Diaphragmatic and excursion thickness in newborns using diaphragmatic kinesiology ultrasound: an observational study

Espessura e excursão diafragmática em recém-nascidos usando ultrassonografia cinesiológica do diafragma: um estudo observacional

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Abstract

Introduction: The study of the diaphragm muscle has aroused the interest of physiotherapists who work with kinesiological ultrasonography, but still little explored; however, its findings can contribute to the clinical practice of hospitalized patients in neonatal intensive care units. **Objective:** To measure the excursion and thickening of the diaphragm and describe measurements among neonates, preterm, and full-term. **Methods:** Diaphragmatic kinesiological ultrasonography was performed on hospitalized newborns, in Neonatal Unit Care Unit, placed in supine position in their own bed, on the sixth day of life. Three repeated measurements of the same respiratory cycle were made, both for excursion and for diaphragmatic thickening. **Results:** 37 newborns participated in the study and 25 were premature. The mean weight at the time of collection was 2,307.0 ± 672.76 grams and the gestational age was 35.7 ± 3.3 weeks. Diaphragmatic excursion increased with increasing gestational age ($p = 0.01$, $df = 0.21$) in term infants ($p = 0.17$, $df = 0.35$). **Conclusion:** There was a positive correlation between diaphragmatic excursion and gestational age. There was no statistically significant difference in the measurements of excursion and inspiratory diaphragm thickening between preterm and term newborns, although pointing to higher measurements in the latter group.

Keywords: Diaphragm. Neonatal Intensive Care Unit. Newborn. Physiotherapy. Ultrasonography.

Resumo

Introdução: *O estudo do músculo diafragma tem despertado o interesse dos fisioterapeutas que trabalham com ultrassonografia cinesiológica. Ainda pouco explorado, contudo, seus achados podem contribuir para a prática clínica dos pacientes internados em unidades de terapia intensiva neonatal (UTIN).* ***Objetivo:*** *Mensurar a excursão e o espessamento diafragmático e descrever as medidas entre recém-nascidos prematuros e a termo.* ***Métodos:*** *Realizou-se ultrassonografia cinesiológica diafragmática em recém-nascidos internados em UTIN, posicionados em supino em seu próprio leito, no sexto dia de vida. Foram realizadas três medidas repetidas do mesmo ciclo respiratório, tanto da excursão quanto do espessamento diafragmático.* ***Resultados:*** *Participaram do estudo 37 recém-nascidos, dos quais 25 eram prematuros. O peso no momento da coleta foi de 2.307,0 ± 672,76 gramas e a idade gestacional foi de 35,7 ± 3,3 semanas. A excursão diafragmática aumentou de acordo com o aumento da idade gestacional (p = 0,01; df = 0,21). A espessura variou entre 0,10 e 0,16 cm durante a inspiração nos prematuros e entre 0,11 e 0,19 cm nos nascidos a termo (p = 0,17; df = 0,35).* ***Conclusão:*** *Houve correlação positiva entre a excursão diafragmática e a idade gestacional. Não observou-se diferença estatisticamente significativa das medidas de excursão e de espessamento diafragmático inspiratório entre recém-nascidos prematuros e recém-nascidos a termo, embora apontando para maiores medidas neste último grupo.*

Palavras-chave: *Diafragma. Unidade de Terapia Intensiva Neonatal. Recém-nascido. Fisioterapia. Ultrassonografia.*

Introduction

The functionality of the diaphragm is related to the lung volumes mobilized in each respiratory cycle.[1] Premature newborns have different anatomical and physiological characteristics compared to term babies and infants.[2] In terms of anatomy, when compared to adults, the thorax of premature newborns has a rounder shape, as the anteroposterior and transverse diameters are similar, resulting in a cylindrical thorax with less capacity for expansion. As a result, the ribs are horizontal and the intercostal muscles are weaker, which makes muscle work more difficult.[3] This anatomical constitution causes the neonatal diaphragm to be morphologically flattened and attached to the chest wall at a greater angle, resulting in a smaller area of apposition and amplitude of displacement of the diaphragm, which reduces its ability to generate force during the respiratory process. This mechanical limitation can lead to distortions during the respiratory work of the premature newborn.[3]

