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## Is Prolonged Slow Expiration a Reproducible Airway Clearance Technique?

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**Background.** Prolonged slow expiration (PSE) is a manual chest physical therapy technique routinely performed in clinical practice. However, the reliability and agreement of the technique have not been tested.

**Objective.** The objective of this study was to assess reliability and agreement between physical therapists during the application of PSE in infants with wheezing.

**Design.** This was a cross-sectional study.

**Methods.** Infants with a mean age of 59 weeks (SD = 26 weeks) were included in this study. Two physical therapists (physical therapist 1 and physical therapist 2) randomly performed 3 PSE sequences (A, B, and C). The expiratory reserve volume (ERV) was measured with a pneumotachograph connected to a face mask. ERV was used to evaluate the reproducibility of the technique between sequences and between physical therapist 1 and physical therapist 2.

**Results.** The mean ERV of the infants was 63 mL (SD = 21 mL). There was no statistically significant difference between the ERV values in the 3 sequences for physical therapist 1 (A: mean = 46.6 mL [SD = 17.8 mL]; B: mean = 45.7 mL [SD = 19.9 mL]; C: mean = 53.3 mL [SD = 26.3 mL]) and physical therapist 2 (A: mean = 43.5 mL [SD = 15.4 mL]; B: mean = 43.2 mL [SD = 18.3 mL]; C: mean = 44.8 mL [SD = 25.0 mL]). There was excellent reliability between the sequences for physical therapist 1 (ICC = 0.88 [95% CI = 0.63–0.95]) and physical therapist 2 (ICC = 0.82 [95% CI = 0.48–0.93]). Moderate agreement was observed between physical therapist 1 and physical therapist 2 (ICC = 0.67 [95% CI = 0.01–0.88]). According to Bland-Altman analysis, the mean difference between physical therapist 1 and physical therapist 2 was 4.1 mL (95% CI = –38.5 to 46.5 mL).

**Limitations.** The data were collected in infants with wheezing who were not in crisis. This decreased lung mucus; however, it also reduced evaluation risks.

**Conclusions.** PSE was a reproducible chest physical therapy technique between physical therapists.



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**C**hest physical therapy techniques have been widely used in infants with pulmonary hypersecretion to increase mucociliary clearance and reduce respiratory distress.<sup>1</sup>

Prolonged slow expiration (PSE) is a manual chest physical therapy technique routinely used to reduce respiratory distress in children.<sup>1,2</sup> The chest compression during PSE increases pleural pressure so that it becomes higher than pressure at the mouth. This pressure difference improves pulmonary air flow from the alveoli to the trachea, which remove mucus. Studies have shown that PSE reduces respiratory distress and improves oxygen saturation (SpO<sub>2</sub>) in infants hospitalized for bronchiolitis.<sup>2-4</sup> However, some randomized clinical trials, studying the same population, did not describe positive results for this technique.<sup>5-7</sup> Aspects such as the severity of patient condition, the outcomes studied, and the variability in the application of this manual technique may have caused diversity in the results.

Although PSE has been described in the literature since the 1990s, studies have mostly focused on the clinical aspects of the technique, such as respiratory distress, SpO<sub>2</sub>, heart rate, and respiratory rate.<sup>2-4,6</sup> However, it is known that tidal volume and expiratory reserve volume (ERV) are better variables for assessing the results of this technique. PSE has been reported to change the tidal volume, the ERV,<sup>8</sup> and the airway resistance,<sup>9</sup> but there have been no reports of the reliability of this technique based on these variables.

Manual chest physical therapy techniques may have wide variability, which can impact effectiveness. The reliability of a similar technique (slow expiration with glottis opened in infralateral decubitus position [ELTGOL]) was previously described,<sup>10</sup> but it has a different execution than PSE. To the best of our knowledge, the reliability of PSE has not been tested. Because PSE is a manual technique, this is an important issue to examine. Given the clear instructions for performing this technique, we hypothesize that PSE is reproducible and is consistently applied by physical therapists. Thus, the objective of this study was to evaluate the reliability and agreement of PSE in infants with wheezing.

## Methods

This cross-sectional study was conducted on infants with wheezing who were recommended for a lung function test by a physician. All parents (or legal guardians) provided written informed consent. This study was approved by the local Ethics Committee (under no. 1054/07).

