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The success rate of spirometry tests in Thai children

Klaita Srisingh, Nadda Padsee, Chutima Phuaksaman*

Department of Pediatrics, Faculty of Medicine, Naresuan University, Phitsanulok, 65000, Thailand

Abstract

English:

Introduction: *Spirometry is a widely used pulmonary function test that requires several steps to be performed. In Thailand, there is only limited amount of data on the success rate and associated factors in children.*
Objective: *To determine the success rate and factors affecting spirometry performance.*
Method: *This cross-sectional study involved participants aged 5–18 years who underwent spirometry testing at the Naresuan University Hospital between 1 January 2015 and 31 December 2020. The subjects were divided into success and failure groups using the American Thoracic Society and European Respiratory Society 2005 criteria for acceptability and repeatability. The data collected include general characteristics, spirometry techniques and processes to determine the success rate and its associated factors.*
Results: *A total of 132 subjects underwent spirometry testing, with a success rate of 71.2%. The success group's mean age, weight and height were significantly greater than the failure group. The most unsuccessful spirometry step in the failure group was a prolonged exhalation. Between the two groups, there was a statistically significant difference in the plateau phase of the volume time curve (85.1% vs. 55.3%, P < 0.001).*
Conclusion: *Children's age, weight and height are all considered predictor variables of success. The most frequently step failure in spirometry tests is prolonged exhalation phase. However, the plateau on volume time curves is a critical component of success. To achieve optimal success, encourage children to blow vigorously as long as they can be stable throughout the prolonged exhalation phase and assess their ability to follow instructions.*

Keywords

asthma • pulmonary function test • PFT • success • factor

Rata de succes a spirometriei la copiii thailandezi

Rezumat

Romanian:

Introducere: *Spirometria este un test funcțional pulmonar utilizat pe scară largă, care necesită mai mulți pași pentru a fi efectuat. În Thailanda, există date limitate despre rata de succes și factorii asociați la copii.*
Obiective: *Scopul studiului a fost de a determina rata de succes și factorii care afectează performanța spirometriei.*
Metodă: *Acest studiu transversal a implicat participanți cu vârsta cuprinsă între 5 și 18 ani care au fost supuși testării spirometriei la Spitalul Universitar Naresuan între 1 ianuarie 2015 și 31 decembrie 2020. Subiecții au fost împărțiți în grupuri de succes și eșec, folosind criteriile ATS/ERS 2005 pentru acceptabilitate și repetabilitate. Datele colectate includ caracteristici generale, tehnici de spirometrie și procese pentru a determina rata de succes și factorii asociați.*
Rezultate: *Un total de 132 de subiecți au efectuat spirometrie, cu o rată de succes de 71,2% (IC 95%: 62,7-78,8). Vârsta medie, greutatea și înălțimea copiilor din grupul de succes au fost semnificativ mai mari decât cele ale grupului de eșec. Etapa spirometriei cea mai sortită eșecului în grupul de eșec a fost obținerea expirului prelungit. Între cele două grupuri, a existat o diferență semnificativă statistic în faza de platou a curbei volum-timp (85,1% vs. 55,3%, P < 0,001).*
Concluzie: *Copiii thailandezi au avut o rată de succes de aproximativ 71%. Vârsta, greutatea și înălțimea copiilor sunt toate considerate variabile predictoare ale succesului. Cea mai frecventă eroare în testele de spirometrie este faza de expir prelungit. Cu toate acestea, platoul pe curbele volum-timp este o componentă critică a succesului. Pentru a obține un succes optim în timpul testării spirometriei cu copii, ei trebuie încurajați să sufle energic atâta timp cât se pot menține pe toată durata fazei de expirație prelungită iar capacitatea lor de a urma instrucțiunile trebuie să fie evaluate.*

