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Predictive Value of Spirometry in Screening of Children with Respiratory Disease

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ABSTRACT

Introduction: The diagnostic value of spirometry in the evaluation of pulmonary function is known; however, the predictive potential of this method has always been undervalued. In the present systematic review, we aimed to collect all available data to analyze whether spirometry can be used in screening programs to predict future pulmonary diseases.

Methods: A database search was performed in Ovid, Science Direct, PubMed, Scopus, Web of Science, Embase, and Google Scholar using "spirometry" and "predictive value" as the main search terms.

Results: After excluding irrelevant articles, 19 related studies were selected, and data extraction was performed. The results of the included literature showed that spirometry is a safe and reliable method for the evaluation of pulmonary function. It was also reported that spirometry can provide useful information, which can be complementary to other methods of evaluation.

Conclusion: Findings showed that spirometry is a valid and non-invasive method of assessment for the diagnosis of respiratory diseases such as asthma and airway obstruction. Moreover, spirometric parameters may help to predict future pulmonary conditions, at least in children.

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Introduction

Respiratory diseases are a group of disorders that affect the function of the respiratory system, especially the lungs. Respiratory diseases are the major leading causes of death and disability in children. Estimations show that the late diagnosis of obstructive pulmonary disease in children contributes to a majority of re-hospitalization and mortality in this age group. The five common types of respiratory diseases include acute respiratory infections, asthma, tuberculosis, lung cancer, and chronic obstructive pulmonary disease (1). Pneumonia is a common cause of death in children and is responsible for about 1.3 milliondeaths annually. Asthma is also the most common non-acquired respiratory disease in children. Respiratory diseases in childhood can lead to chronic lung disease in adulthood; therefore, immunization in childhood can specifically reduce the prevalence and severity of lung disease in adulthood (2).

As diagnosis at the early stages of the disease can have a profound effect on the success of the treatment procedure, repeated assessment of respiratory function in children should be

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part of screening programs (3). The wide range of respiratory diseases and their high prevalence can lead to severe complications and high healthcare costs. Diagnostic methods such as physical examination, lung diffusing capacity, arterial blood gases (ABGs), and spirometry have been developed for the diagnosis of respiratory illnesses (4). Most of these methods are applicable at the late stages of the disease; hence, a low-cost and highly accessible diagnostic method, that can detect respiratory illnesses at the early onset of the disease, can significantly reduce mortality and disability among patients, especially in children.

As described, there are a variety of tests available to evaluate the pulmonary function in infants and children. Some of these methods require sedation and advanced laboratory apparatuses. However, spirometry is a procedure used to diagnose, manage, and monitor various respiratory diseases and does not require sedation or advanced laboratory techniques (5, 6). Spirometry, on the other hand, is also one of the safest methods of measuring lung function and is very efficient for the evaluation of small airways (7). Because spirometry can be used to diagnose changes in the airway before any symptoms in arterial blood gas (ABG) and chest X-ray and before disease worsening, it can be considered a helpful diagnostic procedure in patients with obstructive or restrictive airway symptoms (8).

Besides all diagnostic values of spirometry, its potential in the early detection of respiratory problems in children has always been controversial. In the current study, we aimed to systematically review the role of spirometry in the early diagnosis, treatment, and follow-up of children with respiratory diseases.

Methods

2-1. Study search and inclusion criteria

In this systematic review, we aimed at the advantages and diagnostic value of spirometry in the screening of children. For this purpose, a systematic search was performed in April 2020 in electronic databases including Ovid, Science Direct, PubMed, Scopus, Web of Science, Embase, and Google Scholar. The key terms used for this purpose included “spirometry” and “diagnostic value” with all their equivalents in the keyword search. First, the search was limited to English articles, and review articles, case reports, and conference papers were excluded. Afterward, we limited the search to the pediatric age of ≤ 18 years. Finally, irrelevant articles and studies which reported adults or elder population were excluded. The search was performed by two authors independently, and any disagreement between the authors was resolved in each step by double-checking. All the procedures for study design and article selection process were performed based on the PRISMA checklist 2009, which is a reliable protocol for performing systematic reviews (9).

