Journal of Taibah University Medical Sciences (2023) 18(6), 1254–1260

Taibah University

Journal of Taibah University Medical Sciences

www.sciencedirect.com

Original Article

Effect of intrathoracic oscillations on pulmonary functions in children with cerebral palsy

Alaa M. El-Moatasem, PhD [a] and Mai E. Abbass, PhD [b,*]

[a] *Department of Cardiovascular/Respiratory Disorder and Geriatrics, Faculty of Physical Therapy, Cairo University, Giza, Egypt*
[b] *Department of Physical Therapy for Paediatrics, Faculty of Physical Therapy, Cairo University, Giza, Egypt*

Received 13 October 2022; revised 10 March 2023; accepted 4 May 2023; Available online 16 May 2023

المخلص

أهداف البحث: للتحقيق في تأثير التذبذبات داخل الصدر على وظائف الرئة لدى الأطفال المصابين بالشلل الدماغي الرباعي التشنجي.

طرق البحث: شملت هذه الدراسة 24 طفلا من كلا الجنسين مصابين بالشلل الدماغي الرباعي التشنجي. تراوحت أعمار الأطفال بين 6 و 8 سنوات. وفقا لمقياس أشوورث المعدل، كانت درجة الشناج 2 إلى 2+. كان الأطفال قادرين على الجلوس بشكل مستقل واتباع التعليمات. تم تقسيم الأطفال بشكل عشوائي إلى مجموعتين (مجموعة الدراسة والمجموعة الضابطة). تم استخدام مقياس التنفس لفحص كل طفل قبل وبعد 6 أسابيع. تلقى الأطفال في المجموعة الضابطة العلاج الطبيعي التقليدي للصدر (التصريف الوضعي والقرع)، بينما خضع الأطفال في مجموعة الدراسة للتدريب على جهاز الزلزال. لمدة ستة أسابيع، تلقت المجموعتان أربع جلسات في الأسبوع. تم جمع نتائج العلاج بعد. تم تطبيق اختبار ت المقترن واختبار ت للعينات المستقلة لمقارنة متوسط نتائج المجموعة الواحدة ونتائج المجموعتين على التوالي.

النتائج: أظهرت نتائج ما بعد العلاج لحجم الزفير القسري في ثانية واحدة، ذروة تدفق الزفير، السعة الحيوية القسرية، وحجم الزفير القسري في ثانية واحدة إلى نسبة السعة الحيوية القسرية أهمية كبيرة الفرق لصالح مجموعة الدراسة على مجموعة التحكم.

الاستنتاجات: قد تؤدي التذبذبات داخل الصدر إلى تحسين وظائف الرئة لدى الأطفال المصابين بالشلل الدماغي الرباعي.

الكلمات المفتاحية: الشلل الدماغي؛ التذبذبات داخل الصدر؛ وظائف الرئة؛ الشلل الرباعي التشنجي

Abstract

Objectives: This study was aimed at investigating the effects of intrathoracic oscillations on pulmonary function in children with spastic quadriplegic cerebral palsy.

Methods: This study comprised 24 boys and girls 6–8 years of age with spastic quadriplegic cerebral palsy. According to the modified Ashworth scale, the degree of spasticity was 2 to 2+. The children were able to sit independently and follow instructions. The children were randomly divided into a study group and control group. A spirometer was used to examine each child before and after 6 weeks. Children in the control group received traditional chest physiotherapy (postural drainage and percussion), whereas children in the study group underwent quake device training. For 6 weeks, both groups received four sessions per week. After treatment, the results were collected. Paired t-test and independent-samples t-test were applied to compare the means for each group. p-values <0.05 were considered significant.

Results: The post-treatment results of forced expiratory volume at 1 s, peak expiratory flow, forced vital capacity, and the ratio of forced expiratory volume at 1 s to forced vital capacity demonstrated significant differences favoring the study group over the control group ($p < 0.001$, $p < 0.001$, $p = 0.002$, and $p = 0.023$, respectively).

Conclusion: Intrathoracic oscillations may improve pulmonary function in children with quadriplegic cerebral palsy.

Keywords: Cerebral palsy; Intrathoracic oscillations; Pulmonary function; Spastic quadriplegia

* Corresponding address: Department of Physical Therapy for Paediatrics, Faculty of Physical Therapy, Cairo University, Giza, Egypt.
E-mail: mai.tamer.elmasry@cu.edu.eg (M.E. Abbass)
Peer review under responsibility of Taibah University.