## Participants

Infants who had recurrent wheezing (3 or more episodes of wheezing in the last year) and were free of respiratory infections for at least 20 days were included. Infants with heart disease, gastroesophageal reflux disease, and

obstruction of the upper airway were excluded, along with those who could not complete the test because of insufficient sedation or early awakening.

## Protocol

The infants were evaluated before the routine lung function test. The duration of the PSE protocol was 10 to 15 minutes, and the infants were continuously monitored during the procedure (heart rate and SpO<sub>2</sub> were measured with Dixtal Biomedica oximeter model DX2405 [Dixtal Biomedica, Sao Paulo, Brazil]). The order of PSE application by the physical therapists was randomized, and there were 5 minutes of washout between applications. After the PSE protocol was completed, the lung function test was performed (Fig. 1). A physician and a physical therapist supervised the entire protocol.

## Prolonged Slow Expiration

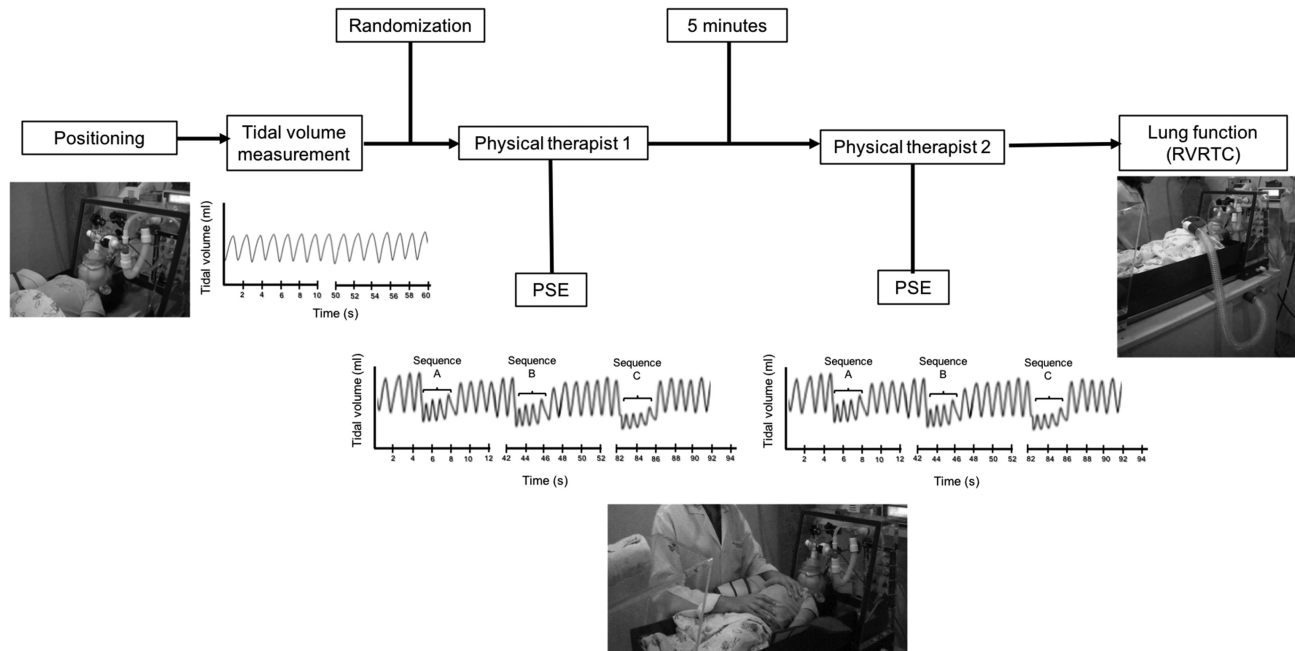
After oral sedation with chloral hydrate, which is required to perform the lung function test, the infant was placed in a supine position, and a face mask was attached to the pneumotachograph (Hans Rudolph, Kansas City, MO, USA).

Before applying the PSE technique, tidal volume was measured for 60 seconds to check the infant's breathing pattern (Fig. 1). The PSE was carried out as previously described.<sup>11</sup> The physical therapist positioned the hypothenar region of 1 hand on the infant's thorax, below the suprasternal notch, and placed the hypothenar region of the other hand on the infant's abdomen. The physical therapist visually identified the inspiratory and expiratory phases by observing the infant's thorax movement, and, at the end of the expiratory phase, the physical therapist applied compression with both hands. The infant's subsequent 3 inspirations were restricted, and the physical therapist's compression movements continued into the expiratory phase. This procedure was repeated 3 times (sequences A, B, and C), with intervals of 30 seconds between sequences (Fig. 1).

