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RESEARCH PAPER (ORIGINAL)
ARTIGO DE INVESTIGAÇÃO (ORIGINAL)

Effectiveness of the breath-stacking technique in the respiratory function of women undergoing bariatric surgery

Eficácia da técnica de *breath stacking* na função respiratória em mulheres submetidas a cirurgia bariátrica

Eficacia de la técnica de *breath stacking* sobre la función respiratoria en mujeres sometidas a cirugía bariátrica

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Abstract

Background: Upper abdominal surgery is associated with a high incidence of pulmonary complications. The breath-stacking (BS) technique is considered a resource with therapeutic potential for rehabilitation nursing.
Objective: To assess the effectiveness of the BS technique in improving the respiratory function.
Methodology: Quasi-experimental study with 36 women undergoing bariatric surgery, distributed into a control group (CG) and an intervention group (IG). The forced vital capacity (FVC), the forced expiratory volume in one second (FEV1), the maximal inspiratory pressure (MIP), the maximal expiratory pressure (MEP), the peripheral oxygen saturation (SpO2), and the respiratory rate (RR) were evaluated in the pre and postoperative periods. The BS technique was applied to the IG in the pre and postoperative periods. Both descriptive and inferential statistics were used.
Results: Statistically significant postoperative differences were observed between the CG and the IG in FVC (-20.29 vs. -13.60), FEV1 (-23.05 vs. -13.38), MIP (-22.96 vs. -14.93), MEP (-14.10 vs. -10.32), and RF (12.29 vs. 6.45).
Conclusion: The BS technique improved the respiratory function of the IG and reversed the predictable changes in the postoperative period of bariatric surgery.

Keywords: obesity; respiratory system; pulmonary ventilation; rehabilitation nursing

Resumo

Enquadramento: A cirurgia abdominal alta está associada a alta incidência de complicações pulmonares. A técnica *breath stacking* (BS) perspetiva-se como recurso com potencial terapêutico para a enfermagem de reabilitação.
Objetivo: Avaliar a eficácia da técnica BS na melhoria da função respiratória.
Metodologia: Estudo quasi-experimental com 36 mulheres submetidas a cirurgia bariátrica, distribuídas pelos grupos de controlo (GC) e intervenção (GI). Foram avaliadas no pré e pós-operatório as medidas capacidade vital forçada (CVF), volume expiratório forçado no primeiro segundo (VEF1), pressão inspiratória máxima (PIm), pressão expiratória máxima (PEm), saturação periférica de oxigénio (SpO2) e frequência respiratória (FR). Foi aplicada a técnica BS no GI no pré e pós-operatório. Recorreu-se à análise estatística descritiva e inferencial.
Resultados: Observaram-se diferenças estatisticamente significativas pós-operatórias, entre o GC e o GI, na CVF (-20,29 vs. -13,60), VEF1 (-23,05 vs. -13,38), PIm (-22,96 vs. -14,93), PEm (-14,10 vs -10,32) e FR (12,29 vs 6,45).
Conclusão: A técnica de BS permitiu melhorar a função respiratória do GI e reverter as alterações previsíveis no pós-operatório de cirurgia bariátrica.

Palavras-chave: obesidade; sistema respiratório; ventilação pulmonar; enfermagem em reabilitação

Resumen

Marco contextual: La cirugía abdominal alta se asocia con una elevada incidencia de complicaciones pulmonares. La técnica de breath stacking (BS) se considera un recurso con potencial terapéutico para la enfermería de rehabilitación.
Objetivo: Evaluar la efectividad de la técnica de BS para mejorar la función respiratoria.
Metodología: Estudio cuasi-experimental con 36 mujeres sometidas a cirugía bariátrica, distribuidas entre el grupo de control (GC) y el de intervención (GI). Las mediciones de la capacidad vital forzada (CVF), el volumen espiratorio forzado en el primer segundo (VEF1), la presión inspiratoria máxima (PIm), la presión espiratoria máxima (PEm), la saturación periférica de oxigeno (SpO2) y la frecuencia respiratoria (FR) se evaluaron GI que en el GC antes y después de la cirugía. La técnica BS se aplicó en el GI antes y después de la cirugía. Se utilizó un análisis estadístico descriptivo e inferencial.
Resultados: Se observaron diferencias posoperatorias estadísticamente significativas entre el GC y el GI en la CVF (-20,29 frente a -13,60), VEF1 (-23,05 frente a -13,38), PIm (-22,96 frente a -14,93), PEm (-14,10 frente a -10,32) y FR (12,29 frente a 6,45).
Conclusión: La técnica BS permitió mejorar la función respiratoria del GI y revertir los cambios predecibles en el posoperatorio de cirugía bariátrica.