ELSEVIER Production and hosting by Elsevier

 https://doi.org/10.1016/j.jtumed.2023.05.003

Introduction

The most prevalent physical disability in children is cerebral palsy (CP).[1] Children with CP have a greater chance of respiratory dysfunction than unaffected children. In CP, the respiratory muscles are weak, and the chest walls have restricted mobility and contain deviated structures, thus decreasing pulmonary function.[2] Recurrent chest infections as a result of frequent aspiration increase the risk of morbidity and mortality.[3,4] Children with CP usually have chronic obstructive lung disease, bronchiectasis, sleep apnea, and atelectasis.[5] Respiratory dysfunction in children with CP may present as symptoms such as kyphoscoliosis, weakness of respiratory muscles, poor coughing, and inefficient airway clearance. Children with severe cases of CP are often uncooperative, thus making testing difficult and potentially explaining the limited research on respiratory dysfunction in such children.[6] Normally, people frequently take deep breaths, thus helping keep the respiratory structures and functions healthy. Children with CP, particularly quadriplegic CP, have weak chest muscles and rely on the abdominal muscles rather than the chest muscles for breathing; moreover, they breathe in an uncoordinated manner and have limited chest mobility.[7] The shallow breathing volume decreases lung distensibility and causes extensive microatelectasis.[8] In children with CP who are not fully grown, the lung tissues and chest wall are underdeveloped.[9]

Using percussion and vibration methods in traditional manual treatments to clear the airway requires the aid of another person. Oscillatory devices, a recent physiotherapy technique, do not require postural drainage or even the aid of another person. Oscillatory devices can be used in a sitting position, and use various breathing techniques or equipment to help remove mucus. They work by interrupting the passage of expiratory air. These devices are either intra- or extra-thoracic.[10] Intra-thoracic oscillatory devices are inserted into the mouth to resist exhalation, thus resulting in vibrations that help remove mucus.[11] Extra-thoracic oscillatory devices, such as those coupled with inflatable vests, deliver vibrations at different intensities as the therapist controls the frequency to aid in patient compliance.[12] Oscillations in exhalation airflow are believed to decrease sputum viscoelasticity and mechanically increase mucociliary clearance.[13] Internal and external oscillations have also been suggested to increase airway clearance by using alternating positive pressure, which loosens mucus and facilitates expectoration.[14] According to previous research, respiratory physiotherapy devices are being introduced as possible treatment methods to assist in and enhance mucus clearance, thus improving breathing and lung function.[15–18] These devices are secure and provide sufficient airway opening, as compared with traditional chest physiotherapy.[19] Current respiratory physiotherapy devices, according to research, efficiently increase lung oxygenation and pulmonary function, removing mucus from the airways and enabling greater patient compliance in treatment.[11,12,18,20–26] These devices also lessen the likelihood of respiratory problems. Furthermore, these devices are simple to use and decrease therapeutic costs.[18] Most prior research has examined the effects of using respiratory airway clearance devices in cystic fibrosis,[10,11,22,25,26,12–16,18,20,21] whereas only several studies have examined unaffected participants,[23,24] and patients with bronchiectasis.[27] Only one study has tested the effects of respiratory devices on airway clearance in children with CP.[28]

Published reports testing the effects of respiratory devices in CP are limited, and additional research is required to determine how using these devices may affect children, and how these devices rank among the current treatments in this population. To our knowledge, this is the first study to investigate the effects of intrathoracic oscillations on pulmonary function in children with CP. This study was aimed at investigating the effects of intrathoracic oscillations on pulmonary function in children with spastic quadriplegic CP.

Materials and Methods

Study design

A randomized controlled study was conducted. The children were divided into a study group and control group, each with 12 children. This study adhered to the CONSORT Statement for randomized trials.[29]

Randomization

This study was a double-blind (Participant, Outcomes Assessor) RCT. Simple randomization was performed with closed envelopes: the patients were randomly assigned by a computer program (SPSS), and sealed envelopes were numbered according to a randomization table. The 1st author generated the random sequence and conducted the interventions, and the 2nd author conducted the assessment. The study was conducted in children treated at the outpatient clinic of Cairo University's Faculty of Physical Therapy. The study was conducted from June 2022 to August 2022. The study's flowchart is shown in Figure 1.

Participants

This research comprised 24 boys and girls 6–8 years of age with quadriplegic CP treated at the outpatient clinic of Cairo University's Faculty of Physical Therapy. Before participating in the study, all children's parents were informed of the study's goal and provided signed consent to participate.