The technique was performed in random order by 2 physical therapists who had been duly trained (physical therapist 1 and physical therapist 2), who had at least 5 years of experience treating infants, and who had taken a specific course about PSE. Both physical therapists were blinded. The randomization was performed by a physician who was monitoring the infant. After the randomization, the second randomized physical therapist stayed in another room until the end of the protocol with the first physical therapist. The physician was responsible for monitoring when the first physical therapist had finished and asking the second to start the protocol. The washout time between physical therapists was 5 minutes.

The outcome was the infant's ERV registered in milliliters and as a percentage of predicted value.<sup>12</sup> The ERV was measured as the difference between the tidal volume and

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**Figure 1.**

Sequence of events of the protocol. PSE = prolonged slow expiration; RVRTC = raised lung volume rapid thoracoabdominal compression.

the exhaled volume during each compression (Fig. 2). The average ERV value for sequences A, B, and C conducted by each physical therapist was used for the analysis.

### Lung Function Test

After the PSE protocol was completed, the lung function test was performed. The infant remained in a supine position with the face mask attached. The volumes and pulmonary flows were obtained by the raised lung volume rapid thoracoabdominal compression technique as previously described and in accordance with the recommendations of the American Thoracic Society/European Respiratory Society,<sup>13</sup> using Infant Pulmonary Lab equipment (Collins-nSpire, Longmont, CO, USA). The flow-volume curves were obtained by compression of an inflatable jacket wrapped around the infant's chest and abdomen, and several sequential lung inflations (inspiratory pressure, 30 cm of H<sub>2</sub>O) were delivered to inhibit the respiratory effort prior to the thoracic compression. The forced maneuvers were performed by the automated inflation of the jacket, which compressed the chest and maintained expiratory flow. The measured variables were forced vital capacity, forced expiratory volume in 0.5 second, forced expiratory flow by forced vital capacity, and ERV.

### Data Analysis

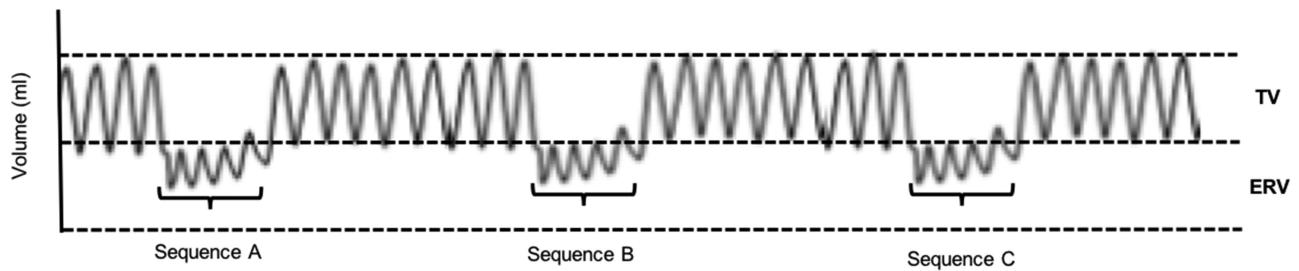
The power of the sample was calculated using the 16 evaluated infants, and the mean and standard deviation of the ERV values were considered. The effect size was 1.8, with an  $\alpha$  value of .05, and a power of 98%. The variables

were expressed as mean and standard deviation after the normality of the data was evaluated using the Shapiro-Wilk test. For comparisons between the 3 sequences (A, B, and C) and between the 2 physical therapists, a 2-way analysis of variance and Bonferroni post hoc tests were performed (2-tailed). The absolute agreement of the ICC and its respective 95% CI were determined for sequences B and C and for each physical therapist. The Cronbach alpha test was performed to determine the agreement between physical therapist 1 and physical therapist 2 (tester analysis), using the B sequence. The limits of agreement were evaluated with Bland-Altman analysis. Statistical significance was considered when the *P* value was < .05. SPSS version 20.0 (IBM SPSS, Chicago, IL, USA) was used for the analysis.