Palabras clave: obesidad; sistema respiratorio; ventilación pulmonar; enfermería en rehabilitación

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Introduction

Obesity is the most common metabolic disease in the world (Formiguera & Cantón, 2016). Its prevalence has tripled since the 1980s and is now considered a public health problem worldwide (Organização Mundial de Saúde, 2016), impacting 20% of the European population.

There is currently a growing scientific interest in the relationship between obesity and its effects on the respiratory system. Changes in respiratory mechanics (Piper & Grunstein, 2010), lung volumes, lung and thoracic compliance (Pelosi & Gregoretti, 2010), strength, respiratory muscle resistance, respiratory rate (RR), and pulmonary function tests (Costa, Barbalho, Miguel, Forti, & Azevedo, 2008) are well described in the literature, and these changes may aggravate in situations of vulnerability, including upper abdominal surgery, like bariatric surgery.

Preoperative rehabilitation, using lung expansion techniques, is fundamental to the prevention of postoperative pulmonary complications. Several techniques have been used in clinical practice, but none has yet been accepted as ideal technique, and there is no universally accepted specific therapeutic concept.

Few studies examine pulmonary changes occurring after abdominal surgery. Also, no studies were found that assess the reversion of respiratory changes in individuals submitted to bariatric surgery after a lung reexpansion program using the breath-stacking (BS) technique, with a control-group comparison, hence the relevance and importance of this study. Therefore, the objective is to assess the effectiveness of the BS lung expansion technique in improving the respiratory function of obese women undergoing bariatric surgery, using a pre and postoperative evaluation of respiratory measures (peripheral oxygen saturation and RR), spirometric measures (forced vital capacity and forced expiratory volume in one second), and muscular strength measures (maximal inspiratory pressure and maximal expiratory pressure) between two groups, a control group and an intervention group.

Background

Upper abdominal surgeries are associated with a high incidence of postoperative pulmonary complications, including progressively lower lung compliance and atelectasis in approximately 90% of patients within 24 hours after extubation (Serejo et al., 2007). Literature shows prevalence rates ranging between 17% and 88% (Overend et al., 2001). These changes can extend for more than two weeks and increase hospitalization time, morbidity, and hospital mortality (Sanches et al., 2007). The BS lung expansion technique uses a facemask with a one-way valve that allows, by blocking the expiratory flow, successive and cumulative inspirations beginning at functional residual capacity (FRC) until total lung capacity (TLC) to gradually increase lung volume (Barcelar et al., 2014). It is a non-invasive, safe, and effective technique to improve respiratory function and lung mechanics in different clinical contexts (Dias, Plácido, Ferreira, Guimarães, & Menezes, 2008). The most significant studies performed in the last decades show that the BS technique contributed to the improvement of pulmonary ventilation by increasing lung volumes and forced vital capacity. It is recommended as a first-line technique for lung expansion and prevention of respiratory complications (Rafiq et al., 2015) requiring 90 and 95 days of antibiotics, respectively (p = 0.34).

Research question/Hypotheses

Does the BS lung expansion technique allow improving the respiratory function (muscle strength, respiratory and spirometric measures) in obese women undergoing bariatric surgery?

H1: The BS lung expansion technique allows improving the respiratory function in obese women undergoing bariatric surgery.

H2: The BS lung expansion technique allows increasing the lung volume in obese women undergoing bariatric surgery.

H3: The BS lung expansion technique allows increasing the respiratory muscle strength in obese women undergoing bariatric surgery.

H4: The BS lung expansion technique allows increasing the peripheral oxygen saturation in obese women undergoing bariatric surgery.

H5: The BS lung expansion technique allows stabilizing the RR in obese women undergoing bariatric surgery.

Methodology

A quasi-experimental study (IG) was conducted with an intervention group and a control group (CG). Quasi-experimental research lacks the element of random group selection and complete control and does not need long periods of observation and data collection.