Inclusion criteria: Children were enrolled in this study if they were classified as having quadriplegic CP, were between the ages of 6 and 8 years, and had a degree of spasticity of 2 to 2+ on the modified Ashworth's scale.[30] They were required to be able to sit on their own; to have grades 4 or 5 according to GMFCs[31]; to be able to follow simple instructions (take deep breath and blow air on their own);

and to have a history of recurrent pneumonia, respiratory infections, and swallowing problems.

Exclusion criteria: Children with uncontrollable convulsions or psychiatric disorders associated with CP, children with moderate to severe spinal deformities, and obese children were excluded from the study.

Outcome measures

A handheld spirometer (SpirOx Plus) was used to assess pulmonary function.[32] The assessor sat beside the child, catching the spirometer and inserting the spirometer's mouthpiece into the child's mouth. Each child was instructed to blow air into the spirometer's mouthpiece as forcefully as possible while sitting in a supported sitting posture with a straight head and trunk. The highest possible value among three trials was recorded. The primary outcome measure was forced expiratory volume at 1 s (FEV1), and secondary measures included peak expiratory flow (PEF), forced vital capacity (FVC), and FEV1/FVC. A previously reported strategy was followed for planning the collection of data.[33,34] Therefore, the study had no missing data.

Intervention

Children were assigned randomly into two groups. The evaluation was performed for both groups before and after six successive weeks, with a handheld spirometer (SpirOx Plus).[32] The children in the control group received traditional chest physiotherapy (postural drainage and percussion), whereas the children in the study group received treatment with a Quake device. Both groups received four sessions per week for 6 weeks.

Traditional chest physiotherapy treatment for the control group

An expert pediatric chest physiotherapist conducted postural drainage once per day, four times per week for 6 weeks. The following procedures were implemented: (a) the patient's vital signs were assessed, (b) chest percussion with a cupped hand and vibration were performed manually for 3 min in each postural drainage position, and (c) assisted coughing was performed.[35]

Quake device training for the study group

A Quake Breathing Therapy Device (Thayer's; ASIN: B00IRFXJJY) was used to train the children in the study group. The device oscillates air throughout the inspiratory and expiratory phases of breathing. It uses a cylinder that can be spun manually. This cylinder is inserted into another cylinder, and air passage is allowed only when the slots in the two cylinders are aligned. The air passage is regularly intermittent during crank turning. The frequency of interruption of the airflow is determined by the speed at which the device is rotated: the faster the crank rotates, the lower the expiratory pressure.[10]

Each child sat in a supported sitting position with a straight head and trunk, and the therapist sat beside the child, holding the Quake device in front of the child's mouth. The device's mouthpiece was inserted into the child's mouth. The child was taught to inhale deeply, hold the breath for 3–5 s, and then exhale completely while the rotating handle was turned by the therapist at a steady and comfortable rate of 0.5–1 rotation per second. The therapist watched the abdominal wall to determine whether the abdominal wall rose during deep breathing. Children were taught to suppress the temptation to cough during exhale moments. They were then taught to cough to clear their airways. Six repetitions of the method equaled one set, and ten sets were performed, each separated by a 10-min rest period.[27] Figure 2 illustrates the Quake device.

Statistical analysis

Data were analyzed in Statistical Package for the Social Sciences, version 23.0. (SPSS Inc., Chicago, Illinois, USA). Mean, standard deviation, and range are provided for the quantitative data. Data were examined for normality with the Shapiro-Wilk and Kolmogorov-Smirnov tests. For comparison of means for two groups, independent-samples t-test of significance was applied. For comparison of the means before and after treatment for each group, paired t-test was applied. The effect size was <0.8. The acceptable margin of error was set at 5%, and the confidence interval was set at 95%. The P-value was considered significant when it was below 0.05.

Results

Sample size

A statistical calculator based on a 95% confidence interval was used to determine the sample size in MedCalc® version 12.3.0.0 software (Ostend, Belgium). Because FEV1 was the primary outcome variable in the current investigation, we used Student's t-test to compare FEV1 after therapy for independent samples.

A pilot study was performed on ten patients post-treatment, with five patients in each group. The mean of FEV1 after treatment in the patient group was 0.79, with an SD of 0.17, and that in the control group was 0.60, with an SD of 0.15 and a mean difference in 0.19. The effect size was 1.201.

On the basis of the results of the pilot study with a minimal acceptable mean difference of 24.1%, the after-treatment FEV1 was considered significant in sample size estimation, that was clinically significant between groups. For a power of 0.95 and an alpha error of 0.05, a minimum sample size of 11 patients was calculated for each group, by assuming a drop-out ratio of 10%. The desired sample size was therefore 12 per group, with a total sample size of 24 participants in the study.