The diaphragm, as the main muscle in breathing, is the target of physiotherapy treatments, since its muscular contraction expands the rib cage during inspiration and promotes an increase in mobilized lung volumes.[4,5] To evaluate the diaphragm, some techniques can be used in addition to ultrasound, such as nuclear magnetic resonance and computerized tomography.[6]

Initially, ultrasound diaphragmatic assessments were developed for the adult population and adapted for newborns.[7] It is a non-invasive, radiation-free technique that can be used by physiotherapists,[8] easy to use at the bedside, providing information on the functioning of the respiratory muscle pump.[3,9] Color Doppler ultrasound makes it possible to assess the excursion and shortening of this muscle, and this assessment of functionality is related to the lung volumes mobilized in each respiratory cycle.[1,10] In children, diaphragmatic assessment showed a positive correlation with maximum inspiratory pressure.[11]

While in the adult[12] and pediatric[13] population the values of thickness and excursion, measured by diaphragmatic kinesiological ultrasound, are well known and provide the team with information to guide the weaning and extubation processes,[14-17] in the neonatal population, with specific physiological characteristics that vary according to gestational age, these values are still being investigated.[18,19]

Establishing values related to mobility and diaphragmatic shortening in the neonatal population to facilitate decision-making is still a challenge.[18] Thus, the aim of this study was to evaluate diaphragmatic excursion and thickening in term and premature newborns.

Methods

This is a cross-sectional observational study, conducted in a tertiary Neonatal Intensive Care Unit (NICU) in southern Brazil, from June to August 2021. The study was approved by the Ethics Committee of the Clinical Hospital Complex of the Federal University of Paraná (number 36202920.2.0000.0096) and registered with the Brazilian Registry of Clinical Trials (protocol RBR-6vnftw).

Convenience sampling was estimated considering a type I error of 5%, type II error of 15%, three levels, calculating an effect size of 0.25 mm, indicating a minimum sample of 10 cases in each group. All clinically stable newborns, on the sixth day of life, on room air or receiving non-invasive supplementary oxygen modalities (nasal catheter) were included. Those with central nervous system malformations, in respiratory isolation, with chest drains or thoracic or abdominal surgeries, pulmonary hemorrhage, diaphragmatic hernia, severe pulmonary hypertension, undrained pneumothorax, thrombocytopenia, omphalocele or gastroschisis not yet corrected were excluded. Demographic data (gestational age, gender and birth weight) and anthropometric data (length and cephalic, thoracic and abdominal circumference measurements) were collected.

For diaphragmatic ultrasound, the newborns were placed in the supine position, with their heads in midline, in their own incubator, using SonoSite M-turbo® equipment (Gorham St., Canada), with a 5 MHz transducer for assessing diaphragmatic excursions and a 10 MHz transducer for measuring diaphragmatic thickness. The transducer was directed medially cephalad to keep the ultrasound beam perpendicular to the posterior third of the right hemidiaphragm, in the subcostal region. The 2D mode was used to visualize and obtain the best approach, with the liver serving as an acoustic window on the right to select the line of exploration. M-mode was used to display and measure the amplitude of craniocaudal diaphragmatic excursion during inspiration and expiration. To measure diaphragm thickness, the transducer was positioned on the axillary line, in the diaphragm apposition zone, between the 8th and 11th intercostal spaces (Figure 1). The values of three consecutive respiratory cycles were recorded.[9,20,21] The excursion and thickening values are given in centimeters.

All tests were carried out on eupneic newborns one hour after feeding, with monitoring of vital data. The assessments were always carried out by the research physiotherapist, who had been previously trained, accompanied by the cardiologist supervisor.

Statistical analysis

Continuous variables are presented as arithmetic mean and standard deviation for those with a normal distribution and median and interquartile range (25-75%) for those with an asymmetric distribution. The Shapiro-Wilk test was used to assess the normality of the distribution.