2-2. Data synthesis and the variables

For data synthesis, all informative data including the first author’s name, demographic information, publication date, study type, number of patients, and their mean age were extracted and are listed in Table 1 in chronological order. Furthermore, the measured variables and the main findings in each study were extracted and used for qualitative data analysis. The most important variables include forced expiratory volume in 1 second (FEV1), total lung capacity (TLC), forced vital capacity (FVC), and forced expiratory flow at 25-75% of the pulmonary volume (FEF25–75%).

Results

A total of 811 articles were found through a database search, of which 770 and 29 articles were found respectively in PubMed and Scopus, as the two major databases. Additional 12 articles were found in other databases. Also, three articles were found through manual screening of the reference list of the previously included articles. After the exclusion of irrelevant papers in several steps, a total of 19 related articles were collected for qualitative analysis, of which 4 articles were retrospective, 7 were prospective cohort, 7 were cross-sectional, and 1 article was a randomized controlled trial. The step-by-step article selection procedure is presented in Figure 1.

Overall, 3813 patients had been enrolled in the included studies, of whom 989 were male, 807 were female, and the sex of 2017 patients had not been mentioned. The age of patients varied between 6 months and 18 years. Only in one study, the age range was ≤ 20 years. Demographic information and general data of the included articles are presented in Table 1.

Findings

Based on the findings of the included studies, the results can be categorized into four groups:
1.Studies that were entirely in favor of spirometry;
2.Documents that denied the predictive role of spirometry for future respiratory illnesses;
3.Studies that did not have a conclusive finding and recommended further evaluation;
4.Studies that did not find a diagnostic value but still recommended spirometry due to providing valuable complementary results.

Considering the categories above, 12 articles

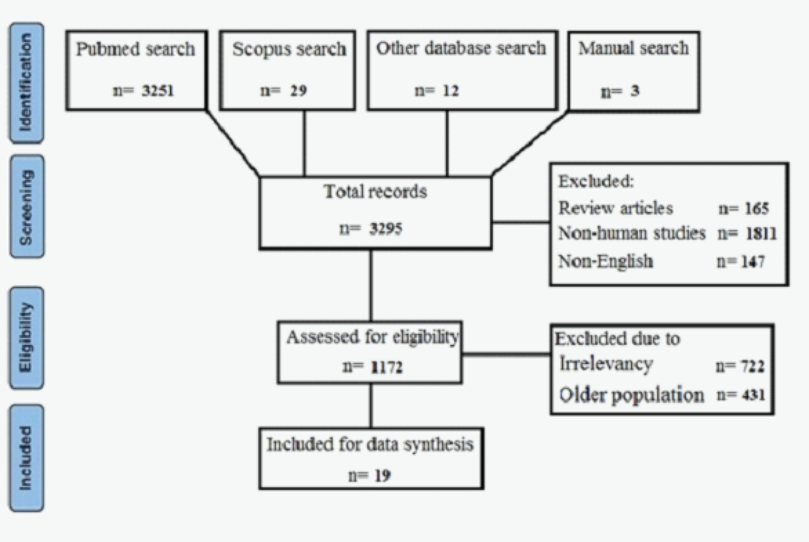

Figure 1. Selection process of articles

with a study population of 1847 patients, showed that spirometry can be considered a powerful tool for the screening of patients, which can lead to a diagnosis in the early stages of pulmonary disease in children. It was also noted that spirometry measurement is a safe, inexpensive, and accessible diagnostic method by which a high-risk patient with pulmonary illness can be prospectively identified (10).

However, 4 studies with 692 patients overall reported that spirometry does not have a predictive value and only shows the current state of the respiratory system, so it cannot be recommended for the prediction of future pulmonary disorders. These studies reported that although spirometry provides valuable information, the assessment of respiratory function cannot be reliable, based solely on spirometry. Further, spirometry is not sensitive to detect small changes in respiratory function, and the correlation between respiratory symptoms and spirometric values is low (11, 12).

