the same time, there was an increase in the inspiratory and expiratory reserve volumes which are beneficial to the maintenance or restoration of pulmonary function.

Conclusions

Based on the present findings, it can be concluded that the obese women who underwent bariatric surgery and received postoperative respiratory physical therapy did not have a reduction in pulmonary volumes. There were significant changes in the VC compartments and in the dynamics of the respiratory movements. These results may be linked to the natural decompression of the thorax and abdomen due to fat tissue loss after the bariatric surgery, as well as the improved dynamics of the respiratory muscles, especially the diaphragm, due to the conventional respiratory physical therapy and particularly to the TEDS.

References

1. Enzi G, Baggio B, Vianello A. Respiratory disturbances in visceral obesity. Int J Obesity. 1990;14 Suppl 2:26.
2. Pelosi P, Croci M, Ravagnan I, Tredici S, Pedoto A, Lissoni A, et al. The effects of body mass on lung volumes, respiratory mechanics, and gas exchange during general anesthesia. Anesth Analg. 1998;87(3):654-60.
3. Gibson GJ. Obesity, respiratory function and breathlessness. Thorax. 2000;55 Suppl 1:S41-4.
4. Naimark A, Cherniack RM. Compliance of the respiratory system and its components in health and obesity. J Appl Physiol. 1960;15: 377-82.
5. Wadström C, Muller-Suur R, Backman L. Influence of excessive weight loss on respiratory function. A study of obese patients following gastroplasty. Eur J Surg. 1991;157(5):341-6.
6. Weiner P, Waizman J, Weiner M, Rabner M, Magadle R, Zamir D. Influence of excessive weight loss after gastroplasty for morbid obesity on expiratory muscle performance. Thorax. 1998;53(1):39-42.
7. Eichenberger A, Proietti S, Wicky S, Frascarolo P, Suter M, Sapan DR, et al. Morbid obesity and postoperative pulmonary atelectasis: an underestimated problem. Anesth Analg. 2002;95(6):1788-92.
8. Siafakas NM, Mistrouska I, Bouros D, Georgopoulos D. Surgery and the respiratory muscles. Thorax. 1999;54(5):458-65.
9. Lawrence VA, Cornell JE, Smetana GW, American Collage of Physicians. Strategies to reduce postoperative pulmonary complications after noncardiothoracic surgery: systematic review for the american college of physicians. Ann Intern Med. 2006;144(8):596-608.
10. Chuter TA, Weissman C, Mathews DM, Starker PM. Diaphragmatic breathing maneuvers movement of the diaphragm after cholecystectomy. Chest. 1990;97(5):1110-4.
11. Joris JL, Hinque VL, Laurent PE, Desaive CJ, Lamy ML. Pulmonary function and pain after gastroplasty performed via laparotomy or laparoscopy in morbidly obese patients. Br J Anaesth. 1998;80(3):283-8.
12. Nguyen NT, Goldeman C, Rosenquist CJ, Arango A, Cole CJ, Lee SJ, et al. Laparoscopic versus open gastric bypass: a randomized study of outcomes, quality of life, and costs. Ann Surg. 2001;234(3):279-89.
13. Geddes LA, Voorhees WD, Lagler R, Riscili C, Foster K, Bourland JD. Electrically produced artificial ventilation. Med Instrum. 1988;22(5): 263-71.
14. Forti EMP, Pachani GP, Montebelo MIL, Costa D. Eletroestimulação diafragmática transcutânea em indivíduos saudáveis. Fisioter Bras. 2005;6(4):261-4.
15. Miller MR, Hankinson J, Brusasco V. Burgos F, Casaburi R, Coates A, et al. Series ATS\ERS task torce: standardisation of lung function testing. standardisation of spirometry. Eur Respir J. 2005;26(2):319-38.
16. Pereira CAC. Diretrizes para Testes de Função Pulmonar. J Pneumol. 2002;28 Suppl 3:S1-82.
17. Jamami M, Pires VA, Oishi J, Costa D. Efeitos da intervenção fisioterápica na reabilitação pulmonar de pacientes com doença pulmonar obstrutiva crônica (DPOC). Rev Fisioter Univ São Paulo. 1999;6(2):140-53.
18. Geddes LA, Voorhees WD, Boulland JD, Riscili CE. Optimum stimulus frequency for contracting the inspiratory muscle with chest-surface electrodes to produce artificial respiration. Rev Ann Biomed Eng. 1990;18(1):103-8.
19. Luce JM. Respiratory complications of obesity. Chest. 1980;78(4):626-31.
20. Caldeira VS, Starling CCD, Britto RR, Martins JA, Sampaio RF, Parreira VF. Precisão e acurácia da cirtometria em adultos saudáveis. J Bras Pneumol. 2007;33(5):519-26.
21. Maciel SS, Paulo MQ, Souza CO, Silva LG, Tavares RR. Efeito broncodilatador do acanthospermum hispidum DC, nos doentes pulmonares obstrutivos crônicos (DPOC). Rev Bras Cienc Saúde. 1997;1(1/3):23-30.
22. Costa D, Sampaio LMM, Lorenzzo VAP, Jamami M, Damaso AR. Avaliação da força muscular respiratória e amplitudes torácicas e abdominais após a RFR em indivíduos obesos. Rev Latinoam Enferm. 2003;11(2):156-60.
23. Tribastone F. Tratado de exercícios corretivos aplicados à reeducação motora postural. São Paulo: Manole; 2001.
24. Sue DY. Obesity and pulmonary function: more or less? Chest. 1997;111(4):844-5.

25. Charlebois D, Wilmoth D. Critical care of patients with obesity. Critical Care Nurse 2004;24(4):19-27.

26. Auler Jr JOC, Giannini CG, Saragiotto DF. Desafios no manuseio peri-operatório de pacientes obesos mórbidos: como prevenir complicações. Rev Bras Anestesiol. 2003;53(2):227-36.

27. Sharp JT, Henry JP, Sweany SK, Meadows WR, Pietras RJ. The total work of breathing in normal and obese men. J Clin Invest. 1964;43:728-39.

28. Surat PM, Wilhoit SC, Hsiao HS, Atkinson RL, Rochester DF. Compliance of chest wall in obese subjects. J Appl Physiol. 1984;57(2):403-7.

29. Nguyen NT, Wolfe BM. The physiologic effects of penumoperitoneum in the morbidly obese. Ann Surg. 2005;241(2):219-26.