Scientific Knowledge Group

ISSN: 3067-9451

Research Article

Journal of Clinical Cases and Medical Reports

Pulmonary Function Test of Pediatric Patients Diagnosed with Covid-19 Infection: A Meta-Analysis

Patricia Joy B Lunas[1]*, Kevin L Bautista[1], Maria Cristina H Lozada[1], Marimel G Reyes-Pagcatipunan[2]

[1]*Pediatric Pulmonology, Philippine General Hospital, Taft Manila*

[2]*Pediatric Infectious Disease, Philippine General Hospital, Taft Manila*

***Corresponding author:**
Patricia Joy B Lunas, MD, Pediatric Pulmonology, Philippine General Hospital, Taft Manila. Tel: 0917-5293925.

ABSTRACT

***BACKGROUND**: COVID-19 infection has affected the pediatric population but the severity of lung injury is still inconclusive. This study aims to determine the pulmonary function of pediatric patients with a history of COVID-19.*

***METHODOLOGY:** This was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. This study included all published studies reported that evaluated pulmonary function in pediatric patients after COVID-19 infection. Fixed effects meta-analysis was used to pool reported mean values for pulmonary function test findings.*

***RESULTS:** Seven cohort studies were included in the systematic review and six were pooled in the meta-analysis. Sample size ranged from 16 to 589 patients (total of 841 patients). Median age ranged between 6.8 to 15.8 years old. Majority have asymptomatic to moderate infection, with only one study reporting severe infection with pneumonia. Pulmonary function tests were taken 4 weeks to 6 months (average of 3 months) post-discharge, showing normal oxygen saturations and diffusing capacity of the lungs for carbon monoxide (DLCO). Pooled spirometry results showed: FEV1% is equal to 101.5% (92.0% to 111.0%), FVC% is equal to 100.9% (91.3 to 110.5%), FEV1/FVC ratio is equal to 93.7% (85.7% to 101.8%). All studies are homogenous (I2=0%).*

***CONCLUSIONS**: Pulmonary function assessed using spirometry, oxygen saturations, and DLCO remains normal three months after COVID-19 infection. Further studies are recommended to determine if lung function during early stage of infection predicts significant lung injury caused by COVID-19.*

Keywords: COVID-19, post-COVID-19, Spirometry, Pulmonary Function Test.

Received: March 05, 2025;
Accepted: March 11, 2025;
Published: April 03, 2025

Introduction

A. Background of the study

In the year 2019, Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), a novel coronavirus was identified to cause a cluster of pneumonia cases in Wuhan, China. The rapid spread caused an epidemic, followed by an increasing number throughout the world. By March 2020, the novel Coronavirus Disease of 2019 (COVID-19) was then declared to cause a global pandemic.

It has been documented that most cases of COVID-19 affected adults. However, children of all ages have acquired COVID-19 as well. The World Health Organization has declared more than 600 million cases of the abovementioned illness [1]. In a study by Alborote et.al last 2020, the most common presenting pulmonary symptoms of COVID-19 in children were cough (44%) and dyspnea (24%), while tachypnea, crackles, and peripheral oxygen desaturation were the most common pulmonary signs. Indeterminate findings for COVID-19 were the most commonly identified among patients who had chest radiographs and chest computed tomography (CT) scans. Invasive ventilatory support commencing with 100% fractional inspired oxygen (FiO2) was administered to severe and critical cases [2].

As one of the COVID-19 centers in the Philippines, the Philippine General Hospital had a total of 448 patients (probable and confirmed) admitted from April 1, 2020 to

Citation: Patricia Joy B Lunas, Kevin L Bautista, Maria Cristina H Lozada, Marimel G Reyes-Pagcatipunan (2025) Pulmonary Function Test of Pediatric Patients Diagnosed with Covid-19 Infection: A Meta-Analysis. J Clin Case Med Rep 1: 1-9.