Table 1. General information of included studies

Author/year	Country	Study type	Mean age	Number of patients	Male/Female
Mondal P, 2019 (10)	USA	RS	11.59 (4-18)	56	32/24
Eke Gungor H, 2019 (11)	Turkey	CSS	-	216	-
Sorkness RL, 2018 (12)	USA	PCS	12.4 (6-17)	560	327/233
Busi LE, 2017 (13)	Australia, Argentina	RCT	4.9 (3-5)	289	170/119
Silva AM, 2016 (14)	Portugal	CSS	12 (6-18)	33	16/17
Tan CC, 2014 (15)	USA	RS	11.2	82	-
Schifano ED, 2014 (16)	USA	RS	5-19	894	-
Cook J, 2013 (17)	UK	CSS	7-16	25	16/9
Langhan ML, 2009 (18)	USA	CSS	12	34	-
Rodrigo GJ, 2008 (19)	Uruguay	CSS	20 ≥	35	-
Rosenthal M, 2008 (20)	UK	PCS	-	298	151/147
Kjaer HF, 2008 (21)	Denmark	PCS	6	404	200/204
Brouwer AF, 2006 (22)	Netherlands	PCS	6-16	36	25/11
Abramson JM, 2003 (23)	USA	PCS	12.4 (10.3-17.1)	535	-
Marostica PJ, 2002 (24)	USA	CSS	3-6	33	20/13
Phillips MF, 2001 (25)	UK	RS	12 (10-18)	58	-
Hewson PH, 1996 (26)	USA	PCS	10-15	27	-
Linna O, 1996 (27)	Finland	PCS	11.4 (6-16)	65	32/33
Silver RB, 1984 (28)	USA	CSS	10 (4-17)	133	-
CSS: Cross-sectional study, RS: Retrospective study, PCS: Prospective cohort study, RCT: Randomized clinical trials				N= 3813	M= 989 F= 807 ?= 2017

were in favor of spirometry which reported a predictive value for spirometry in the early detection of respiratory illnesses. These studies Besides, 2 articles with a total of 1192 patients reported that spirometry alone does not predict future pulmonary conditions, but it was recommended since it can provide very useful complementary information that can be used for such a purpose. The results of these studies suggested that abnormal spirometric values between the age of 8 and 12 years cannot be considered as a predictor of mortality and morbidity caused by a respiratory illness in near future (13). The most prevalent diseases among the pediatric population include asthma, followed by cysticfibrosis, sickle cell disease, allergic rhinitis, and Duchenne muscular dystrophy. It has been reported that children with asthma have significantly lower FEV1/FVC and FEF25–75%, suggesting that FEF25-75% can be considered a valuable predictive parameter for the early diagnosis of children with asthma (14, 15).

It was also found that the mean spirometric values in boys were lower than in girls, indicating a sex difference (16). The major predictive marker and the main findings of the included studies are summarized in Table 2.

Table 2. Predictive marker of spirometry test and the main findings of included studies

First author	Type of disease	Recommended marker	Main outcome
Mondal P	Sickle cell disease	Impulse oscillometry	Sensitivity of spirometry to smaller changes in respiratory function is low.
Eke Gungor H	Asthma with or without allergic rhinitis	FEV1/FVC, FEV1%, FEF25-75	Early spirometric parameters are useful to evaluate the children with asthma and or allergic rhinitis.
Sorkness RL	Asthma	FEV1	Spirometry can indicate the risk of asthma severity.
Busi LE	Asthma	FEF75	Spirometry is a reliable test to discriminate asthma.
Silva AM	Cystic fibrosis	FEV1, FEF25-75	Spirometric values are risk predictors for nocturnal desaturation.
Tan CC	Asthma	-	The value of spirometry on asthmatic children prior to hospital discharge is unclear.
Schifano ED	Asthma	FEV1/FVC	Ability of spirometry in determining asthma severity is low.
Cook J	Sickle cell disease	FEV1, FVC	Spirometric abnormalities are suggestive of restrictive lung disease.
Langhan ML	Asthma	FEV1/FVC, FEV1	Spirometry provides objective, and non-invasive measurements for exacerbations of asthma.
Rodrigo GJ	Asthma	FEV1	Spirometry provides important complementary information about asthma severity.
Rosenthal M	Cystic fibrosis	-	Spirometry as judged by FEV1 do not assist long-term prognosis.
Kjaer HF	Asthma	FEV1	Spirometry aids the diagnosis of asthma in young children.
Brouwer AF	Asthma	-	Spirometry shows poor concordance with other indices of disease activity.
Abramson JM	Asthma	-	Spirometry cannot be recommended for school-based asthma screening.
Marostica PJ	Cystic fibrosis	FEV1, FVC	Spirometry can successfully assess lung function in children with cystic fibrosis.
Phillips MF	Duchenne muscular dystrophy	FVC, FVC 64%	Repeated spirometry provides a powerful means of assessing disease progression.
Hewson PH	Asthma	FEV1, FEF25-75	Spirometry should be part of the routine assessment of acute and chronic asthmatics.
Linna O	Asthma	-	Assessment of the asthma severity cannot be reliable based solely on spirometry.
Silver RB	Asthma	FEV1, FVC	Spirometry is an adjunct to clinical evaluation in the early identification of acutely ill asthmatic children.