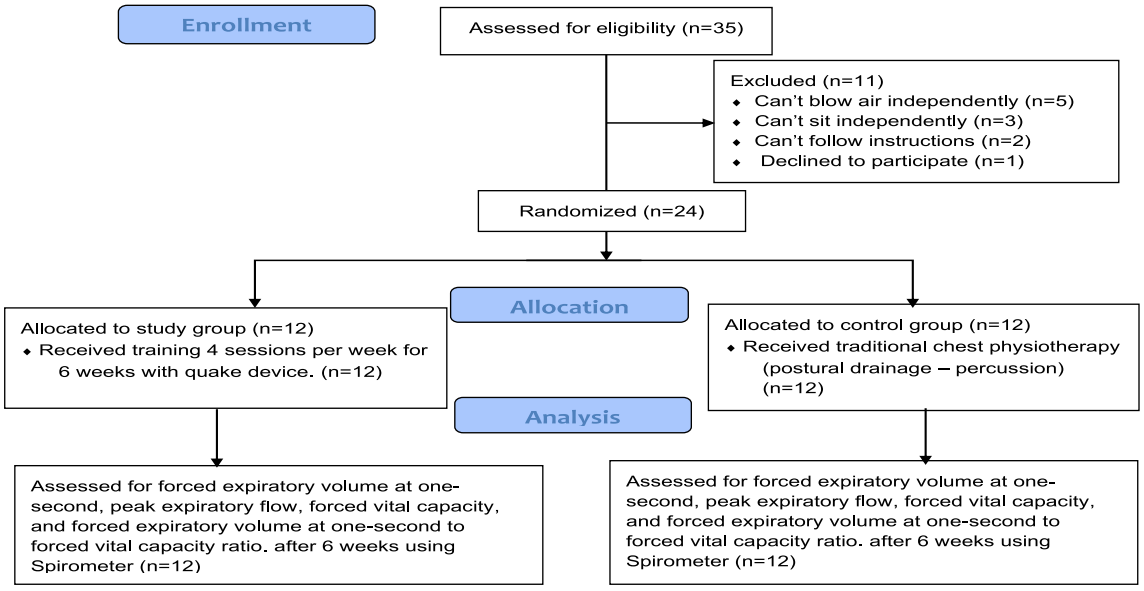

Figure 1: Flow chart of the study.

Descriptive results for the study and control groups

Twenty-four children with CP were included in this study; each group included 12 children. Both sexes were included, and five and six girls were included in the study and control groups, respectively. Table 1 shows a comparison of the study and control groups' baseline characteristics.

Figure 2: The Quake device

Comparison of results before and after treatment in the study and control groups

Table 2 compares the results of PEF, FEV1, FVC, and FEV1/FVC in both groups before and after treatment.

Discussion

This study was conducted to investigate the effects of intrathoracic oscillations on pulmonary function in children with spastic quadriplegic CP. For this purpose, 24 children with spastic quadriplegic CP were studied.

Children with CP have respiratory dysfunction as a result of a restricted breathing pattern,[36] obstructive sleep apnea,[37] improper chest wall and lung compliance,[38] unsynchronized ventilation and perfusion,[39] and upper airway obstruction.[6]

The chest wall functions as a breathing system pump. Children with severe CP have a fast and irregular respiratory pattern.[38] Respiratory dysfunction can occur as a result of a

Table 1: Comparison of the study and control groups according to baseline characteristics.

Baseline characteristics	Study group	Control group	t-test value[a]	p-value
Age (years)				
Mean ± SD	6.58 ± 0.79	6.58 ± 0.67	t = 0.000	1.000
Range	6–8	6–8		
Weight (kg)				
Mean ± SD	24.17 ± 4.76	24.75 ± 3.55	t = −0.340	0.737
Range	15–30	18–29		
Height (cm)				
Mean ± SD	123.33 ± 5.60	124.08 ± 3.55	t = −0.392	0.699
Range	110–129	115–129		
Chest expansion (cm)				
Mean ± SD	60.00 ± 2.76	60.33 ± 2.31	t = −0.321	0.752
Range	55–63	56–63		

SD, standard deviation.
[a] Using independent samples t-test.

Table 2: Comparison of pre-treatment and post-treatment results for FEV1, PEF, FVC, and FEV1/FVC in the study and control groups.