### Results

The study included 19 infants. Three did not complete the study because there was insufficient sedation, and they awoke prematurely. Thus, 16 infants were evaluated. The mean age was 59 weeks (SD = 26 weeks), and 11 were male. Eight infants had abnormalities in the lung function test. Of those, 6 had moderate and 2 had mild lung obstructive disease. The mean number of wheezing episodes was 4.9 (SD = 1.2). Table 1 describes the characteristics of the study population.

During the protocol, none of the infants exhibited signs of respiratory distress or wheezing, the SpO<sub>2</sub> of all the infants remained above 93%, and the heart rate range was 110 to 140 beats per minute.



**Figure 2.**

Sequences (A, B, and C). Each sequence had 3 or 4 consecutive compressions followed by 30-s intervals. The difference between tidal volume (TV) and exhaled volume during PSE was used as outcome. The average expiratory reserve volume (ERV) in each sequence was used for analysis.

**Table 1.**

Characteristics of 16 Studied Infants<sup>a</sup>

Variable	Mean	SD	% of the predicted value		z Score	
			Mean	SD	Mean	SD
Age (wk)	59	26				
Weight (g)	9734	1548				
Height (cm)	74	6				
RR (bpm)	33	6				
Tidal volume (mL)	105	26	106	17		
FVC (mL)	401	140			-0.2	0.6
FEV <sub>0.5</sub> (mL)	301	100			-0.6	0.6
FEV <sub>0.5</sub> /FVC	76	6			-0.6	1.0
FEF <sub>25-75</sub>	620	234			-0.5	1.3
ERV (mL)	63	21	100	14		
RV (mL)	188	58	121	32		
FRC (mL)	251	68	112	23		
TLC (mL)	581	169	98	12		

<sup>a</sup>bpm = beats/min; ERV = expiratory reserve volume; FEF = forced expiratory flow; FEV<sub>0.5</sub> = forced expiratory volume in 0.5 s; FRC = functional residual capacity; FEF<sub>25-75</sub> = FEF as a percentage of forced vital capacity (FVC); RR = respiratory rate; RV = residual volume; TLC = total lung capacity.

Physical therapist 1 began the protocol on 9 infants. There was no difference in the mean ERV value (all sequences) for physical therapist 1 (50.3 [SD = 22.4] mL) or for physical therapist 2 (45.5 [SD = 20.7] mL) ( $P = .27$ ). There was no difference within the sequences (A, B, and C) for each physical therapist or for each sequence between the physical therapists ( $P > .05$ ) (Tab. 2).

The ICC between the B and C sequences for physical therapist 1 was 0.88 (95% CI = 0.63–0.95) ( $P < .001$ ), and the corresponding ICC for physical therapist 2 was 0.82 (95% CI = 0.48–0.93) ( $P = .001$ ). To test the agreement of the PSE procedures performed by the 2 physical therapists, the B sequence was tested, and the Cronbach alpha value was 0.67 (95% CI = 0.01–0.88) ( $P = .02$ ).

The Bland-Altman analysis revealed a mean difference of -5 mL (95% CI = -37 to 26 mL) between the B and C sequences performed by physical therapist 1 (Fig. 3A). For physical therapist 2, the mean difference was -2 mL (95% CI = -33 to 38 mL) (Fig. 3B). The Bland-Altman analysis between physical therapist 1 and physical therapist 2 showed a mean difference of 4.1 mL (95% CI = -38.5 to 46.5 mL) (Fig. 3C).

### Discussion

PSE is a reproducible manual technique for treating infants with wheezing and can be consistently applied by physical therapists.