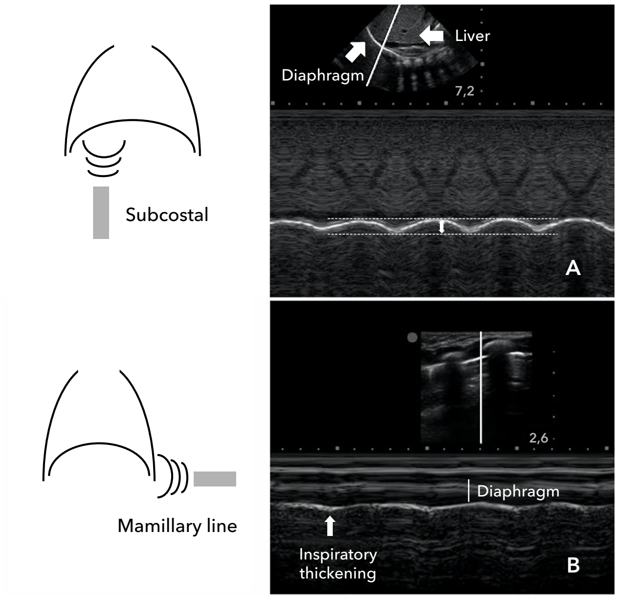

Figure 1 - Position of the transducer and images obtained from the excursion (A) and thickness (B) of the diaphragm.

Categorical variables are presented as absolute and relative frequencies. In order to obtain the average of the best-fitting measurements, the three diaphragm measurements were assessed for their differences using the Bland-Altman method (which assesses the degree of difference and agreement between the measurements), the one-sample t-test (which checks whether the differences between the measurements are different from zero) and Lin's coefficient of agreement (which checks the reproducibility of the measurements, with a value of 1 indicating maximum agreement). The decision on which measures to use to calculate the average was made based on the three evaluations, with priority given to Lin's coefficient of agreement.[22]

The t Student test was applied to estimate possible differences between continuous variables with symmetric distribution, while for those with asymmetric distribution, the Mann-Whitney test and Anova from Kruskal-Wallis were applied with Wilcoxon's post-hoc test. Categorical variables were studied using Fisher's exact test and Pearson's chi-square test, depending on the contingency tables. Spearman's correlation was used to assess the association between diaphragmatic measurements and gestational age. A 5% significance level was used for all tests (StatSoft Power Solutions®, Inc., Palo Alto, California, USA).

Results

The study sample consisted of 37 newborns, 25 premature and 12 full-term. The distribution of gestational age, gender, weight and the relationship between weight and height in each group is described in Table 1. The hospitalized newborns who took part in the study had a clinical diagnosis of newborn respiratory distress syndrome, apnea and transient tachypnea of the newborn. Maternal age was similar in both groups, with an average of 29.4 ± 6.8 in the group of premature newborns and of 29.7 ± 7.9 among full-term newborns ($p = 0.92$).

Figure 2 shows the correlation between gestational age at the time of the ultrasound scan and diaphragmatic excursion ($r = 0.43$). This correlation coefficient was even more significant when only female newborns were studied ($r = 0.57$). A similar positive correlation was observed between diaphragmatic excursion and measurements of birth weight ($r = 0.42$), cephalic perimeter ($r = 0.51$), thoracic perimeter ($r = 0.41$), abdominal perimeter ($r = 0.45$) and length ($r = 0.46$).

When the newborns were stratified according to corrected gestational age at the time of the ultrasound examination, into < 34 weeks, > 34 < 37 weeks and > 37 weeks, greater diaphragmatic excursion was observed the higher the gestational age category (Table 2). Greater diaphragmatic thickening was observed during inspiration compared to expiration, both in premature and term newborns ($p < 0.001$) (Figure 3).