Population and sample

The population of this study was composed of 18-year-old or older female volunteers, with scheduled bariatric surgery and admitted to the Center of High Differentiation of Obesity of Hospital São João in Porto. The sample comprised 36 women selected by convenience between 3 January and 5 March 2017. The inclusion criteria were body mass index (BMI) ≥ 35kg/m^2, women in the preoperative period of bariatric surgery, in the postoperative period of bariatric surgery with orotracheal intubation and need for general anesthesia, hemodynamic stability without needing vasoactive drugs during surgery, and signed informed consent form. Women with smoking habits, previous respiratory, cardiac, and neuromuscular pathology, previous cognitive deficit, facemask intolerance, postoperative complications that require admission in an intensive or intermediate care unit, extubation more than 24 hours after surgery, and postoperative level of consciousness incompatible with BS technique were excluded. After fulfilling the inclusion criteria, the women were distributed in turn and evenly by order of hospitalization between the CG and IG (woman 1 in the CG, woman 2 in the IG, and so forth). Data were collected in two phases, as shown in Table 1.

Table 1
Pre- and postoperative evaluation

Evaluations	Preoperative period		Postoperative period	
	24 hours	24 hours	48 hours	72 hours
Anthropometric (Weight, height, BMI)	CG + IG	---	---	---
Respiratory measures (SpO_2, RR)	CG + IG	---	---	CG + IG
Spirometric (FVC, FEV1)	CG + IG	---	---	CG + IG
Muscle strength (MIP, MEP)	CG + IG	---	---	CG + IG
Breath-stacking technique	IG	IG	IG	IG

Note. CG = Control Group; IG = Intervention Group; BMI = Body Mass Index; SPO2 = Peripheral Oxygen Saturation; RR = Respiratory Rate; FVC = Forcer Vital Capacity; FEV1 = Forced Expiratory Volume in 1 secound; MIP = Maximal Inspiratory Pressuret; MED = Maximal Expiratory Pressure.

Evaluation instruments

This research complied with a protocol to record data of all the participants in an evaluation form containing: age, weight, height, body mass index, inclusion and exclusion criteria, and evaluation of the spirometric, anthropometric, respiratory, and respiratory muscle strength measures in both pre and postoperative periods. The same examiner collected the data, and the evaluations were carried out using the same equipment.

Both groups underwent evaluation of respiratory, spirometric, and respiratory muscle strength measures on the day before bariatric surgery (first evaluation) and at 72 hours after surgery (second evaluation). The spirometric measures "forced vital capacity" (FVC) and "forced expiratory volume in one second" (FEV1) were determined using a portable digital Contec CMS-SP10 spirometer, in accordance with the reproducibility and acceptability criteria of the American Thoracic Society/European Respiratory Society. The maximal inspiratory pressure (MIP) and maximal expiratory pressure (MEP) were evaluated based on residual volume and total lung capacity, respectively, using a hand-operated Instrumentation Industries pressure gauge, model NS 120-TRR, connected to a nozzle with a 20cm-long tube. At least three inspiratory and expiratory maneuvers were performed, and the best of three were selected. Each patient performed at least three acceptable maneuvers, with 30-second intervals between them.

Intervention protocol

The BS lung expansion technique was applied in the IG in the preoperative period (after the first evaluation) and at 24, 48, and 72 hours after surgery. A silicone facemask was used to cover the nose and mouth, attached to a one-way valve, which allowed only inspiration. The patients were told to perform successive inspirations beginning at functional residual capacity (FRC) until total lung capacity (TLC). The technique was completed after TLC was reached and the 5-second absence of inspired air volume was confirmed. The technique was performed six times, with 30-second intervals between each maneuver. There were no obstacles or complications during the study. No participant refused or withdrew from the research.

Data treatment and analysis

Statistical treatment of data was carried out using the Stata® software, version 14.0. Descriptive statistics were based on the mean ± standard deviation and minimum and maximum values. The sample size (*n*) indicates the number of individuals subjected to the evaluations. The Mann-Whitney bilateral test was applied to compare the two independent groups. The Mann-Whitney non-parametric test (*U*) can be used when the sample is small, and the number variable does not show a normal variation, or when there are no homogeneous variances. It is suitable for the comparison of two independent groups that do not meet the requirements for Student's *t*-test and to confirm if they belong or not to the same population. The Mann-Whitney test (*U*) can be considered the non-parametric version of the *t*-test for independent samples. The Wilcoxon test was also used to compare the results of the first evaluation with the results of the second evaluation of both groups independently. The statistical tests were carried out with a 95% confidence level, considering $p < 0.05$ a substantial significance level.

