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Physiological changes associated with respiratory muscle training in patients on mechanical ventilation

Cambios fisiológicos relacionados con entrenamiento muscular respiratorio en pacientes con ventilación mecánica

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Abstract

Introduction: Respiratory muscle training is a technique that aims to increase the strength of the respiratory muscles. However, few studies have addressed physiological changes related to this intervention in patients on mechanical ventilation.
Objective: To determine the physiological changes associated with respiratory muscle training in patients on mechanical ventilation.
Materials and methods: A secondary data analysis was performed. The population was made up of the 62 patients in the experimental group of the main study, who received respiratory muscle training. Heart rate, respiratory rate, blood pressure, oxygen saturation, and tidal volume values were obtained. The difference between the means of each of the variables was analyzed through the paired t-test, while physiological changes between training sessions were analyzed using the Kruskal-Wallis test. Differences with a p<0.05 value were considered statistically significant.
Results: Statistically significant differences were found between physiological variables before and after respiratory muscle training (p<0.05), except for tidal volume and mean blood pressure (p>0.05). In contrast, when the effect was evaluated according to the number of training sessions received by the patients, no significant differences were observed in any of the variables (p>0.05).
Conclusions: Respiratory muscle training is a viable and tolerable therapeutic intervention in this population.
Keywords: Training; Safety; Intensive Care; Physical Therapy Specialty; Respiratory Muscles (MeSH).

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Resumen

Introducción. El entrenamiento muscular respiratorio es una técnica fisioterapéutica usada para incrementar la fuerza de la musculatura respiratoria, sin embargo pocos estudios han abordado los cambios fisiológicos relacionados con esta intervención en pacientes con ventilación mecánica.
Objetivo. Determinar los cambios fisiológicos relacionados con el entrenamiento muscular respiratorio en pacientes con ventilación mecánica.
Materiales y métodos. Se realizó un análisis de datos secundarios. La población estuvo conformada por los 62 pacientes del grupo experimental del estudio principal, quienes recibieron entrenamiento muscular respiratorio. Los valores de frecuencia cardiaca, frecuencia respiratoria, presión arterial, saturación de oxígeno y volumen corriente fueron registrados. La diferencia entre el promedio de cada una de las variables fue analizada mediante la prueba de t pareada, mientras que para el análisis de los cambios fisiológicos entre sesiones de entrenamiento se empleó la prueba de Kruskal-Wallis. Las diferencias con un valor p<0.05 se consideraron como estadísticamente significativas.
Resultados. Se observaron diferencias estadísticamente significativas entre las variables fisiológicas antes y después del entrenamiento muscular respiratorio (p<0.05), a excepción de volumen corriente y la presión arterial media (p>0.05). Por el contrario, cuando se evaluó el efecto según el número de sesiones de entrenamiento recibidas por los pacientes, no se observaron diferencias significativas en ninguna de las variables (p>0.05).
Conclusiones. El entrenamiento muscular respiratorio es una intervención terapéutica viable y tolerable en esta población.
Palabras clave: Entrenamiento; Seguridad; Cuidado intensivo; Terapia física; Músculos respiratorios (DeCS).

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Introduction

Mechanical ventilation (MV) is a life-support treatment often used in intensive care units (ICUs) as part of the standard management of acute respiratory failure.[1] 33% percent of patients admitted to the ICU require MV;[1] of these, 5% fail their first attempt to wean[2] and require prolonged MV, which has been associated with complications such as changes in respiratory mechanics, airway injuries, acute lung injury, and pneumonia.[3,4] Since functionality in patients with prolonged MV is affected when they leave the ICU, and consequently their quality of life worsens, it is necessary to implement strategies to accelerate weaning and thus reduce sequelae of this treatment.

Respiratory muscle training (RMT) is a physical therapy strategy used to increase respiratory muscle strength and improve exercise tolerance to facilitate weaning from MV.[5,6] This intervention has been implemented in patients with chronic obstructive pulmonary disease and heart failure, achieving effective results.[7] In patients on MV, evidence is growing and its implementation is suggested in populations with well-defined criteria, taking into account specific vital signs and ventilator parameters.[8]

The reported benefits of RMT in ICU patients are increased maximal inspiratory pressure,[5,9-11] increased tidal volume[10] and improved exercise tolerance and performance of daily activities.[11] Multiple controlled clinical trials have evaluated tolerance to RMT and the presence of adverse events in patients on MV,[5,9-11] reporting that it is a tolerable and safe strategy in this population; however, little research has assessed physiological changes related to RMT in these patients. Some of these research works are the study conducted by Santos-Pascotini *et al.*,[12] who evaluated RMT-related changes in tidal volume, respiratory rate and heart rate in 14 tracheostomy patients with difficult MV weaning, and determined that this strategy did not produce significant changes in the variables evaluated; in turn, Bissett *et al.*,[8] studied the physiological response to RMS in a cohort of 10 tracheostomy patients and reported that it was a safe therapeutic intervention in this population.