June 30, 2022. Majority of the cases had a final COVID-19 severity classification of asymptomatic (N=93), mild (N=173, moderate (N=65), severe (N=67) and critical (N=37) [3].

Several studies were done to associate COVID-19 infection with possible short and long-term effects in pulmonary function. It has also been shown that higher severity of the disease may cause sequelae such as decreased pulmonary function. Spirometry has been demonstrated to be a useful tool in detecting lung diseases such as restrictive, obstructive, or mixed.

This study determined the pulmonary function status of pediatric patients who have acquired COVID-19 infection in terms of the presence of respiratory symptoms, oxygen saturations, peak expiratory flow, and spirometry.

B. Significance of the Study

The respiratory system has been known to be subjected to major involvement in COVID-19 infection. Hence, the possibility of suffering from pulmonary dysfunction is also increased. However, upon extensive review of literature, various factors leading to decreased lung function are not well explained. This study will evaluate the pulmonary function of children with a history of COVID-19 infection. This will be relevant for healthcare professionals in the preparation of future COVID-19 guidelines in order to improve management and provision of patient care. Optimum management of the patients who have suffered the mentioned illness will be monitored and will have adequate care on subsequent follow-ups. No local study about the association between COVID-19 infection in children and pulmonary function test using spirometry has been done and published yet.

C. Research Objectives

General Objective

To determine the characteristics and pulmonary function of pediatric patients with a history of COVID-19 from 2020 to 2023:

Specific Objectives

1. To describe the characteristics of pediatric patients with a history of COVID-19 infection:

a. Demographic data (age, gender)

b. Clinical presentation (severity of disease, length of hospital stay)

c. Outcome upon discharge

2. To determine the pulmonary function of pediatric patients with a history of COVID-19 infection based on:

a. Oxygen Saturation with pulse oximetry on room air

b. Peak expiratory flow rate (PEFR, L/min)

c. Spirometry [Forced Vital Cavity, FVC (% predicted), Forced expiratory volume in the first second, FEV1 (% predicted), FEV1/FVC ratio, and Peak expiratory flow rate, PEFR (L/minute)]

d. Diffusing capacity of the lungs for carbon monoxide (DLCO)

Review of Related Literature

Coronavirus infection has a major involvement of the respiratory system. Patients with severe pulmonary involvement during SARS-CoV-2 infection showed impairment of pulmonary function. Radiological abnormalities, reduced exercise capacity and impaired pulmonary function may improve over time, however may still be persistent in some after a few months or even years [4].

Long COVID, a devastating illness, usually includes persistent breathing problems to a lower extent and abnormalities in pulmonary physiology or imaging. The most frequently reported pulmonary symptoms related to long COVID were coughing, chest discomfort, and shortness of breath. About 10% of patients diagnosed with COVID-19 experience persistent post-acute symptoms. Hospitalized patients due to COVID-19 were usually the population of most research to assess lung function abnormalities [5].

Post-infection COVID-19 patients have also been shown to have altered respiratory function. In the study by Torres-Castroa in 2020, about 40% of patients had diffusion capacity were most importantly affected [6].

In a study evaluating 34 children with COVID-19 a month after acute infection through clinic follow-ups (N=14) and phone call follow-ups (N=20), no symptoms were reported by the patients during the phone call follow-ups. However, for those who followed up in the clinic, pulmonary sequelae were noted in seven (50%) of the 14 patients (3 patients had spots or patches of opacities while 4 patients presented with fibrosis). CT scan showed fibrous stripes in areas other than the original lesion in some patients, which suggested the likelihood of sustained effects of the disease on the lungs. In the abovementioned study, it was found that 28% of the patients had pulmonary symptoms 3 months after infection [7].

Most recently, a systematic review and meta-analysis on pulmonary function in patients who acquired COVID-19 have reported altered diffusing capacity of the lungs for carbon monoxide (DLCO) in about 40% of the patients. However, the results must be analyzed carefully, because pulmonary comorbidities and varied timing of evaluations should be considered. It is still imprecise whether pulmonary vascular or interstitial abnormalities contributed to the deranged DLCO in those patients [8].