Ethical considerations

The study was approved by the Health Ethics Committee of the Hospital Center of São João/ Faculty of Medicine of the University of Porto, and proof of approval was provided to all participants. All women signed the informed consent form, which explained the purpose of the study, ensured confidentiality of collected data and freedom to withdraw or refuse to participate in any of the stages of the study.

Results

The sample was composed of 36 female individuals, evenly distributed between the two groups. Regarding age, both groups showed homogeneity: the CG with a mean of 44.83 ± 9.15 years and the IG with a mean of 45.78 ± 8.03 years. The BMI was similar in the CG and IG with means of 43.24 ± 4.83 Kg/ m^2 and 43.47 ± 4.02 Kg/m^2, respectively (Table 2). Regarding studies on the BS technique, literature showed a significant variability of individuals in the intervention groups and their age means, ranging between 12 (Dias et al., 2008) and 179 individuals (Toussaint, Boitano, Gathot, Steens, & Soudon, 2009), with age means between 11 (Jenkins, Stocki, Kriellaars, & Pasterkamp, 2014) and 64 years (Rafiq et al., 2015). As regards studies on pulmonary changes after abdominal surgery, variations were found ranging from 21 (Paisani, Chiavegato, & Faresin, 2005) and 70 individuals (Nguyen et al., 2001), with age means between 33 (Joris, Hinque, Laurent, Desaive, & Lamy, 1998) and 42 years (Nguyen et al., 2001).

Table 2

Sample distribution by groups according to age (Mann-Whitney bilateral test)

Variable	*n*		Mean		*SD*		Minimum		Maximum		*p*
	CG	IG	CG	IG	CG	IG	CG	IG	CG	IG	
Age (years)	18	18	44.83	45.78	9.15	8.03	31	33	62	62	0.623

Note. CG = control group; IG = intervention group; *SD* = standard deviation; *p* = significance.

The homogeneity of both groups regarding the anthropometric variables was evident, as shown in Table 3. The BMI was similar in the control and intervention groups with means of 43.24 ± 4.83 Kg/m^2 and 43.47 ± 4.02 Kg/m^2, respectively. The BMI values recorded in the consulted studies vary between 43.45 Kg/m^2 (Barcelar et al., 2014) and 50 Kg/m^2 (Paisani et al., 2005).

Table 3

Sample distribution by groups according to weight, height, and BMI (Mann-Whitney bilateral test)

Variable	*n*		Mean		*SD*		Minimum		Maximum		*p*
	CG	IG	CG	IG	CG	IG	CG	IG	CG	IG	
Weight (Kg)	18	18	112.28	114.05	14.13	10.88	93	101	139	135	0.568
Height (cm)	18	18	161.11	162.05	6.04	6.27	150	150	169	173	0.656
BMI (Kg/m^2)	18	18	43.24	43.47	4.83	4.02	37.8	37.1	55.8	52.7	0.762

Note. CG = control group; IG = intervention group; *SD* = standard deviation; *p* = significance.

As shown in Table 4, there is no statistically significant preoperative difference between the control and intervention groups regarding FVC, FEV1, MIP, MEP, SpO_2, and RR. The two groups obtained identical results in the first evaluation, and there were no different results that could lead to bias.

Table 4

Results of the spirometric parameters, respiratory muscle strength, and respiratory measures in the first evaluation, distributed by groups (Mann-Whitney *bilateral test)*

Variable	CG	IG	*p*
	1st evaluation		
	(*N* = 18) Mean ± *SD* min/max	(*N* = 18) Mean ± *SD* min/max	
FVC (ml)	3113.89±645.53 1530/4340	3067.78±431.99 2100/3750	0.825
FEV1 (ml)	2763.33±571.66 1400/3560	2713.89±466.78 1580/3340	0.658
MIP (cm/H_2O)	74.78±13.77 40/96	78.22±13.25 40/100	0.388
MEP (cm/H_2O)	83.33±15.17 56/104	87.11±18.79 36/116	0.435
SpO_2 (%)	97.89±1.18 94/99	97.67±1.08 95/99	0.434
RR (c/min)	17.44±1.09 16/20	18.22±1.06 16/20	0.333