	Pre-treatment Mean ± SD Range	Post-treatment Mean ± SD Range	MD±SD	t-test[a]	p-value
FEV1 (L) of the control group	0.53 ± 0.09 0.4–0.7	0.62 ± 0.10 0.5–0.84	0.10 ± 0.03	−11.32	<0.001[c]
FEV1 (L) of the study group	0.55 ± 0.08 0.43–0.7	0.83 ± 0.11 0.65–0.99	0.28 ± 0.14	−6.93	<0.001[c]
t-test[b]	0.718	4.793			
p-value	0.480	<0.001[c]			
PEF (L/min) of the control group	79.92 ± 9.24 64–95	93.25 ± 9.37 74–110	13.3 ± 2.31	20.00	<0.001[c]
PEF (L/min) of the study group	81.25 ± 8.24 67–95	141.5 ± 19.8 115–180	60.25 ± 13.97	14.94	<0.001[c]
t-test[b]	0.37	7.65			
p-value	0.713	<0.001[c]			
FVC (L) of the control group	0.74 ± 0.10 0.58–0.91	0.83 ± 0.12 0.69–1.1	0.09 ± 0.04	−7.45	<0.001[c]
FVC (L) of the study group	0.74 ± 0.10 0.59–0.89	1.04 ± 0.17 0.81–1.4	0.30 ± 0.17	−6.15	<0.001[c]
t-test[b]	0.061	3.504			
p-value	0.952	0.002[c]			
FEV1/FVC of the control group	71.52 ± 3.23 66.15–76.92	75.48 ± 3.20 70.66–81.25	3.96 ± 3.09	−4.43	0.002[c]
FEV1/FVC of the study group	74.74 ± 4.94 65–82.85	80.14 ± 5.79 70.71–87.91	5.40 ± 3.7	−5.079	<0.001[c]
t-test[b]	1.889	2.440			
p-value	0.072	0.023[c]			

FEV1, forced expiratory volume at 1 s; MD, mean difference, peak expiratory flow; FVC, forced vital capacity; SD, standard deviation.
[a] Using paired t-test.
[b] Using independent samples t-test.
[c] Significant, $p < 0.05$.

divergence from the ideal chest wall structure.[40] Compared with properly growing children, children with severe CP have a low upper-to-lower chest diameter ratio, thereby resulting in upper chest hypoventilation, according to Park et al. (2006).[7] Mechanical inadequacy, exhaustion, and failure of the respiratory muscles; abnormal resting lung volume; and abnormal ventilation may all occur because of a divergence from the optimum chest wall structure.[40]

Children with CP have inefficient and uncoordinated coughing. An efficient coughing mechanism requires powerful contraction of the intercostal and abdominal muscles, and coordinated synchronized action of the expiratory and glottic muscles. The uncoordinated contraction of respiratory muscles results in aspiration, problems in the clearance of the lower airway secretions, and subsequent respiratory infections.[6]

The results of this study revealed that clearance of the airway secretions with the Quake device improved respiratory function. The post-treatment FEV1, PEF, FVC, and FEV1/FVC ratio showed significant differences in favor of the study group over the control group ($p < 0.001$, $p < 0.001$, $p = 0.002$, and $p = 0.023$, respectively). The improvement in the post-treatment results of the study group might have resulted from the intrathoracic oscillations produced by the Quake device, which altered resistance within the airways, thereby providing a regulated oscillating positive pressure that mobilized respiratory secretions, resulted in airway clearance, and improved respiratory function. This finding is in agreement with those of Konstan et al., 1994, who have reported that intrathoracic oscillations result in airway vibrations when the oscillation frequency approaches the pulmonary system's resonance frequency. Mucus loosens from the airway walls as a result of these vibrations. Intermittent fluctuations in endobronchial pressure decrease the collapsibility of the airways during exhalation, thereby increasing the possibility of tracheobronchial secretion clearance. The airflow accelerations enhance the velocity of exhaled air, thus facilitating mucus travel up the airways.[11] In addition, a study by Rogers et al. has concluded that exhaling by using intrathoracic oscillation devices causes positive pressure oscillations in the airways and repeated expiratory airflow accelerations, all of which have been found to increase mucus clearance.[41]

To our knowledge, no studies have assessed the effects of intrathoracic oscillations on pulmonary function in children with CP, and limited research has assessed the effects of extrathoracic oscillatory devices in decreasing hospitalization and chest radiology in children with neurological impairment and children with CP.[28,42]

In an experiment with 23 participants with CP and neuromuscular diseases, Yuan et al.,2010[28] have observed a tendency toward fewer hospitalizations and improved chest

radiology utilization with the use of high-frequency chest wall oscillation (HFCWC). Fitzgerald et al., 2014[42] have found that using HFCWC to treat children with neurological impairment and respiratory disorders decreases the number of hospitalizations and days spent in the hospital during the second year of treatment. The study has concluded that long-term use of HFCWC is beneficial for these conditions.