Considering that, to date, there are no reports in the literature of studies conducted in Colombia on the subject and that it is important to highlight the relevance of surveillance and monitoring of vital signs and tidal volume during RMT,[13] the objective of this study was to determine the physiological changes related to RMS in patients on WV ≥48 hours in a quaternary care clinic in Cali, Colombia, during the period 2014-2015.

Materials and methods

A secondary data analysis was performed in the framework of the study "Efficacy of respiratory muscle training in weaning from mechanical ventilation in patients with mechanical ventilation for 48 hours or more: a randomized controlled clinical trial".[14]

The population consisted of 62 patients who were part of the experimental group of the main study and met the following inclusion criteria: 1) mechanical ventilation for ≥48 hours, 2) aged ≥18 years, 3) first time requiring mechanical ventilation, 4) intubation at the quaternary care clinic where the study was conducted or other health care facilities and referred no later than 12 hours after intubation, and 5) PaO_2>60 mmHg, FiO_2≤0.5, PEEP<8 cmH20, RASS agitation and sedation scale between -1 and 01[5], and mean blood pressure >60 mmHg without vasopressors or with minimal requirement of vasopressors (dobutamine or dopamine <5 mcg/kg/min/, or epinephrine <1 mcg/kg/min). Patients who met any of the following conditions were excluded: neuromuscular disease, central nervous system injury, spinal cord injury above T5, severe scoliosis, severe kyphoscoliosis, pectus excavatum, pectus carinatum, pre-hospital ventilator support at home, tracheostomy, infection by multi-resistant bacteria, or pregnancy.[14]

The ethical principles established in Resolution 8430 of 1993[16] and the Declaration of Helsinki[17] were followed. The Ethics Committee of the Universidad del Valle approved this study by means of Minutes No. 003-016 of March 31, 2016.

The experimental group in the main study was included in an RMT program twice a day, every day, using the Respironics® Threshold IMT Respiratory Muscle Trainer (Respironics Inc., USA). Following the recommendations made by Caine & McConnell[18] *and* Sprague & Hopkins,[19] the initial RMT load was adjusted to 50% of the maximal inspiratory pressure and, in each session, 3 series of 6-10 repetitions were performed, depending on patient's tolerance, with a rest interval of 2 minutes between series.[18-20]

At the end of each series, dyspnea was evaluated using the modified Borg scale.[21] RMT and the records of the evaluated variables were applied by four physiotherapists who are part of the ICU team of the clinic; they were assigned for the development of the project and had experience in the care of critically ill patients. The physiotherapists were trained according to the indications of the research team, which were based on previous research.[9,22]

The training session was interrupted when the patient presented one of the following signs: 1) breathing rate >35 breaths per minute or >50% at the beginning of the session, 2) heart rate >140 beats per minute or >20% at the beginning of the session, and 3) paradoxical breathing, agitation, hemoptysis, sweating, or arrhythmia.[20]

Patients received the RMT sessions until they were extubated or until they presented any of the following conditions: 1) verbal or written request from the patient or his/her guardian to be excluded from the protocol; 2) septic shock,[23] which was considered if the patient presented systolic blood pressure <90 mmHg, mean blood pressure <65 mmHg and hyperlactation (lactic acid >4 mmol/L), or 3) tracheostomy.

At the beginning of the study, the following data were obtained for each patient: age, sex, height, type of health insurance, diagnostic classification, place of orotracheal intubation, score in the APACHE II classification system, reason for admission to ICU, mechanical ventilation modalities, and medications received during ICU stay.

The main variables assessed (heart rate, respiratory rate, systolic blood pressure, diastolic blood pressure, mean blood pressure, oxygen saturation and tidal volume) were recorded at rest and immediately after the end of each training series. Vital signs and tidal volume measurements were performed using a Nihon Kohden monitor and a Maquet mechanical ventilator (Servo-i 300), respectively.