Table 1 - Characteristics of the newborns participating in the study

Characteristics	**Preterm newborns** (n = 25)	**Full-term ewborns** (n = 12)	p
Gender n (%)			
Male	12 (48)	6 (50)	1.000[2]
Female	13 (52)	6 (50)	
Gestational age at birth	34 ± 2	38 ± 2	< 0.001[1]
Gestational age at collection	34 ± 3	39 ± 2	< 0.001[1]
Birth weight	2088.2 ± 565.3	3141.1 ± 277.2	< 0.001[1]
Weight at collection	1943.0 ± 482.9	3035.0 ± 291.9	< 0.001[1]
Weight/Height n (%)			
Appropriate for gestational age	21 (84.0)	11 (91.7)	0.250[3]
Large for gestational age	3 (12.0)	0 (0.0)	
Small for gestational age	1 (4.0)	1 (8.3)	
Lenght (cm)	42.6 ± 4.0	48.0 ± 1.5	< 0.001[1]
Cephalic perimeter (cm)	30.9 ± 2.7	34.2 ± 1.8	< 0.001[1]
Thoracic perimeter (cm)	27.6 ± 3.2	32.9 ± 1.6	< 0.001[1]
Abdominal perimeter (cm)	25.6 ± 3.0	31.9 ± 2.8	< 0.001[1]

Note: [1]Student's t-test; [2]Fisher's exact test; [3]Pearson's chi-square test. Data expressed as mean (standard deviation), except for gender and weight/height ratio, expressed as absolute and relative frequency.

Table 2 - Measurements of diaphragm excursion and thickening according to gestational age categories

Measures	**< 34 weeks** (n = 10)	**> 34 < 37 weeks** (n = 13)	**> 37 weeks** (n = 14)	p
Diaphragmatic excursion	0.30 (0.20-0.36)	0.35 (0.22-0.47)	0.52 (0.38-0.58)	0.01
Diaphragmatic thickening (I)	0.11 (0.05-0.16)	0.12 (0.12-0.15)	0.16 (0.10-0.21)	0.23
Diaphragmatic thickening (E)	0.07 (0.05-0.11)	0.08 (0.07-009)	0.11 (0.09-0.14)	0.09

Note: Anova from Kruskal-Wallis. Effect size: diaphragmatic excursion = 0.21; diaphragmatic thickening at inspiration (I) = 0.02 and at expiration (E) = 0.07.

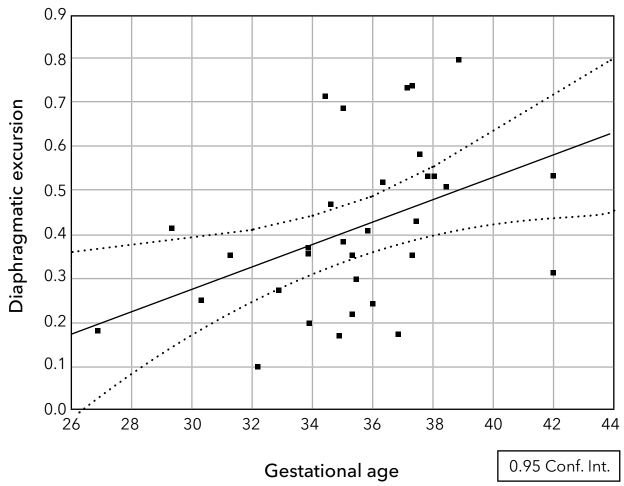

Figure 2 - Correlation between diaphragmatic excursion measurement (mm) and gestational age at ultrasound examination.

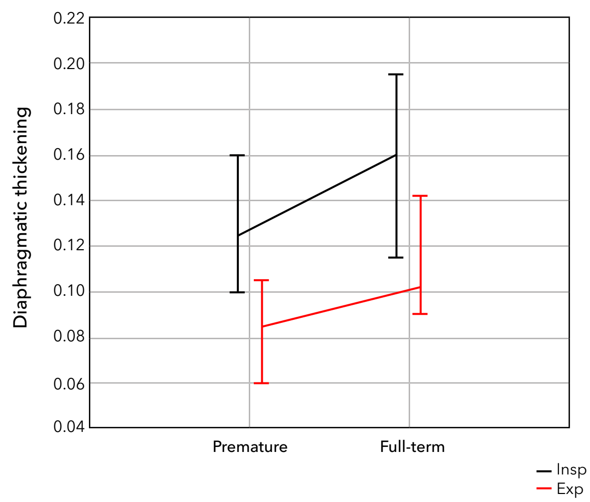

Figure 3 - Diaphragmatic thickening (mm) on inspiration and expiration according to the groups of preterm and term newborns.