Cuvinte-cheie

astm bronșic • test funcțional pulmonar • succes • factor

**Corresponding author: Chutima Phuaksaman*

E-mail: chutimaph@nu.ac.th

Introduction

The pulmonary function test is beneficial for diagnosing lung disease and determining airway obstruction, restrictive lung disease and diffusion defect (1). Spirometry is one of the pulmonary function tests that is frequently used to evaluate airway responsiveness, diagnose and monitor treatment in patients with asthma (2). It is a multi-step process that involves physical exertion and a proper technique (1). According to American Thoracic Society and European Respiratory Society (ATS/ERS) 2005, the acceptability criteria and repeatability criteria should be met to achieve the standardised criteria, which are needed to interpret the results (3). The examination of the flow volume and volume time curves requires assurance in order to minimise technical error. Spirometry has a high success rate in adults but differs significantly in children (4). Age is an essential factor to determine on how well a subject follows a command (5). In a spirometry test, the individual is instructed to exhale rapidly and forcefully until the lungs feel empty. The subject is then instructed and subjected to the test several times until good efforts are obtained, which may be complicated for children below the age of five (5). In Thailand, there were limited data on the success rate and associated factors in this age group. The information gathered in this study is necessary for reducing error and maintaining high-quality spirometry tests.

Objective

The aim of the study was to determine the success rate and factors affecting spirometry performance.

Material and method

Study design

This is a cross-sectional study that enrolled children and adolescents aged 5–18 years and had completed a spirometry test between 1 January 2015 and 31 December 2020. A single well-trained technician encouraged and facilitated children's spirometry testing. The participants were divided into two groups: success and failure groups. The success group included subjects who underwent spirometry tests that met the ATS/ERS 2005 criteria for acceptability and repeatability, whereas the failure group included subjects who failed the spirometry test as they did not meet the acceptability and repeatability criteria.

Definition

Acceptability criteria

An acceptable quality spirometry test is defined as follows:

1. Free from artefacts: coughs, glottis closure, early termination, maximum effort, leak and obstructed mouthpiece
2. Good start of the test: explosive take-off of peak expiratory flow and extrapolated volume < 5% of forced vital capacity (FVC) or < 150 mL
3. Meet end-of-test criteria: satisfactory exhalation duration of more than 6 s (3 s in children below 10 years old) or until reaching a plateau phase sustained at a minimum of 1 s (3).

Repeatability criteria

After producing three acceptable spirometry tests, the two best values of FVC and forced expiratory volume in 1 s (FEV_1) fulfil the repeatability criteria. The two best of FVC and FEV_1 values should be within 150 mL of each other (3).

Inclusion criteria

This study enrolled children aged 5–18 years who had spirometry testing at the Naresuan University Hospital during the data collection period. On the day of the test, subjects were free of respiratory tract infection and required to discontinue medications that had an effect on the result of spirometry [bronchodilators (e.g. short-acting beta 2 agonists: salbutamol, albuterol, fenoterol, cessation at less than 4–6 h); corticosteroid cessation at less than 12 h].

Procedure of spirometry testing

Anthropometric measurements were taken in duplicate or until two similar measurements were obtained. Weight measurements were obtained using a digital scale (Nagata®, Tainan City, Taiwan) with 100 g precision. Height was measured using a portable stadiometer (FBT®, Bangkok, Thailand) with a precision of 1 mm (6,7). The anthropometric measurements were performed according to the Anthropometric Standardization Reference Manual.

Prior to the test, the subjects were instructed about the testing to familiarise themselves with the technique. On the testing day, respondents were interviewed about acute respiratory tract infection symptoms and the medications used. The study included only patients who did not have a respiratory tract infection and were not taking any medication that may affect the result of spirometry.

Spirometry tests were performed by a single experienced medical technician who was responsible for carrying out the recommended procedure. The equipment was connected to a hose, attached to an isolator filter and to a piece with an inner diameter of 2.5 cm, which connected to a mouthpiece. The semi-rigid and flat mouthpiece had an orifice of approximately 1 mm. To avoid air leaking, individuals were asked to keep the mouthpiece firm around the lips. Spirometry measurements were performed by body plethysmograph (Platinum Elite™ body plethysmograph®, Minnesota, USA), calibrated and