Discussion

The high prevalence of respiratory disorders urges the need for evaluation of lung function, particularly in the early stages of the disease. Therefore a repeated assessment of lung function in childhood and thereafter can help to diagnose an abnormal pulmonary function at early stages. On the other hand, an abnormal pulmonary function has been shown to be associated with diseases such as asthma, hypoxemia, and restrictive lung disease (17).

Epidemiological studies have shown that spirometry can have a prognostic value for a specific respiratory condition. For example, findings have shown that VC and FVC can respectively be considered as powerful indicators of chronic obstructive pulmonary disease (COPD) and premature death (18, 19). Spirometry values can also be expressed as T-scores, which have been shown to predict respiratory and COPD death (20). Moreover, total lung capacity (TLC) measurement has been recommended to be performed for functional assessment of patients with interstitial lung disease (ILD) (21).

In addition, abnormal spirometry finding has been reported as an important predictor of pulmonary disorders (22, 23). Moreover, spirometric values can be considered as risk predictors for nocturnal desaturation (24). Accordingly, a change in the values of spirometric parameters can be predictive for the survival rate of respiratory diseases; hence, repeated spirometric measurements can provide useful information for the evaluation of disease progression (25). There are also pieces of evidence supporting that bronchodilator response (BDR) and measurements of FEV1 are reliable spirometric parameters for the prediction of future asthma in preschool children (4, 26). Spirometry has been reported as a non-invasive measurement tool that can successfully predict the severity of airway obstruction in children, with higher efficiency than an examination of clinical signs (27).

On the other hand, the findings of many studies do not support the predictive capacity of spirometry in early childhood (11). In this regard, some studies reported that spirometry, alone, has limited capacity to detect asthma, and asthma severity can be rapidly determined by clinical examination rather than with spirometry (5, 15, 16). These conflicting views may partly arise from different schemes of studies since many studies have reported that spirometric values vary among different populations, ethnic groups, and even between males and females, and this should be considered in every spirometry evaluation (16, 28, 29). Also, spirometry criteria for adults do not necessarily apply to children. Therefore, it is suggested that for a sensitivity analysis of pulmonary function, several parameters and different thresholds should be considered for each selected population.

Overall, findings suggested that spirometry is helpful in primary care practice and adds a lot of useful data to existing information provided by medical examination or other diagnostic tools, which may be used to provide more optimal management (3, 30). Furthermore, a significant positive correlation has been reported between radiological findings and spirometric parameters, suggesting that spirometry, as a screening method, can be successfully used to assess lung function from infancy (31). Consistent with these findings, many studies on adults and the elder population showed that spirometry can be beneficial for discrimination of patients with lung disease (2). However, further studies in larger communities and on groups of different sex, age, and ethnic background are necessary to clarify the strength and drawbacks of spirometry.

Conclusion

The results of the included studies showed that spirometry is a safe and reliable method for the evaluation of pulmonary function. Although spirometry may provide limited information, it can be helpful in identifying patients who are at higher risk of asthma exacerbations and may be helpful to predict future pulmonary conditions, at least in children. Spirometry can also provide useful information complementary to other methods of evaluation. It has also been suggested that the accuracy of spirometry values can be optimized by using other complementary methods, such as clinical examination. However, considering controversial discussions, further studies in larger communities with diverse backgrounds may help to draw a firmer conclusion about the strength and limitations of spirometry.

Conflict of Interest

The authors declare no conflict of interest.

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