The clinical impact of this study is that it is, to our knowledge, the first to investigate the effects of intrathoracic oscillations on pulmonary function in children with CP. Children with severe CP are frequently uncooperative, thus making testing challenging and possibly explaining the lack of studies on respiratory dysfunction in these children.[6] This study investigated therapeutic alternatives to achieve better results at lower therapeutic cost. Incorporating these devices into treatment plans for severe CP decreases the likelihood of respiratory problems. Additionally, these devices are simple to use, and decrease therapeutic costs.[18] These devices are more secure and provide adequate airway opening, as compared with traditional chest physiotherapy.[19]

This study is limited by its small sample size. Although a sample size estimate was performed, larger samples might have resulted in greater generalizability of the results. In addition, the study was limited to quadriplegic CP. Larger samples and other types of CP should therefore be studied. Other clinical studies on the effects of other types of intrathoracic oscillatory devices on pulmonary function in children with CP are also recommended.

Conclusion

Intrathoracic oscillations may improve pulmonary function in children with quadriplegic CP.

Source of funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not for-profit sectors.

Conflict of interest

The authors declare no conflicts of interest.

Ethical approval

The Faculty of Physical Therapy's ethics committee approved this trial, which was given the number P.T.REC/012/003589 and registered on ClinicalTrials.gov under NCT05252663.

Authors' contributions

The project was developed and designed by AME and MEA, who also performed the research, and gathered, categorized, and processed the data. Research resources were provided by AME. MEA wrote the article's first and last drafts. The content and similarity index of the paper are the responsibility of all authors, who also critically assessed and approved the final text. All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

Acknowledgements

We thank all parents and children who participated in this study.

References

1. Stavsky M, Mor O, Mastrolia SA, Greenbaum S, Than NG, Erez O. Cerebral palsy-trends in epidemiology and recent development in prenatal mechanisms of disease, treatment, and prevention. **Front Pediatr 2017**; 5. https://doi.org/10.3389/fped.2017.00021.
2. Wang HY, Chen CC, Hsiao SF. Relationships between respiratory muscle strength and daily living function in children with cerebral palsy. **Res Dev Disabil 2012**; 33(4): 1176–1182. https://doi.org/10.1016/J.RIDD.2012.02.004.
3. Arvedson JC. Feeding children with cerebral palsy and swallowing difficulties. **Eur J Clin Nutr 2013**; 67: S9–S12. https://doi.org/10.1038/ejcn.2013.224.
4. Parkes J, Hill N, Platt MJ, Donnelly C. Oromotor dysfunction and communication impairments in children with cerebral palsy: a register study. **Dev Med Child Neurol 2010**; 52(12): 1113–1119. https://doi.org/10.1111/j.1469-8749.2010.03765.x.
5. Proesmans M. Respiratory illness in children with disability: a serious problem? **Breathe 2016**; 12(4): e97–e103. https://doi.org/10.1183/20734735.017416.
6. Seddon PC, Khan Y. Respiratory problems in children with neurological impairment. **Arch Dis Child 2003**; 88(1): 75–78. https://doi.org/10.1136/adc.88.1.75.
7. Park ES, Park JH, Rha D-W, Park C Il, Park CW. Comparison of the ratio of upper to lower chest wall in children with spastic quadriplegic cerebral palsy and normally developed children. **Yonsei Med J 2006**; 47(2): 237–242. https://doi.org/10.3349/ymj.2006.47.2.237.
8. Park ES, Park JH, Rha DW, Park C Il, Park CW. Comparison of the ratio of upper to lower chest wall in children with spastic quadriplegic cerebral palsy and normally developed children. **Yonsei Med J 2006**; 47(2): 237–242. https://doi.org/10.3349/ymj.2006.47.2.237.
9. Estenne M, De Troyer A. The effects of tetraplegia on chest wall statics. **Am Rev Respir Dis 1986**; 134(1): 121–124. https://doi.org/10.1164/arrd.1986.134.1.121.
10. Morrison L, Innes S. Oscillating devices for airway clearance in people with cystic fibrosis. **Cochrane Database Syst Rev 2017**; 5(5): CD006842. https://doi.org/10.1002/14651858.CD006842.pub4.
11. Konstan MW, Stern RC, Doershuk CF. Efficacy of the Flutter device for airway mucus clearance in patients with cystic fibrosis. **J Pediatr 1994**; 124(5 Pt 1): 689–693. https://doi.org/10.1016/s0022-3476(05)81356-3.
12. Warwick WJ, Hansen LG. The long-term effect of high-frequency chest compression therapy on pulmonary complications of cystic fibrosis. **Pediatr Pulmonol 1991**; 11(3): 265–271. https://doi.org/10.1002/ppul.1950110314.
13. Newbold ME, Tullis E, Corey M, Ross B, Brooks D. The flutter device versus the PEP mask in the treatment of adults with cystic fibrosis. **Physiother Can 2005**; 57(3): 199–207. https://doi.org/10.3138/ptc.57.3.199.
14. Oermann CM, Sockrider MM, Giles D, Sontag MK, Accurso FJ, Castile RG. Comparison of high-frequency chest wall oscillation and oscillating positive expiratory pressure in