validated by the ATS and with a system of the open type. This is a flow-based spirometer, which has an animation programme to aid the extension of the expiration and also enables the visualisation of volume-time and flow-volume curves; so, forced expiratory maneuvers can be analysed. Spirometry was performed in patients at upright position (sit) and with the use of a nasal clip. The technique consists deep inhalation, followed by a rapid and forced expiration with a minimum duration of 1 s, with the aid of computerised incentive and standardised verbal stimuli from the technician. All participants performed at least three forced expiration maneuvers (maximum of eight trial), and the choice of the best curve was performed by a piece of software and by the evaluator when pertinent. Spirometry parameters evaluated included the following: FVC, FEV_1 and forced expiratory flow (FEF) of 25% and 75% (FEF 25%–75%).

The highest values of FEV_1, FVC and FEF 25%–75% were used for data analysis. The findings of the spirometry were standardised using an international equation and expressed as a percentage of the expected value.

Data collection

The Naresuan University Hospital is a tertiary care facility located in the lower northern part of Thailand. We collected data from 1 January 2015, through 31 December 2020. Age, gender, weight and height were collected along with the information about underlying diseases, the indication for spirometry testing, previous spirometry test, the total number of spirometry test taken by each subject, the spirometry step performance, the outcome of the spirometry test and the diagnosis and other general health and respiratory symptoms.

Ethics

This study was approved by the Naresuan University Institutional Review Board (No. 255/2021).

Statistics

The success rate of spirometry in children is approximately 91.2%, with 5% maximum acceptable difference. Thus, we estimated that at least 126 individuals would be included.

The Chi-square and Fisher's exact tests were used to compare categorical variables, and independent t-test was used to compare continuous variables. A two-tailed *P*-value of <0.05 was considered statistically significant. The statistical analysis was performed using STATA, version 12.1 (College Station, TX, USA).

Result

Between 1 January 2015 and 31 December 2020, a total of 132 participants underwent spirometry testing at the Naresuan University Hospital. The prevalence of successful spirometry testing was 71.2% (95% CI: 62.7–78.8), whereas the failure rate was 28.8% (95% CI: 21.2–37.3). Three subjects in the success group failed to meet the repeatability criteria. Acceptability and repeatability criteria were met by around 68.9% of the participants.

The total mean age of all participants was 10.96 ± 3.28 years. The success group's mean age was considerably higher than that of the failure group (11.52 ± 2.30 years vs. 9.57 ± 3.78 years, $P = 0.002$). There were a total of 87 (65.90%) male participants in this study: 62 in the success group and 25 in the failure group. The success group had a higher mean weight than the failure group (43.32 ± 16.00 kg vs. 33.61 ± 11.94 kg, $P = 0.001$). The mean height in the success group was 147.42 ± 15.99 cm. and that in the failure group was 134.14 ± 18.47 cm. ($P = 0.001$). The spirometry test was indicated to aid in diagnosing pulmonary diseases in both groups (62.00% and 79.00%). The mean body mass index (BMI), underlying disease and symptoms of respiratory illnesses were not significantly different between the two groups. The majority of the subjects lacked prior experience in spirometry testing (69.70%; Table 1). In the failure group, the most unsuccessful spirometry step was prolonged exhalation (36.80%), followed by rapid and forceful exhalation (13.20%) and deep inhalation (7.90%) (Table 2).

The plateau phase of the volume time curve showed a statistically significant difference between the two groups, with 85.1% significance in the success group and 55.3% in the failure group ($P < 0.001$). The success group had a longer expiratory time than the failure group, although the difference was not statistically significant (71.3% vs. 76.3%, $P = 0.556$). However, subgroup analysis revealed a statistically significant difference between the success and failure groups (100.0% vs. 75.0%, $P = 0.006$) in terms of expiratory duration in children below 10 years. The mean forced expiratory time (FET) was 5.28 ± 1.06 s in this age group, but it was 5.77 ± 0.79 s in those older than 10 years (Table 3).

Discussion

The quality of spirometry is important for the accurate interpretation of measurement results. To achieve a high level of quality, it is necessary to use an appropriate spirometer, exert considerable effort and calibrate the tools. Spirometry success rates were 71.2% lower in our study than those in Western countries (8–10). There are no previous data on spirometry success rates in Asian children. These data suggest that race and ethnicity may have an effect on the success rate. Western children's growth and lung capacity may be different, affecting spirometry performance (8–10).