Discussion

Diaphragmatic ultrasound indicated greater diaphragmatic excursion on inspiration regardless of gestational age, increasing in direct proportion with gestational age, with greater strength of association in females.

Measurements of diaphragmatic excursion and thickness at the bedside make it possible to assess the workload of the respiratory system and help diagnose muscle paresis and weakness.[23] The thickness of the right hemidiaphragm is also related to the degree of contractile activation of the muscle during ventilation, so this technique can be used in the adult population to assess diaphragm atrophy.[24]

Rehan and McCool[18] measured the diaphragm in a group of 34 premature newborns and observed a greater thickness of the diaphragm according to the greater weight, cephalic perimeter and length measurements of the newborns, with no association, however, with gestational age. In this study, there was a correlation between body measurements and diaphragmatic excursion, but no difference in diaphragmatic thickening between preterm and term newborns. Alonso-Ojembarrena e Oulego-Erroz[25] also observed greater diaphragm thickness in full-term newborns, with no difference in the shortening fraction compared to premature newborns.

There is no doubt that diaphragmatic ultrasound can be a useful tool for assessing diaphragmatic function. It has numerous advantages over other techniques, such as the fact that it is non-invasive, does not use ionizing radiation, is reproducible, easy to apply, low-cost and applicable to different clinical contexts;[7] however, it is not yet part of the arsenal of research and therapeutic support in daily practice. Some of the reasons for this include the lack of recognition of diaphragmatic involvement in many clinical situations and the lack of technical expertise. The learning curve in diaphragmatic ultrasound training is steep, indicating that doctors and physiotherapists who are properly trained and dedicated to clinical care can achieve mastery and good accuracy in ultrasound assessment of the diaphragm.[26]

In the USA, physiotherapists have been using ultrasound for research and clinical practice involving muscle tissue, tendons, and ligaments since 1980.[27] In Brazil, regulatory bodies began to allow physiotherapists to operate ultrasound equipment for research purposes, as well as to establish functional diagnoses to guide physiotherapy treatment and prognosis, as of 2021.[7]

Thoracic ultrasound, for the purpose of pulmonary and/or diaphragmatic assessment, can be a major advance in respiratory care.[27] Ultrasound is undoubtedly a test with an assessment-dependent component, which requires targeted learning,[28] but trained with validated decision-making algorithms,[29] can make it a valuable complement for evaluating and guiding the most effective treatment for premature newborns admitted to intensive care,[19] because it is known that the functionality of the diaphragm is directly related to the lung volumes mobilized in each respiratory cycle.[1]

In healthy adult individuals, physiotherapists' assessments of diaphragm function and contraction strength indicate that there is a good correlation between diaphragm function, amplitude of excursion and thickening, and the strength tested using spirometry.[30,31] This study is a further contribution to a better understanding of diaphragm measurements in newborns in intensive care. Type II error, due to the size of the sample, especially in the analyses performed according to gestational age categories, is a limitation in interpreting the results obtained. Thus, although no statistically significant difference was found between preterm and term newborns, the p-values between 0.08 and 0.17, located in the area considered by many to be of statistical uncertainty,[32] point to higher values among full-term newborns and indicate that more studies should be carried out to define reference values for diaphragmatic dimensions in newborns.

Conclusion

There was a positive correlation between diaphragmatic excursion and gestational age, as well as a positive correlation also associated with body measurements of birth weight, length, cephalic, thoracic and abdominal perimeter, suggesting that diaphragmatic dimensions follow growth. There was no statistically significant difference in the measurements of inspiratory and expiratory diaphragmatic excursion and thickening between premature and full-term newborns, although the latter group showed greater measurements.

Authors' contributions

MGA, SV and MNL were responsible for the bibliographic research and data collection, which were analyzed by MNL. All authors participated in the study design and MGA, CNB, RPGVCS and MNL, in the preparation of the manuscript. All authors reviewed the manuscript and approved the final version.

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