A case series by Colombo et. al., assessed adult patients (N=13) with COVID-19 bilateral pneumonia admitted to the respiratory acute care ward. The study concluded that COVID-19 pneumonia may result in clinically relevant alterations in pulmonary function tests, with a restrictive pattern in 10 out of 13 patients at the time of hospital discharge. After 6 weeks, pulmonary function improved, but some degree of restrictive alteration still persisted [9].

A retrospective observational study in Bangladesh assessed 262 COVID-19 diagnosed and recovered but had exertional dyspnea. The major abnormalities noted were reduced volumes and diffusion defects (RV, ERV, TLC). Hence, it is the reduced volume and diffusion membrane abnormality that leads to difficulty in breathing upon exertion in the enrolled subjects [10].

In contrast, despite evidence of pulmonary involvement in coronavirus infection, limited studies up to the present have demonstrated a clear relationship between decreased pulmonary function test as short and long-term effects right after the infection.

A retrospective analysis by Lewis, et. al, identified patients based on having COVID-19 and pulmonary function tests taken before the infection and within a year after the infection. It concluded that there is no significant difference in lung function as measured by pulmonary function tests done pre- and post-COVID-19 infection in non-critically ill classified patients. There could be a relationship between definite underlying lung diseases (interstitial lung disease and cystic fibrosis) and abnormal lung function after acquiring the infection. This data should help clinicians in their interpretation of pulmonary function tests obtained after COVID-19 infection [11]. In a multicenter prospective study, 270 COVID-19-positive pediatric patients were evaluated with pulmonary function tests (spirometry, plethysmography, and CO diffusion) after 3 months and 6 months. In the 3rd month, there was noted significant differences between FEV1<80%(n:28), FEV1>80%(n:242) groups due to the presence of additional diseases($p<0.001$), having pulmonary ($p=0.006$) and cardiovascular($p=0.004$) system pathological examination findings, interlobular septal thickening ($p=0.020$) on Chest Computed Tomography Scan, high level of C-reactive protein ($p=0.032$), interleukin-6 (IL-6) ($p=0.048$), ferritin($p=0,020$) during the acute phase of infection. It was then concluded that acquiring COVID-19 pneumonia has no effect on spirometric test results. No significant difference was found on both 3rd and 6th month follow- ups spirometry results of the same patient [12].

Figure 1: Conceptual Framework

Methodology

a. Search Criteria

1. Types of Studies

This study included all published studies reported in any language that evaluated pulmonary function in pediatric patients after COVID-19 infection.

2. Participants

The investigators reviewed all data from the articles being analyzed on pediatric patients diagnosed with COVID-19 infection aged 6 to less than 19 years old from March 1, 2020 to March 31, 2023. The diagnosis of COVID-19 infection was based on the clinical manifestations and confirmed by results of COVID-19 RT-PCR or Rapid Antigen Testing. All studies with complete documentation of COVID-19 patients and available exams were included. All studies that had patients who were unable to perform pulmonary function test such as less than 6 years of age, diagnosed with cerebral palsy, intellectual delay, obstructive and restrictive lung disease were excluded.

3. Intervention

The studies included in this study involved evaluating pulmonary function tests such as:

- Oxygen Saturation with pulse oximetry on room air
- Peak expiratory flow rate (PEFR, L/min)
- Spirometry [Forced Vital Cavity, FVC (% predicted), Forced expiratory volume in the first second, FEV1 (% predicted), FEV1/FVC ratio, and Peak expiratory flow rate, PEFR (L/minute)]
- Diffusing capacity of the lungs for carbon monoxide (DLCO)
-

4. Outcomes

The primary outcome assessed was pulmonary function test findings while secondary outcomes included mortality and length of hospitalization.

b. Search Method

1. Electronic Searches

An electronic search was conducted in MEDLINE via Pubmed, Embase, Cochrane Central Register of Controlled Trials, ClinicalKey, Herdin Plus and Google Scholar, with the following search terms: COVID-19, post-COVID-19, spirometry, pulmonary function test (PFT), lung function test, and long-term COVID-19 effects. Database-specific limiters for cohort, clinical trials, and publication dates within three years were also used. No language restriction was set.