Note. FVC = forced vital capacity; FEV1 = forced expiratory volume in one second; MIP = maximal inspiratory pressure; MEP = maximal expiratory pressure; SpO_2 = peripheral oxygen saturation; RR = respiratory rate; *p* = significance

As shown in Table 5, the comparison between the first and second evaluations obtained a significant reduction of lung volumes (FVC and FEV1) and respiratory muscle strength (MIP and MEP), being more prominent in the CG, in absolute terms. The RR values in the second evaluation increased in both groups, more significantly in the CG, and neither group manifested SpO_2 changes.

Table 5

Results of the spirometric parameters, respiratory muscle strength, and respiratory measures in the first and second evaluations, distributed by groups (Wilcoxon test)

Variable	CG		*p*	IG		*p*
	1st evaluation	2nd evaluation		1st evaluation	2nd evaluation	
	(*N* = 18) Mean ± *SD* min/max	(*N* = 18) Mean ± *SD* min/max		(*N* = 18) Mean ± *SD* min/max	(*N* = 18) Mean ± *SD* min/max	
FVC (ml)	3113.89±645.53 1530/4340	2491.11±608.89 1110/3470	0.000	3067.78±431.99 2100/3750	2650.56±510.99 1520/3510	0.000
FEV1 (ml)	2763.33±571.66 1400/3560	2136.11±536.92 940/ 2920	0.000	2713.89±466.78 1580/3340	2348.33±505.04 1350/3140	0.000

MIP (cm/H_2O)	74.78±13.77 40/96	58±16.66 32/84	0.000	78.22±13.25 40/100	66.44±16.69 32/92	0.000
MEP (cm/H_2O)	83.33±15.17 56/104	71.22±14.19 52/96	0.000	87.11±18.79 36/116	79.56±23.56 20/108	0.004
SpO_2 (%)	97.89±1.18 94/99	97.28±1.07 94/99	0.222	97.67±1.08 95/99	97.67±1.029 95/99	1.000
RR (c/min)	17.44±1.09 16/20	19.56±1.25 18/22	0.000	18.22±1.06 16/20	19.39±1.54 16/22	0.002

Note. FVC = forced vital capacity; FEV1 = forced expiratory volume in one second; MIP = maximal inspiratory pressure; MEP = maximal expiratory pressure; SpO_2 = peripheral oxygen saturation; RR = respiratory rate; CG = control group; IG = intervention group; *p* = significance

Table 6 shows that there are statistically significant postoperative differences between the control and intervention groups regarding FVC, FEV1, MIP, MEP, and RR. No statistically significant differences relating to SpO_2 occurred.

Table 6

Variations of the spirometric parameters, respiratory muscle strength, and respiratory measures in the second evaluation, distributed by groups (Mann-Whitney bilateral test)

Variable	*n*		Mean		Standard deviation		Minimum		Maximum		*p*
	CG	IG	CG	IG	CG	IG	CG	IG	CG	IG	
FVC (%)	18	18	-20.29	-13.60	8.14	11.12	-40.99	-48.82	-7.72	-4.098	$p<0.0049$
FEV1 (%)	18	18	-23.05	-13.38	9.15	11.26	-42.09	-48.34	-7.67	-3.98	$p<0.0021$
MIP (%)	18	18	-22.96	-14.93	13.92	15.75	-46.66	-54.54	5.26	0	$p<0.0183$
MEP (%)	18	18	-14.10	-10.32	9.71	16.75	-43.48	-45	0	21.05	$p<0.0410$
SpO_2 (%)	18	18	-0.62	-0.001	0.62	0.35	2.02	-1.01	0	1.03	---
RR (%)	18	18	12.29	6.45	6.84	6.71	0	-5.88	25	22.22	$p<0.0135$

Note. FVC = forced vital capacity; FEV1 = forced expiratory volume in one second; MIP = maximal inspiratory pressure; MEP = maximal expiratory pressure; SpO^2 = peripheral oxygen saturation; RR = respiratory rate; CG = control group; IG = intervention group; *p* = significance

Discussion

The IG and the CG presented similar results regarding the variables age, weight, height, and BMI and the preoperative evaluation of FVC, FEV1, MIP, MEP, SpO_2, and RR. Comparing the two evaluation moments, both the CG and the IG had lower results in FVC, FEV1, MIP, and MEP in the second evaluation. However, this decrease was statistically lower in the IG than in the CG.

