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Thoracoabdominal interaction and its relationship with biological risk factors in premature newborns

Interação toracoabdominal e sua relação com os fatores de risco biológico em recém-nascidos prematuros

Interacción toracoabdominal y su relación con los factores de riesgo biológico en recién nacidos prematuros

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ABSTRACT | The objective of this study was to assess the participation of thoracoabdominal muscles in breathing and its relationship with clinical risk factors in preterm newborns (PTNBs). This is a multicenter, cross-sectional study conducted in two neonatal intermediate care units with PTNBs between 26 and 35 weeks of age, hemodynamically stable, who used oxygen or ventilatory support during hospital stay. The lateral movements of the thorax were filmed for 2 minutes and the videos were quantitatively evaluated by a researcher blinded to sample data using the MATLAB Software for assessing thoracoabdominal participation patterns. Data for the maximum, minimum and mean values of the participation of the thorax and abdomen were expressed graphically in cm^2. The Pearson correlation coefficient was used to assess the correlation between neonatal variables and mobility. We evaluated 2,080 frames of 26 newborns with an average gestational age of 31 weeks ±2.34. The greater the age and weight, the greater the participation of the thorax in breathing ($r=0.55$, $p=0.001$); and the longer the hospital stay, the lower the thoracic participation ($r=-0.40$, $p=0.04$). The participation of the abdomen increases according to the increase in the number of days of oxygen use ($r=0.33$, $p=0.001$) and decreases with higher age and weight ($r=-0.41$, $p=0.001$). The thoracoabdominal participation pattern is directly related to gestational age and weight. Prolonged use of oxygen and the length of hospital stay adversely affect the respiratory pattern, since increasing abdominal participation in respiratory biomechanics may increase energy expenditure.

Keywords | Infant, Premature; Respiratory Mechanics; Thoracic Wall; Abdominal Wall; Photogrammetry.

RESUMO | O objetivo do estudo foi avaliar a participação toracoabdominal durante a respiração e sua relação com os fatores de risco clínicos em recém-nascidos prematuros (RNPT). Trata-se de um estudo multicêntrico, transversal, realizado em duas unidades de cuidado intermediário neonatal com RNPT entre 26-35 semanas, estáveis hemodinamicamente, que fizeram uso de oxigênio ou suporte ventilatório durante a fase da internação. O movimento lateral do tronco foi filmado por 2 minutos e os vídeos foram avaliados no *software* MATLAB® para interpretação quantitativa da participação toracoabdominal, por um pesquisador cego sobre os dados da amostra. Os dados foram expressos graficamente em cm^2 representando os valores máximos, mínimos e médios da participação de tórax e abdômen. O coeficiente

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de Pearson foi usado para avaliar a correlação entre as variáveis neonatais com a mobilidade. Foram avaliados 2.080 *frames* de 26 RNPT com idade gestacional média de 31 semanas ±2,34. Quanto maior a idade e o peso, maior a participação do tórax na respiração (r=0,55; p=0,001); e quanto maior o tempo de internação, menor é a sua participação (r=-0,40; p=0,04). A participação do abdômen aumenta de acordo com o aumento do número de dias em uso de oxigênio (r=0,33; p=0,001) e diminui com o aumento da idade e do peso (r=-0,41; p=0,001). A participação toracoabdominal tem relação direta com a idade gestacional e o peso. Como fatores externos, o uso prolongado de oxigênio e o tempo de internação interferem negativamente no padrão respiratório, uma vez que o aumento da participação abdominal durante a biomecânica respiratória pode representar um gasto energético.
Descritores | Recém-Nascido Prematuro; Mecânica Respiratória; Parede Torácica; Parede Abdominal; Fotogrametria.