Table 1. Characteristics of the study subjects who underwent spirometry testing.

Base characteristics	Total (*n* = 132)	Success group (*n* = 94)	Failure group (*n* = 38)	*P*-value
Age (years) mean±SD	10.96 ± 3.28	11.52 ± 2.30	9.57 ± 3.78	0.002[c]*
≤7, *n* (%)	22 (16.7)	7 (31.8)	15 (68.2)	
8–9, *n* (%)	31 (23.5)	20 (64.5)	11 (35.5)	
10–11, *n* (%)	22 (16.7)	18 (81.8)	4 (18.2)	
12–13, *n* (%)	27 (20.4)	23 (85.2)	4 (14.8)	
≥14, *n* (%)	30 (22.7)	24 (80)	6 (20.0)	
Gender, male	87 (65.9)	62 (66.0)	25 (65.8)	0.985[a]
Weight (kg) mean ± SD	40.52 ± 15.54	43.32 ± 16.00	33.61 ± 11.94	0.001[c]*
Height (cm) mean ± SD	143.60 ± 17.73	147.42 ± 15.99	134.14 ± 18.47	<0.001[c]*
BMI (kg/m^2) mean ± SD	19.15 ± 4.80	19.42 ± 4.79	18.50 ± 4.90	0.326[c]
Underlying disease	65 (49.2)	49 (52.1)	16 (42.1)	0.297[a]
Indication				0.088[b]
Pre-operative	2 (1.5)	1 (2.1)	1 (2.6)	
Diagnosis	89 (67.4)	59 (62.8)	30 (79.0)	
Follow up	41 (31.1)	34 (36.1)	7 (18.4)	
Previous number of tests				0.152[b]
0	92 (69.7)	60 (63.8)	32 (84.3)	
1	28 (21.2)	24 (25.5)	4 (10.5)	
2	8 (6.1)	7 (7.5)	1 (2.6)	
3	3 (2.3)	2 (2.1)	1 (2.6)	
4	1 (0.7)	1 (1.1)	0 (0.0)	

BMI, body mass index.
[a]Chi-square tests.
[b]Fisher's exact test.
[c]Independent *t*-test.
*$P < 0.05$.

Table 2. Data on the performance of spirometry procedures in the failure group.

Steps in the performance of spirometry test	Failure group (*n* = 38)
Deep inhalation	
Not pass	3 (7.9)
Pass	35 (92.1)
Rapid and forced exhalation	
Not pass	5 (13.2)
Pass	33 (86.8)
Prolonged exhalation	
Not pass	14 (36.8)
Pass	24 (63.2)

Age, weight and height were found to be dependent on the feasibility of the spirometer, with higher values indicating a higher success rate in children, consistent with a previous study (10,11) This study revealed that children under the age of 7 years old had a 31.8% success rate, which is lower than the 82% success rate observed in a study by Gaffin et al. (12) on 4–5-year-old American children and the 88% success rate in a study by Santos et al. (11). on 2–6-year-old Portuguese children. However, this study found that individuals over the age of 10 years had a success rate of more than 80%, whereas Friedrich et al. (8). discovered that individuals aged 9 years had a success rate of 100% when undergoing spirometry. Children develop brain connections and complexity once they reach the age of five or more. During the adolescent years, children develop neural pathways that impact their capacity to cooperate, focus and follow directions (13). Additionally, as weight and height increase, the size of the lungs and the diameter of the airways increases. In comparison to Western nations, the lower nutritional status, weight and height of Thai children may impair cognitive performance, which is critical for getting reliable spirometry readings (14).

Table 3. Volume time curves in both groups.