Literature shows FVC decrease values in the first postoperative day, like 44% (Ebeo, Benotti, Byrd, Elmaghraby, & Lui, 2002), 50% (Joris et al., 1998) and 53% (Nguyen et al., 2001). Paisani et al. (2005) observed a reduction from 47% to 30% from the first to the third postoperative day. In this study, the use of the BS technique allowed the IG to lose 7% less ($p < 0.0049$) in FVC than the CG, probably due to the recruitment of collapsed alveoli and reexpansion of areas of atelectasis.

Consulted studies showed a decrease in FEV1 in the first postoperative day, whose values were 44% (Ebeo et al., 2002), 50% (Joris et al., 1998) and 54% (Nguyen et al., 2001). The FEV1 decrease values obtained in this study are significantly smaller and match an evaluation carried out on the third postoperative day. When assessing the obstructive pattern, it was found that the BS technique allowed obtaining results approximately 10% better ($p < 0.0021$) in the IG than in the CG, which is assumingly related to the capacity to mobilize larger volumes, the increase in thoracic and lung compliance, and the reversal of areas of atelectasis (McKim, Katz, Barrowman, Ni, & LeBlanc, 2012).

Of all the studies on respiratory function after bariatric surgery, only Paisani et al. (2005) refer to respiratory pressures, presenting decrease values of 51% and 30% in MIP and 39% and 29% in MEP, in the first and third postoperative days, respectively. The MIP and MEP decrease values obtained in this study are significantly lower and are probably related to the use of the BS lung expansion technique. In the postoperative period, a rapid and superficial breathing pattern is expected to occur, with lower lung volumes and probable formation of areas of atelectasis. Reolon, Casagrande, Lorenzon, and Kessler (2009) found an improved respiratory muscle strength in individuals submitted to the BS technique, which led to an increased chest wall expandability, static and dynamic lung compliance, and improvement in oxygenation. Compared to MIP, the lowest gain obtained is probably related to the different contributions of the various muscles to the respiratory process, as well as their specific degree of affectation. Therefore, it is safe to say that the BS technique allowed improving MIP results in 8% ($p < 0.0183$) and MEP results in 4% ($p < 0.0410$) in the IG during the second evaluation, more than in the CG.

This study showed no changes in peripheral oxygen saturation (SpO_2) in any of the groups. Only Paisani et al. (2005) refer to the SpO_2 parameter, showing 17% and 11% reductions in the first and third postoperative days, respectively. The FVC decrease in the two groups could predict a SpO_2 reduction (the result of a partial oxygen pressure reduction). Such an occurrence can be explained by two mechanisms, such as a decrease in the vital capacity that would lead to atelectasis and peripheral alveolar collapse, and premature small-airway closure that could lead to alveolar collapse. There was no SpO_2 decrease in the third postoperative day, meaning that there was no dramatic arterial hypoxemia in the postoperative period and, also, that lung compliance and partial oxygen pressure (PaO_2) retrieved their normal values after deep lung inflations in the CG. Besides, a compensation mechanism may have occurred to maintain the SpO_2 basal levels in the IG.

The RR may increase due to diminished lung muscle strength and resistance, as well as higher energetic cost of breathing and subsequent lower respiratory efficiency (Costa et al., 2008). The expected decrease in lung compliance and increase in respiratory resistance during the postoperative period may influence a higher RR through an increased inspiratory drive to compensate for these mechanical changes (Barcelar, 2011). This kind of situation leads to higher energy consumption, which can cause a higher risk of fatigue, muscle weakness and inefficiency (Barcelar, 2011). These data suggest a relation between the lower inspiratory muscle strength and the increased inspiratory drive.