RESUMEN | El presente estudio tuvo como objetivo evaluar la participación toracoabdominal durante la respiración y su relación con los factores de riesgo clínico en recién nacidos prematuros (RNPT). Este es un estudio transversal, multicéntrico, realizado en dos unidades de cuidados intermedios neonatales con RNPT entre 26-35 semanas, hemodinámicamente estables, que utilizaron oxígeno o soporte ventilatorio durante la hospitalización. El movimiento lateral del tronco se filmó durante 2 minutos, y un investigador a ciegas sobre los datos de la muestra evaluó los videos por medio del *software* MATLAB® para la interpretación cuantitativa de la participación toracoabdominal. Los datos se reprodujeron gráficamente en cm² representando los valores máximos, mínimos y promedio de la participación del tórax y el abdomen. El coeficiente de Pearson se utilizó para evaluar la correlación entre las variables neonatales con la movilidad. Se evaluaron 2.080 *frames* de 26 RNPT con una edad gestacional promedio de 31 semanas ±2,34. Cuanto mayor es la edad y el peso, mayor es la participación del tórax en la respiración (r=0,55; p=0,001), y cuanto más largo es el tiempo de hospitalización, menor será su participación (r=-0,40; p=0,04). La participación del abdomen aumenta conforme aumenta la cantidad de días utilizando oxígeno (r=0,33; p=0,001) y disminuye con el aumento de la edad y el peso (r=-0,41; p=0,001). La participación toracoabdominal está directamente relacionada con la edad gestacional y el peso. Como factores externos, el uso prolongado de oxígeno y el tiempo de hospitalización afectan negativamente al patrón de respiración, ya que el aumento de la participación abdominal durante la biomecánica respiratoria puede representar un gasto de energía.
Palabras clave | Recién Nacido Prematuro; Mecánica Respiratoria; Pared Torácica; Pared Abdominal; Fotogrametría.

INTRODUCTION

The anatomical conditions of the respiratory mechanics in a preterm newborn (PTNB) are not favorable for the maintenance of a stable lung volume without energy expenditure[1,2]. The ribs are cartilaginous and more horizontal, the rib cage is compliant and circular, the number of alveoli is reduced, and collateral ventilation is almost nonexistent[3].

The diaphragm muscle is more flattened and its insertion angle in the rib cage is more horizontal, hampering the lever mechanism during muscle contraction. In addition, respiratory and other skeletal muscles are weakened, due to the reduced size and number of muscle fibers[1,4].

All of these characteristics decrease the lung's ventilatory efficiency and lead to increased energy expenditure, becoming a great concern for the prognosis[2].

Improvements in non-invasive technologies and in ICU (Intensive Care Unit) procedures, aimed at monitoring respiratory mechanics, contribute to a more accurate assessment and allow a thoracoabdominal mobility analysis to be performed[5,6]. These technologies and procedures have long been considered clinically useful in the assessment of respiratory distress in newborn infants and are used routinely to measure the degree of respiratory difficulty in neonatology[7-11].

One of the methods that have showed to be accurate in the description of thoracoabdominal mobility and also allowed an accessible, reproducible and low-cost assessment is videogrammetry[12-14].

Even though videogammetry is capable of revealing respiratory mechanical behaviors that are clinically relevant for respiratory physiotherapy[9,11-13]–such as the evolution of respiratory muscle control in strategies complementary to the treatment of respiratory diseases and in physiotherapy clinical practice[3,10,14] – there are still no studies addressing its application to PTNBs. In view of this, our study aims to evaluate, through a videogrammetric analysis, the thoracoabdominal participation pattern during breathing and its relationship with clinical risk factors in PTNBs.

METHODOLOGY

This is a multicenter, cross-sectional study, carried out at the neonatal intermediate care units of two hospitals, one located in the Southeast and the other in the Northeast of Brazil.

A convenience sampling was adopted, and the selection of participants took place between April and December 2017. All PTNBs included in the study had used some type of ventilatory support (invasive mechanical ventilation, intermittent non-invasive ventilation, continuous positive airway pressure); were born with a gestational age of less than 37 weeks and six days; weighed more than 1.3 kg; were receiving full enteral feeding; and breathed without assistance on the day of the evaluation.