Data analysis

The information collected in the main study was entered into a database previously designed in Epi Info™ 7 and subsequently exported to Stata 12 for analysis. The creation of the database and the typing was carried out by the researchers of the study, and an external evaluator compared the typed data with the records contained in the collection forms to evaluate the quality of the data.

To assess the normality of the data, the Shapiro-Wilk test was used. To assess changes in physiologic variables, the difference between the average of each variable before the start of the first RMT series and after the end of each RMT session was analyzed using the paired t-test. To analyze physiological changes according to the number of RMT sessions, the population was divided into three categories: patients who received one RMT session, patients who received two RMT sessions and patients who received more than two RMT sessions. Non-parametric variance was analyzed using the Kruskal-Wallis test for each of the variables. A value $p<0.05$ was statistically significant.

Results

Table 1 presents the clinical and socio-demographic characteristics of the participants.

Table 1. Clinical and socio-demographic characteristics.

Variables		n (%)
Age (years)		61(40-70) *
Sex	Male	33(53.23)
	Female	29(46.77)
Height (cm)		162.00(9.38) †
Race	White	23(37.10)
	Mestizo	23(37.09)
	Black	10(16.12)
	Indigenous	6(9.68)
OTI	OTI at the clinic	49(79.03)
	OTI at other care facility	13(20.97)
APACHE II		26.54(11.47) †
Reason for admission	Medical	45(72.59)
	Surgery	17(27.41)
Diagnostic classification	Respiratory	29(46.78)
	Gastrointestinal	19(30.64)
	Cardiovascular	13(20.97)
	Kidney	1(1.61)
MV mode	Assist	42(30-72) *
	Control	6(0-27) *
	Spontaneous	0(0-3) *
Medication	Midazolam	143.5(55-232)
	Fentanyl	9575(3450-18150)
	Dexmedetomidine	0(0-9150)
	Propofol n (%)	2(3.23)
	Norcuron® n (%)	1(1.61)

OTI: orotracheal intubation; VM: mechanical ventilation.
* median and interquartile range.
† mean and standard deviation.
Source: Own elaboration.

The median age of the patients in the study was 61 years. 45 (72.59%) were admitted to the ICU for medical reasons, and the respiratory system was the most affected system in 29 (46.78%).

Patients received between 1 and 14 RMT sessions, distributed as follows: 26 (42%), one session; 31 (50%), 2 sessions; and 5 (8%), 3 to 14 sessions, for a total of 159 sessions. Table 2 presents the changes in the participants' physiological parameters before and after RMT.

Thus, it was observed that after RMT, the means of all physiological variables had a statistically significant increase ($p<0.05$), except for tidal volume and blood pressure. However, when the effect of RMT was evaluated according to the number of sessions received by the patients, no statistically significant differences were observed in any of the variables (Table 3).

Table 2. Changes in physiological variables before and after respiratory muscle training.

Vital sign	Pre-training		Post-training		p-value
	Median	SD	Median	SD	
Heart rate (BPM)	81.16	19.57	82.95	20.22	0.020
Breathing rate (BRPM) n=154	18.34	5.17	19.42	5.94	0.000
Mean arterial pressure (mmHg) n=158	86.75	12.63	88.29	13.46	0.050
Systolic blood pressure (mmHg)	125.56	1.44	129.94	1.56	0.000
Diastolic blood pressure (mmHg)	67.36	14.29	68.99	13.80	0.030
% of oxygen saturation	98.1	2.29	98.71	1.94	0.000
Tidal volume (ml)	447.04	105.59	456.36	97.21	0.200

SD: standard deviation; BPM: beats per minute; BRPM: breaths per minute.
Source: Own elaboration.

Table 3. Changes in physiological variables before and after training according to the number of sessions received.