The IG manifested a lower RR increase in the second evaluation, probably due to a higher lung volume (a result of BS) and recruitment of areas of atelectasis, which obtained a better ventilation-perfusion ratio. The CG presented a higher RR, without altering the SpO_2 and impacting more significantly on pulmonary function related to the spirometric parameters. This means that the higher RR may have contributed to the maintenance of SpO_2 in the CG. The study of Paisani et al. (2005) shows reductions of 17% to 11% in the first to the third postoperative day, meaning that the lower RR improved 6%. This study shows that the CG obtained RR results with an improvement of 6% more ($p < 0.0135$) than the IG.

Conclusion

This study aimed to determine whether the BS technique allows improving the respiratory function to revert the expected changes after bariatric surgery, resulting in an increased lung volume, increased respiratory muscle strength, and increased peripheral oxygen saturation, as well as in a stabilized respiratory rate. This study primarily concludes that the lung expansion program using the BS technique contributed to positive results in all respiratory variables in the IG, compared to the CG. These statistically significant changes substantiate the clinical gains obtained and confirm the previously established hypotheses. The breath-stacking technique is considered safe, and its effectiveness has been confirmed in different contexts. Several authors agree that the breath-stacking technique is responsible for the improvement of respiratory function and lung mechanics through increased FVC and lung volumes, and contributes to surgical recovery and reduction of the incidence of postoperative pulmonary complications. The results of this study show that the BS technique is effective in reverting changes in pulmonary ventilation after a pulmonary reexpansion program and expand the knowledge about the effects of bariatric surgery on the respiratory system. The BS technique is easy to perform, practical for the examining professional, and advantageous for the patient, and requires low-cost equipment. Due to the effective applicability of this technique in clinical practice, the authors consider it a resource with therapeutic potential for rehabilitation nurses and respiratory rehabilitation programs. This study presented some limitations, like the small sample size (n = 36) and the lack of peri- and postoperative control of variables that may have caused a higher probability of development of areas of atelectasis and influenced the volume mobilized by patients, such as: duration of surgery; quantity and duration of oxygen administration; type, period, and amount of medication (anesthetics, analgesics, and muscle relaxants); recruitment maneuvers before and after extubation (PEEP, FiO_2 at 100%, continuous positive airway pressure), and interventions that improve respiratory function (nebulizers). The control of the aforementioned variables is recommended for future studies. There is no established protocol for the application of this technique. A large number of the studies suggest a daily breath-stacking session applied by authors with repetitions ranging from 2 to 6 for 15 to 20 seconds and different intervals between each repetition. Although its use is seemingly effective in short sessions, the authors of this study consider that it would be relevant to standardize its application, defining the number of sets and optimal repetitions to create protocols suited for the different therapeutic settings, hence the need for more studies.

References

Barcelar, J. (2011). *Avaliação da eficácia da técnica de breath stacking em mulheres obesas mórbidas quanto à distribuição de ventilação regional na caixa torácica* (Master's Dissertation). Universidade Federal de Pernambuco. Retrieved from https://repositorio.ufpe.br/handle/123456789/9098

Barcelar, J., Aliverti, A., Rattes, C., Ximenes, M. E., Campos, S. L., Brandão, D. C., … de Andrade, A. D. (2014). The expansion of the pulmonary rib cage during breath stacking is influenced by age in obese women. *PLoS ONE*, *9*(11), e110959. doi:10.1371/journal.pone.0110959

Costa, D., Barbalho, M., Miguel, G., Forti, E., & Azevedo, J. (2008). The impact of obesity on pulmonary function in adult women. *Clinics*, *63*(6), 719–724. doi: 10.1590/S1807-59322008000600002

Dias, C., Plácido, T., Ferreira, M., Guimarães, F., & Menezes, S. (2008). Incentive spirometry and breath stacking: Effects on the inspiratory capacity of individuals submitted to abdominal surgery. *Brazilian Journal of Physical Therapy*, *12*(2), 94–99. doi:10.1590/S1413-35552008000200004

Ebeo, C., Benotti, P., Byrd, R., Elmaghraby, Z., & Lui, J. (2002). The effect of bi-level positive airway pressure on postoperative pulmonary function following gastric surgery for obesity. *Respiratory Medicine*, *96*(9), 672–676. doi:10.1053/rmed.2002.1357

Formiguera, X., & Cantón, A. (2016). Obesity: Epidemiology and clinical aspects. *Best Practice & Research. Clinical Gastroenterology*, *18*(6), 1125–1146. doi:10.1016/j.bpg.2004.06.030