Filming procedures

To refine data collection procedures at the two hospitals, both teams participated in a training session using video conferencing applications, which involved the evaluation of five PTNBs who did not participate in the study. The setting for data collection and the positioning of the newborns were identical at the two units and the two teams discussed together all five experiments.

The filming stage was built on top of a wooden structure with a thickness of 1.5 cm, 56 cm high and 61 cm wide. The filming structure was covered with black Ethyl Vinyl Acetate (EVA) sheets. PTNBs were positioned on the structure in a supine position, without clothing; the upper limbs were flexed, abducted and externally rotated; hips were flexed at approximately 110° to ensure maximum exposure of the thoracoabdominal region; and three dark green circular adhesive markers were applied to the side of the thorax[3,6].

Three evaluators participated in the experiment. The first was positioned at the head of the PTNB to ensure correct positioning. The second was placed at the feet of the newborn, keeping the hips flexed at more than 90° and preventing the lower limbs from being in contact with the abdomen. The third was in charge of filming with a cell phone camera positioned on a 1-meter high tripod and prepared to capture all lateral movements of the thorax.

The newborns were filmed once for 120 seconds and, when necessary, before filming, they were fed a non-nutritive diluted glucose solution (0.1mL of sucrose at 24%) to calm them[7]. This methodology was based on the methods adopted in the studies by Ricieri and Rosário Filho[5], Ripka et al.[12].

Interpretation of the videos and statistical analysis

The videos were analyzed by a researcher blinded to the sample data using the MATLAB® software to quantitatively assess thoracoabdominal participation patterns. Data for the maximum, minimum and mean values of the participation of the thorax and abdomen in respiratory mobility were expressed graphically in cm^2 and descriptive variables were analyzed using means and standard deviations values. The Kolmogorov-Sminov test was used to examine the normality of quantitative variables. The Pearson correlation coefficient (r) was used to assess and measure the linear correlation between neonatal quantitative variables and mobility, which was classified as follows for interpretation purposes: r=0.1 to 0.3 (weak); r=0.4 to 0.6 (moderate); r=0.7 to 1 (strong).

RESULTS

We evaluated 2,320 frames from 29 PTNBs, but three newborns were excluded from the study due to failure in the analysis of the videos, thus leaving 2,080 frames corresponding to 26 PTNBs to be examined. All newborns included had used some ventilatory support and the average number of days of oxygen use was 11 (±19) days. The sample's descriptive data are shown in Table 1.

Table 1. Demographic data for the sample

	Minimum	Maximum	Average	SD
Gestational age (weeks)	26	35	31	2.34
Birth weight (g)	750	2,240	1,398	383
Hospitalization days	6	84	22	18.11
Abdominal Mobility (cm^2)	45	245	116	62.65
Thoracic Mobility (cm^2)	98	294	184	49.62

The participation of the abdomen showed a negative correlation with gestational age and birth weight and a positive correlation with the number of days of oxygen use. The participation of the thorax showed a positive correlation with gestational age and a negative correlation with days of hospitalization. All correlations were weak, except for that of thoracic participation with birth weight. Pearson correlation coefficients for the selected correlations are shown in Tables 2 and 3.

Table 2. Correlation of the participation of the abdomen with the selected variables

Participation of Abdomen *vs*	r*	p
Gestational age	−0.41	0.01
Birth weight	−0.57	0.01
Days of O_2	0.33	0.04

* Pearson correlation coefficient.

Table 3. Correlation of the participation of the thorax with the selected variables

Participation of Thorax *vs*	r*	p
Gestational age	0.55	0.01
Birth weight	0.96	0.01
Days of hospitalization	−0.4	0.04

* Pearson correlation coefficient.

DISCUSSION

The participation of the thorax was directly proportional to birth weight and gestational age, decreasing with the increase in the number of hospitalization days. Abdominal participation only increased with the increase in the period of oxygen use. This participation was measured by the measurement of the thoracoabdominal expansion, as previously mentioned by other authors[3,5,6,12-14] and which is a procedure that has been recently used in the field of neonatology[3,9,10].