Number of sessions	Pre-training		Post-training		p-value
	Median	Range Intercuartilíco	Median	Range Intercuartilíco	
Heart rate (BPM)					
1	80	70-95	80	73-96	0.9
2	77	69-90	80	71-91	
3-4	76	66-92	79	72-92	
Respiratory rate (BRPM)					
1	16	14-20	17	14.5-21.5	0.7
2	16	15-22	18	15-24	
3-14	18	15-22	20	16-23	
Mean blood pressure (mmHg)					
1	86	78-92	86	79-96	0.61
2	89	77-100	91	80-103	
3-14	85	77-92	83.5	78.5-97	
Systolic blood pressure (mmHg)					
1	125	112-134	123	118-141	0.91
2	126	118-143	130	120-151	
3 a 14	121	111-132	127	116,5-139,5	
Diastolic blood pressure (mmHg)					
1	67	59-77	68	61-78	0.63
2	69	69-77	71	61-81	
3-14	64	58-75	66.5	59.5-76.5	
% of oxygen saturation					
1	99	97-100	100	99-100	0.19
2	99	97-100	99	98-100	
3-14	99	97-100	100	98-100	
Tidal volume (mL)					
1	440	397-518	455.5	403-505	0.52
2	464	400-513	440	401-516	
3-14	420	385-485	452	408-500	

BPM: beats per minute; BRPM: breaths per minute.
Source: Own elaboration.

Discussion

Multiple controlled clinical trials evaluate RMT tolerance and the occurrence of adverse events associated with this intervention in patients on MV. For example, Condessa *et al.*[7] and Martin *et al.*[10] report that this intervention was tolerable and safe in this population.

Marques-Tonella *et al.*,[23] in a study of 21 patients with tracheostomy and difficult weaning from MV, found that RMT, implemented using an electronic device, caused changes in respiratory rate, mean blood pressure, and oxygen saturation, without producing adverse effects. This result is consistent with those of the present study, despite differences in population and time of MV.

The present study showed that heart rate, respiratory rate, systolic blood pressure, diastolic blood pressure, and oxygen saturation increased significantly after completing the RMT session. This differs from the study conducted by Dos Santos-Pascotini *et al.*[12], who describe that RMT did not generate significant changes in tidal volume, respiratory rate, and heart rate after completing it in 14 patients with tracheostomy and difficult weaning from MV. It also differs from Bissett *et al.*,[8] who reported the same result for the variables heart rate, mean blood pressure, respiratory rate, and oxygen saturation in 10 individuals with tracheostomy and failed weaning from MV.

This may be associated with the differences of the study population, the RMT protocol and the total number of sessions received per patient since, in the present study, an RMT protocol with higher loads and longer duration was implemented, possibly resulting in less residual fatigue between training sessions[22] and a greater response in the values of the variables evaluated compared to other RMT protocols with high loads and short duration.[24,25] The 62 patients analyzed here only received a total of 159 sessions since they had a short period of MV after entering the study, so the number of RMT sessions was probably insufficient for them to adapt to the activity.[25-27]

In this study, the physiological variables evaluated remained in the safety range,[28,29] since the maximum values reached in each of these variables did not surpass the limit beyond which physical exercise is contraindicated in this population, even though there were significant increases in heart rate, respiratory rate, systolic and diastolic blood pressure, and oxygen saturation.[30]

When analyzing the physiological changes in patients according to the number of RMT sessions performed, no significant differences were found. This result can be explained, on the one hand, by the small sample size used in the present study, which in turn was its greatest limitation, and, on the other, by the distribution of the number of RMT sessions per participant (between 1 and 14 sessions), considering that they were exposed to MV only for a short period once it was determined that they met the inclusion criteria since the effect of RMT depends largely on its duration, as reported by Seynnes *et al.*[31], who point out that a minimum of 10 days of muscle training is required to increase the strength of the limb muscles, achieving an important clinical impact that also applies to inspiratory muscles.[32] However, some authors have reported that it takes about 14 days to achieve significant changes in muscle strength.[20,31]

The main strengths of the study were the strategies implemented to reduce the possibility of information bias during the implementation of the intervention protocol in the main study, including quality control of the measurement instruments and of the information collection and analysis processes.

Despite the limitation of the sample size, the results of this research are relevant because they allow considering RMT as a fundamental part of physical therapy in the ICU. They also provide evidence of the physiological changes related to RMT and, consequently, they contribute to knowledge in the area of cardiopulmonary physical therapy. Moreover, this is the first study to evaluate physiological changes related to RMT in Colombia, so it is a framework for future research.

Conclusions

RMT was a viable and tolerable therapeutic intervention in the study population since it generated significant increases in heart rate, respiratory rate, oxygen saturation, and systolic and diastolic blood pressure, without exceeding the limit beyond which physical exercise is contraindicated in this population.[30] However, no significant improvements were found in the variables analyzed when evaluating the impact of training according to its duration (number of sessions), so the findings reported here should be confirmed by new studies with larger samples and in patients where the duration of the RMT is longer.

Conflicts of interest

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