the home management of cystic fibrosis: a pilot study. **Pediatr Pulmonol 2001**; 32(5): 372–377. https://doi.org/10.1002/ppul.1146.
15. Gondor M, Nixon PA, Mutich R, Rebovich P, Orenstein DM. Comparison of Flutter device and chest physical therapy in the treatment of cystic fibrosis pulmonary exacerbation. **Pediatr Pulmonol 1999**; 28(4): 255–260. https://doi.org/10.1002/(sici)1099-0496(199910)28:4<255::aid-ppul4>3.0.co;2-k.
16. Homnick DN, White F, de Castro C. Comparison of effects of an intrapulmonary percussive ventilator to standard aerosol and chest physiotherapy in treatment of cystic fibrosis. **Pediatr Pulmonol 1995**; 20(1): 50–55. https://doi.org/10.1002/ppul.1950200110.
17. Langenderfer B. Alternatives to percussion and postural drainage. A review of mucus clearance therapies: percussion and postural drainage, autogenic drainage, positive expiratory pressure, flutter valve, intrapulmonary percussive ventilation, and high-frequency chest co. **J Cardiopulm Rehabil 1998**; 18(4): 283–289. https://doi.org/10.1097/00008483-199807000-00005.
18. McIlwaine PM, Wong LT, Peacock D, Davidson AG. Long-term comparative trial of positive expiratory pressure versus oscillating positive expiratory pressure (flutter) physiotherapy in the treatment of cystic fibrosis. **J Pediatr 2001**; 138(6): 845–850. https://doi.org/10.1067/mpd.2001.114017.
19. Hristara-Papadopoulou A, Tsanakas J, Diomou G, Papadopoulou O. Current devices of respiratory physiotherapy. **Hippokratia 2008**; 12(4): 211–220.
20. Arens R, Gozal D, Omlin KJ, et al. Comparison of high frequency chest compression and conventional chest physiotherapy in hospitalized patients with cystic fibrosis. **Am J Respir Crit Care Med 1994**; 150(4): 1154–1157. https://doi.org/10.1164/ajrccm.150.4.7921452.
21. Kluft J, Beker L, Castagnino M, Gaiser J, Chaney H, Fink RJ. A comparison of bronchial drainage treatments in cystic fibrosis. **Pediatr Pulmonol 1996**; 22(4): 271–274. https://doi.org/10.1002/(SICI)1099-0496(199610)22:4<271::AID-PPUL7>3.0.CO;2-P.
22. Phillips GE, Pike S, Jaffe A, Bush A. Comparison of the active cycle of breathing techniques and external high frequency oscillation jacket for clearance of secretions in children with cystic fibrosis. **THORAX-LONDON-. 1998**; 53. P148–P148.
23. George RJ, Winter RJ, Johnson MA, Slee IP, Geddes DM. Effect of oral high frequency ventilation by jet or oscillator on minute ventilation in normal subjects. **Thorax 1985**; 40(10): 749–755. https://doi.org/10.1136/thx.40.10.749.
24. George RJ, Johnson MA, Pavia D, Agnew JE, Clarke SW, Geddes DM. Increase in mucociliary clearance in normal man induced by oral high frequency oscillation. **Thorax 1985**; 40(6): 433–437. https://doi.org/10.1136/thx.40.6.433.
25. App EM, Kieselmann R, Reinhardt D, et al. Sputum rheology changes in cystic fibrosis lung disease following two different types of physiotherapy: flutter vs autogenic drainage. **Chest 1998**; 114(1): 171–177. https://doi.org/10.1378/chest.114.1.171.
26. Pryor JA, Webber BA. Physiotherapy for cystic fibrosis—which technique? **Physiotherapy 1992**; 78(2): 105–108.
27. Amit VA, Vaishali K, Gopal KA, Shyam K, Zulfeequer Vishak A. Comparison of quake and RC-Cornet for airway clearance in bronchiectasis: a randomised crossover trial. **Int J Health Sci Res 2012**; 2(6 CC-Airways): 20–27. https://www.cochranelibrary.com/central/doi/10.1002/central/CN-01457378/full.