Jenkins, H., Stocki, A., Kriellaars, D., & Pasterkamp, H. (2014). Breath stacking in children with neuromuscular disorders. *Pediatric Pulmonology*, *49*(6), 544–553. doi:10.1002/ppul.22865

Joris, J., Hinque, V., Laurent, P., Desaive, C., & Lamy, M. (1998). Pulmonary function and pain after gastroplasty performed via laparotomy or laparoscopy in morbidly obese patients. *British Journal of Anaesthesia*, *80*(3), 283–288. doi: 10.1093/bja/80.3.283

McKim, D., Katz, S., Barrowman, N., Ni, A., & LeBlanc, C. (2012). Lung volume recruitment slows pulmonary function decline in Duchenne muscular dystrophy. *Archives of Physical Medicine and Rehabilitation*, *93*(7), 1117–1122. doi:10.1016/j.apmr.2012.02.024

Nguyen, N., Lee, S., Goldman, C., Fleming, N., Arango, A., McFall, R., & Wolfe, B. (2001). Comparison of pulmonary function and postoperative pain after laparoscopic versus open gastric bypass: A randomized trial. *Journal of the American College of Surgeons*, *192*(4), 467–469. doi: 10.1016/s1072-7515(01)00822-5

World Health Organization. (2016). *Obesity*. Retrieved from http://www.euro.who.int/en/health-topics/noncommunicable-diseases/obesity

Overend, T., Anderson, C., Lucy, D., Bhatia, C., Jonsson, B., & Timmermans, C. (2001). The effect of incentive spirometry on postoperative pulmonary complications: A systematic review. *Chest*, *120*(3), 971–978. doi:10.1378/chest.120.3.971

Paisani, D., Chiavegato, L., & Faresin, S. (2005). Volumes, capacidades pulmonares e força muscular respiratória no pós-operatório de gastroplastia. *Jornal Brasileiro de Pneumologia*, *31*(2), 125–132. doi:10.1590/S1806-37132005000200007

Pelosi, P., & Gregoretti, C. (2010). Perioperative management of obese patients. *Best Practice & Research. Clinical Anaesthesiology*, *24*(2), 211–225. doi:10.1016/j.bpa.2010.02.001

Piper, A., & Grunstein, R. (2010). Big breathing: The complex interaction of obesity, hypoventilation, weight loss, and respiratory function. *Journal of Applied Physiology*, *108*(1), 199–205. doi:10.1152/japplphysiol.00713.2009

Rafiq, M., Bradburn, M., Proctor, A., Billings, C., Bianchi, S., McDermott, C., & Shaw, P. (2015). A preliminary randomized trial of the mechanical insufflator-exsufflator versus breath-stacking technique in patients with amyotrophic lateral sclerosis. *Amyothrophic Lateral Sclerosis and Frontotemporal Denegeration. 16*(7–8), 448–455. doi:10.3109/21678421.2015.1051992

Reolon, V., Casagrande, J., Lorenzon, I., & Kessler, A. (2009). *Treinamento muscular ventilatório por breath-stacking em indivíduos jovens e hígidos*. Retrieved from http://www.pucrs.br/edipucrs/XSalaoIC/Ciencias_da_Saude/Fisioterapia_e_Terapia_Ocupacional/71493-VITORIO_ORTIZ_REOLON.pdf

Sanches, G., Gazoni, F., Konishi, R., Guimarães, H., Vendrame, L., & Lopes, R. (2007). Cuidados intensivos para pacientes em pós-operatório de cirurgia bariátrica. *Revista Brasileira de Terapia Intensiva, 19*(2), 205-209. doi:10.1590/S0103-507X2007000200011

Serejo, L., da Silva-Júnior, F., Bastos, J., de Bruin, G., Mota, R., & de Bruin, P. (2007). Risk factors for pulmonary complications after emergency abdominal surgery. *Respiratory Medicine*, *101*(4), 808–813. doi:10.1016/j.rmed.2006.07.015

Toussaint, M., Boitano, L. J., Gathot, V., Steens, M., & Soudon, P. (2009). Limits of effective cough-augmentation techniques in patients with neuromuscular disease. *Respiratory Care*, *54*(3), 359–366. Retrieved from https://pdfs.semanticscholar.org/35bf/fd3eb178502e5fa96575d6917e087c20a3b6.pdf