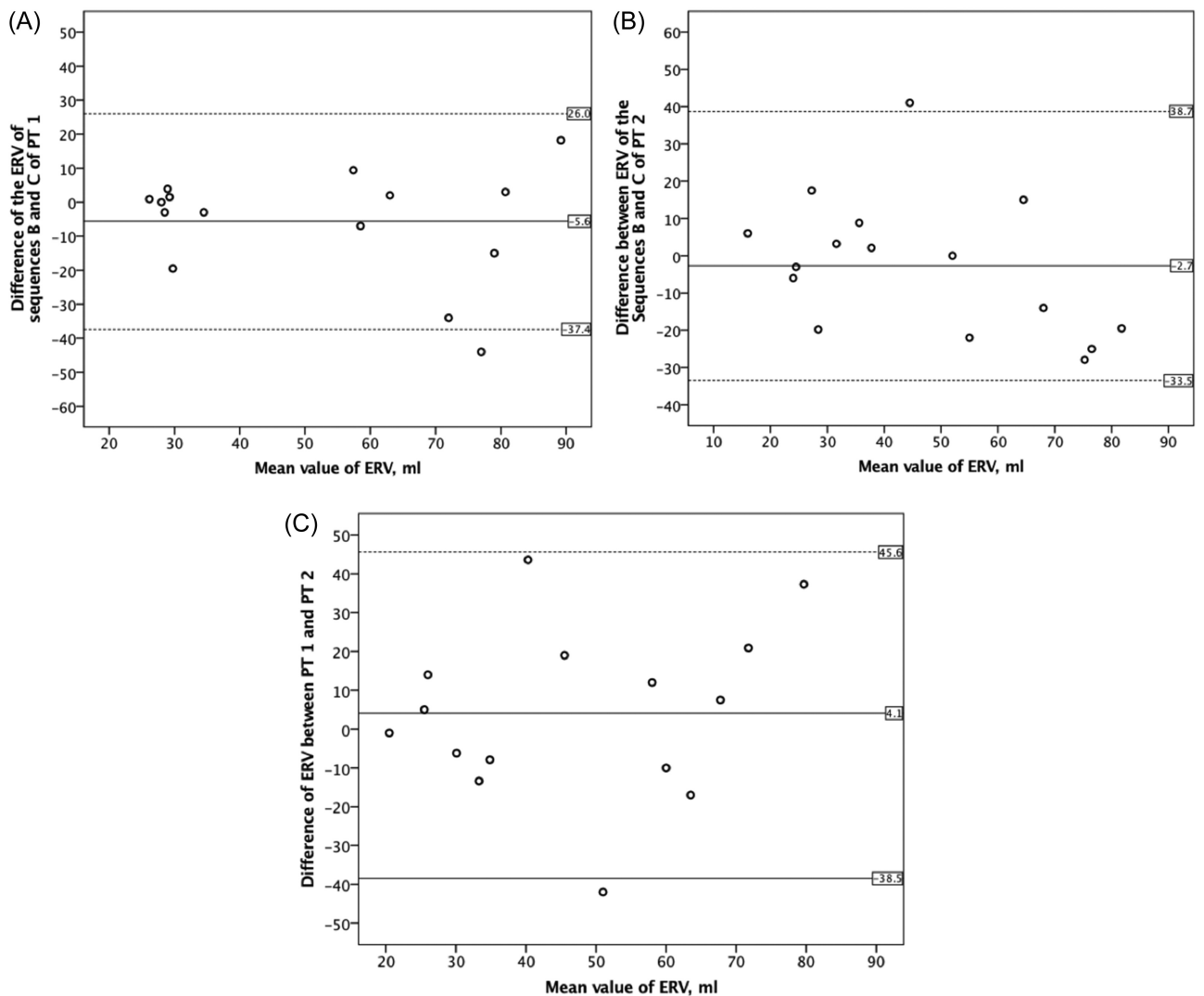
Some infant studies have shown an improvement in clinical outcomes after PSE was applied; however, clinical

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**Table 2.**

Expiratory Reserve Volume (ERV) Values in the 3 Sequences (A, B, and C) of the Prolonged Slow Expiration Technique Performed by Physical Therapists 1 and 2

Physical Therapist	ERV A (mL)		ERV B (mL)		ERV C (mL)		P
	Mean	SD	Mean	SD	Mean	SD	
1	46.6	17.8	45.7	19.9	53.3	26.3	.32
2	43.5	15.4	43.2	18.3	44.8	25.0	1.0
P	.62		.79		.38		



**Figure 3.**

Bland-Altman analysis of expiratory reserve volume (ERV, in mL) between the sequences and for physical therapist 1 (A) and physical therapist 2 (B). Analysis of ERV between physical therapist 1 and physical therapist 2 (C). The solid line represents the mean differences, and the dotted lines represent the lower and upper 95% CIs [mean  $\pm$  (SD  $\times$  1.96)].



trials have concluded that it was not possible to observe the benefits of this technique.<sup>1,2,5,6,9,11,14</sup> One possible reason for this discrepancy is variability in how the technique is performed. Particularly when a technique is applied manually, different responses are possible. The strength of manual compression can vary, interfering with the outcome. Thus, it is important to test the reliability of PSE. If there is a high degree of variability, the results of the procedure will change depending on the operator. The best way to minimize misinterpretation is to determine how much variability exists.