28. Yuan N, Kane P, Shelton K, Matel J, Becker BC, Moss RB. Safety, tolerability, and efficacy of high-frequency chest wall oscillation in pediatric patients with cerebral palsy and neuromuscular diseases: an exploratory randomized controlled trial. **J Child Neurol 2010**; 25(7): 815–821. https://doi.org/10.1177/0883073809350223.
29. Boutron I, Altman DG, Moher D, Schulz KF, Ravaud P. CONSORT statement for randomized trials of nonpharmacologic treatments: a 2017 update and a CONSORT extension for nonpharmacologic trial abstracts. **Ann Intern Med 2017**; 167(1): 40–47. https://doi.org/10.7326/M17-0046.
30. Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. **Phys Ther 1987**; 67(2): 206–207. https://doi.org/10.1093/ptj/67.2.206.
31. Palisano R, Rosenbaum P, Walter S, Russell D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. **Dev Med Child Neurol 1997**; 39(2): 214–223. https://doi.org/10.1111/j.1469-8749.1997.tb07414.x.
32. Ezzahir N, Leske V, Peiffer C, Trang H. Relevance of a portable spirometer for detection of small airways obstruction. **Pediatr Pulmonol 2005**; 39(2): 178–184. https://doi.org/10.1002/ppul.20148.
33. Kang H. The prevention and handling of the missing data. **Korean J Anesthesiol 2013**; 64(5): 402–406. https://doi.org/10.4097/kjae.2013.64.5.402.
34. Wisniewski SR, Leon AC, Otto MW, Trivedi MH. Prevention of missing data in clinical research studies. **Biol Psychiatr 2006**; 59(11): 997–1000. https://doi.org/10.1016/j.biopsych.2006.01.017.
35. Hue YL, Lum LCS, Ahmad SH, et al. Safety, tolerability and efficacy of LEGA-Kid® mechanical percussion device versus conventional chest physiotherapy in children: a randomised, single-blind controlled study. **Singapore Med J 2020**. https://doi.org/10.11622/smedj.2020084. Published online June.
36. Bjure JAN, Berg K. Dynamic and static lung volumes of school children with cerebral palsy. **Acta Paediatr 1970**; 59(S204): 35–39. https://doi.org/10.1111/j.1651-2227.1970.tb06140.x.
37. Kotagal S, Gibbons VP, Stith JA. Sleep abnormalities in patients with severe cerebral palsy. **Dev Med ＼& Child Neurol 1994**; 36(4): 304–311. https://doi.org/10.1111/j.1469-8749.1994.tb11850.x.
38. Blumberg ML. Respiration and speech in the cerebral palsied child. **AMA Am J Dis Child 1955**; 89(1): 48–53. https://doi.org/10.1001/archpedi.1955.02050110064009.
39. Hardy JC. Lung function of athetoid and spastic quadriplegic children. **Dev Med Child Neurol 1964**; 6: 378–388. https://doi.org/10.1111/j.1469-8749.1964.tb08139.x.
40. Papastamelos C, Panitch HB, England SE, Allen JL. Developmental changes in chest wall compliance in infancy and early childhood. **J Appl Physiol 1995**; 78(1): 179–184. https://doi.org/10.1152/jappl.1995.78.1.179.
41. Rogers D, Doull IJM. Physiological principles of airway clearance techniques used in the physiotherapy management of cystic fibrosis. **Curr Paediatr 2005**; 15(3): 233–238. https://doi.org/10.1016/j.cupe.2005.02.007.
42. Fitzgerald K, Dugre J, Pagala S, Homel P, Marcus M, Kazachkov M. High-frequency chest wall compression therapy in neurologically impaired children. **Respir Care 2014**; 59(1): 107–112. https://doi.org/10.4187/respcare.02446.

How to cite this article: El-Moatasem AM, Abbass ME. Effect of intrathoracic oscillations on pulmonary functions in children with cerebral palsy. J Taibah Univ Med Sc 2023;18(6):1254–1260.