In all these studies[3,5,6,12-14], respiratory movements were assessed by measuring the lateral motion of the thoracoabdominal compartment and, despite studying different subjects in different clinical situations, all showed satisfactory results in capturing thoracic and abdominal movements, corroborating our findings.

Videogrammetric analysis was used recently by Gomes et al.[9] and Gomes et al.[10]. In these studies, the authors filmed the newborn for 60 seconds and evaluated, using frames extracted from the footage, the thoracoabdominal motion before and after different respiratory physiotherapy procedures were performed, demonstrating that this is an effective methodology for obtaining measurements and quantitative data for neonatal clinical applications[9,10].

Mechanical and muscle changes in newborns' respiratory system contribute to increasing abdominal mobility and, thus, to a greater energy expenditure and a progressive clinical deterioration[3].

Abdominal movements are part of the neonatal respiratory mechanics and mainly reflect the biomechanical disadvantages of the rib cage, such as increased compliance, more horizontal ribs and diaphragm, reduced diaphragmatic zone of apposition and immature abdominal and intercostal muscles[1]. In our study, abdominal participation was greater the lower the gestational age and birth weight, corroborating the idea of the immaturity of the respiratory system[1] and strengthening the hypothesis of the occurrence of changes in respiratory mechanics and of thoracoabdominal asynchrony[15].

Another finding of our study was the relationship between the use of oxygen and increased abdominal mobility. Studies show that PTNBs who use oxygen for more than 10 days have respiratory depression, pulmonary vasodilation, systemic arterial vasoconstriction and pulmonary fibrosis[15-17]. One hypothesis to explain our findings is related to pulmonary fibrosis, which would decrease rib cage compliance, increasing abdominal participation in breathing and corroborating the findings of Rocha[15] and Pereira[16]. This also explains the fact that the length of hospital stay has a negative relationship with thoracic participation. The longer the hospital stay, the greater the exposure to factors that increase oxidative stress and the release of free radicals[18,19].

This oxidative stress is due to the incomplete development of PTNBs' antioxidant systems, which favors the occurrence of tissue injuries. As a result, toxic radicals oxidize enzymes, break down the structure of DNA, inhibit protease and induce lipid peroxidation. All of these factors trigger inflammatory reactions that interrupt lung growth and development[16-19].

Changes in thoracoabdominal mobility are commonly found in newborns in intensive care[20]. This respiratory pattern is often assessed by measuring the number of respiratory incursions and the quality of chest expansion: the lower the thoracic mobility and the higher the respiratory rate, the worse the clinical condition of the newborn[20]. However, neonatal patients do not voluntarily control muscle synergy during breathing; and the studies that describe these changes are limited to retrospective or subjective data, which compromises the interpretation of results and reinforces the importance of adopting objective methodologies, as that adopted in our study.

Despite high-complexity neonatal special care units having modified their procedures[21], non-invasive methods capable of objectively quantifying respiratory system development are preferable in clinical practice and more reliable when compared with the subjective assessment of chest expansion quality[22].

In this study, we present an objective and quantitative model and demonstrate that external factors, such as prolonged use of oxygen and length of hospital stay, negatively affect the respiratory pattern of PTNBs, increasing abdominal participation during spontaneous breathing.

However, although the study shows promising results regarding the measurement of respiratory mobility in PTNBs, some limitations should be considered. This method requires the newborn to remain motionless in the supine position, which can cause irritation and hinder data collection, requiring a greater number of evaluators or even the use of non-nutritive sucking to contain movements. In the future, the quantitative assessment of respiratory mobility is expected to be achieved with a serial evaluation using filming in equipment routinely used in neonatal units, such as incubators and multiparametric monitors, thus enabling the early identification of mobility changes in newborns of different ages and clinical conditions.

Despite the limitations inherent in the filming process, the method demonstrated sufficiently that thoracoabdominal participation patterns are directly related to gestational age and weight; and external factors, such as prolonged use of oxygen and length of hospital stay, negatively affect the breathing pattern, since the increase in abdominal participation in the respiratory biomechanics can increase energy expenditure.

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