Volume time curve	Total (*n* = 132)	Success group (*n* = 94)	Failure group (*n* = 38)	*P*-value
Expiratory time**				0.556[a]
Pass	96 (72.7)	67 (71.3)	29 (76.3)	
Not pass	36 (27.3)	27 (28.7)	9 (23.7)	
Mean FET (s)	5.28 ± 1.06	5.44 ± 0.83	4.89 ± 1.43	
<10 years (*n* = 53)				0.006[b]*
Pass	47 (88.7)	29 (100.0)	18 (75.0)	
Not pass	6 (11.3)	0 (0.0)	6 (25.0)	
Mean FET (s)	4.56 ± 0.99	4.86 ± 0.63	4.17 ± 1.23	
≥10 years (*n* = 79)				0.160[a]
Pass	49 (62.0)	38 (58.5)	11 (78.6)	
Not pass	30 (38.0)	27 (41.5)	3 (21.4)	
Mean FET (s)	5.77 ± 0.79	5.69 ± 0.79	6.15 ± 0.69	
Plateau				<0.001[a]*
Pass	101 (76.5)	80 (85.1)	21 (55.3)	
Not pass	31 (23.5)	14 (14.9)	17 (44.7)	
Extrapolate volume				0.081[b]
Pass	130 (98.5)	94 (100.0)	36 (94.7)	
Not pass	2 (1.5)	0 (0.0)	2 (5.3)	

FET, forced expiratory time.

[a]Chi-square tests.

[b]Fisher's exact test.

*$P < 0.05$.

**Expiratory time correct by age <10 year; pass mean expiratory time >3 s, if age is equal to or more than 10 years old; pass mean expiratory time >6 s.

Our study demonstrates that gender has no effect on the success rate, which is consistent with previous research (15). Subjects who had prior spirometry experience had a lower failure rate. The data indicated that the failure group had a higher rate of first-time spirometry performance failure. Prior practice and encouragement may assist children to successfully perform the test, as demonstrated in a previous study that supports the use of positive reinforcement techniques before obtaining the spirometry, which illustrate a higher success rate (11,16).

Symptoms for respiratory diseases, which we believe interfere with spirometry performance, had no influence on the failure rate in this study. Chronic cough and chronic rhinorrhoea are two frequent respiratory symptoms that might emerge as a consequence of an underlying illness or allergic reaction.

The spirometry test involves three steps: deep inhalation, rapid and forced exhalation and prolonged exhalation. The most error-prone step in our study is prolonged exhalation (36.8%), during which some patients experienced premature termination, insufficient effort, inspiration and cough. They had a difficult time exhaling until the flow ceased. This finding is significant because one of the factors influencing this study is the plateau on the volume time curve. Also, we discovered that forced expiratory time (FET) is one of the factors that contribute to a successful spirometry test in the younger age group. However, some studies have demonstrated that FET values vary according to age, elastic recoil of lung and airway disease (17,18). Müller-Brandes et al. (9). found that only 18% of children aged 10–18 years met the FET criteria, with a mean FET of 4.2 ± 1.6 s. Although this study demonstrated a higher success rate of approximately 60% in this age group of over 10 years, the mean FET was also 5.77 ± 0.79 s., indicating that the standard FET may not be the optimal value for the cutoff point at this age.

The key strengths of this study include the employment of a single trainer to perform the spirometry, which minimised performance bias, and the fact that this was the first research undertaken on Thai children.

An important limitation needs to be considered in this study. Due to the small sample size resulting from the Coronavirus infectious disease 2019 (COVID-19) outbreak, most data were collected prior to 2019 and we did not use acceptability criteria based on ATS 2019 because data were collected prior to these changes. The minimum FET requirement was eliminated from the acceptability criteria in ATS/ERS 2019, which may result in a higher success rate. However, this hypothesis requires further study.

Conclusion

Thai children had a success rate of approximately 71%. Children's age, weight and height are all considered predictors of success. The most commonly encountered step failure in spirometry test is a prolonged exhalation phase. However, the plateau on volume time curves is a critical component of success.

To improve the success rates of the spirometry test in Asian children, consider their age when giving instructions and evaluate their comprehension as well as their technical capacity to perform the test. Encouragement and demonstration particularly during a prolonged exhalation phase are necessary for success.

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Conflict of interest

All of the authors declare no conflict of interest.

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