Previous studies have evaluated the reliability of different manual techniques, such as those for rib cage mobility,<sup>15,16</sup> peripheral muscle strength and functional capacity,<sup>17</sup> and thoracic vibration.<sup>18</sup> These techniques generally exhibit good reproducibility; however, operator training has been used to minimize technique variability. To the best of our knowledge, no studies have been conducted on PSE reliability. ERV was chosen as the appropriate outcome to test PSE variability because ERV was previously shown to correlate with patient improvement following PSE application.<sup>8</sup>

The results of this study demonstrate that there was no significant difference in the ERV values between the sequences performed by the 2 physical therapists. This means that a physical therapist trained to perform PSE can achieve minimal variability between sequences. Maréchal et al<sup>19</sup> addressed the difficulty in assessing lung volumes during the application of a manual chest physical therapy technique in infants. In that study, they developed a glove with sensors capable of measuring the pressure of manual techniques. One of the aims of the Maréchal et al<sup>19</sup> study was to evaluate the amount of strength that physical therapists applied during a technique called expiratory flow increase. The authors concluded that the technique was reproducible, and the variability of applied pressure was 20% on average, because it was applied by trained physical therapists.<sup>19</sup> Similarly, our data showed a difference of < 15% in the ERV values between the A, B, and C sequences for each physical therapist, and the difference was even smaller for the comparison between the 2 physical therapists. It should be emphasized that in our study, the technique was performed by physical therapists who had been trained to perform PSE. Similar data was previously observed in a study of adults and the manual chest physical therapy techniques ELTGOL<sup>10</sup> and chest wall vibrations.<sup>18</sup>

This study showed ICC values above 0.8, indicating an excellent reliability; thus, PSE was applied with small variability. The procedure was also consistently applied between the 2 physical therapists, even though it is a manual technique. Similar results were previously observed in the slow expiration with the glottis open technique.<sup>10</sup>

The Bland-Altman analysis establishes the correlation between 2 measurements, but it is not able to establish whether these limits are acceptable or not. Acceptable limits should be defined based on clinical need, biological considerations, and other objectives.<sup>20</sup> In the present study, the limits of agreement (and 95% CIs) were above 30 mL and represented almost 50% of the mean value of the measured ERV. However, in the Bland-Altman analysis, 4 volunteers were at the extreme range of the 95% CI. Without these infants, the ERV variability reduces to 20 mL, a value similar to that observed in adults.<sup>10</sup> When the data of these outlier infants were individually observed, they were found to have higher values for FEV<sub>0.5</sub>/FVC. We hypothesize that the better a patient's lung function, the better the chest compressions work and achieve higher volume variability. However, this theory cannot be confirmed with this small sample size.

In the present study, the PSE technique was applied to sedated infants, reducing the changes in breathing patterns during the execution of the technique. Chloral hydrate was chosen as the sedative, because it is recommended by international guidelines for performing a lung function test at this age,<sup>21</sup> it is safe for this population,<sup>22</sup> and it does not change a patient's breathing pattern.<sup>23</sup> Although the infants were wheezing, none had severe changes in lung function.

As a limitation to the present study, we note the small sample size. However, the tested power was > 80%. The ERV outcome used to study the PSE technique is considered the gold standard for patient assessment, because it represents the volume of air mobilized in the lungs during thorax compression. This allowed us to perform the study with fewer infants. Additionally, for safety reasons, the data were collected in infants with wheezing who had no acute symptoms, reducing any side effects.

In conclusion, there was no difference between the ERV values measured during the application of PSE in infants with wheezing, indicating that it is a reliable technique. Additionally, there was good agreement of the procedure between physical therapists. The variability of PSE was found to be approximately 30% of the ERV.

### Author Contributions and Acknowledgments

Concept/idea/research design: G.F. Wandalsen, D. Solé, F.C. Lanza  
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Providing participants: G.F. Wandalsen, D. Solé

Providing facilities/equipment: G.F. Wandalsen

Consultation (including review of manuscript before submitting):

S.N.S. Ribeiro, F.C. Lanza

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This study was performed at the Department of Pediatrics, Universidade Federal de Sao Paulo–UNIFESP.

### Ethics Approval

This study was approved (under no. 1054/07), parents (or legal guardians) provided written informed consent.

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### Disclosure

The authors completed the ICJME Form for Disclosure of Potential Conflicts of Interest and reported no conflicts of interest.

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