2. Searching other Resources

Review of related literature via online searches and communication with authors and experts was done.

c. Data Collection and Analysis

1. Study Selection

Two review authors assessed independently the eligibility of full text articles.

2. Data Extraction and Management

Two authors extracted the data independently and verified the data. A standardized data collection form was used to independently extract study characteristics and outcome data from the studies. Incongruities were checked against the original article. Disagreements in the extracted data were discussed for final decision. The statistician entered the data in RevMan meta-analysis software (Review Manager v5.3)

3. Risk of Bias Assessment in Eligible Studies

For the methodological quality of the individual cohort studies, the Newcastle Ottawa scale for observational studies was used to score Representativeness, Sample Size, Ascertainment of exposure, Outcome and Statistical Test. A score of at least 3 is acceptable.

4. Measure of Treatment Effect

Fixed effects descriptive meta-analysis was employed to pool pulmonary function test findings measured in mean and standard deviation. Forest plots were generated using Review Manager 5.3.

5. Assessment of Heterogeneity

The heterogeneity degree between studies was assessed using the I2 statistic. The I2 statistic defines the percentage of total variation across studies that is caused by heterogeneity rather than by chance. The values of I2 lie between 0% and 100%, where the higher the value, the more considerable the heterogeneity.

The null hypothesis, that the studies are homogeneous, was rejected if the p-value of the test is less than 0.10, or I2 is greater than 50%.

6. Data Synthesis

Statistical analysis was performed with the RevMan 5.3 software.

7. Sensitivity Analysis

Sensitivity analysis was not applicable since this was a descriptive meta-analysis only and did not compare any groups or interventions.

Results

A total of 1,419 records were initially identified from database search. Of these, 36 were initially included after title and abstract screening. After retrieval and full-text review, 29 studies were further excluded because some studies had adult population while others were case series only in design. Finally, 7 studies were included in the systematic review while 6 were pooled in the meta-analysis.

The seven studies included were summarized in Table 1. Two studies were from Italy, two from USA, two from Turkey, and another one in Poland. All studies were cohort in design and sample size ranged between 16 to 589 patients. The male to female ration in the studies were almost equal while median age ranged between 6.8 to 15.3 years old. All studies included severe and non-severe cases. All studies reported pulmonary function test values but none reported on mortality. Only two studies reported on length of hospital stay wherein Bottino et al. 2021 reported a median of 92 days while Ipek et al. 2022 reported a mean of 7 days.

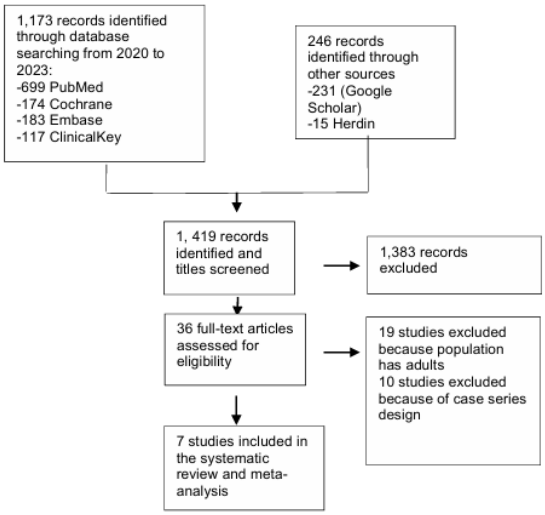

Figure 2: PRISMA Flowchart for studies selection

Table 1: Characteristics and Pulmonary Function Tests of Studies Included

Author, year, country	Study design	Sample size	Population characteristics	Outcomes and pulmonary function tests reported
Bottino, 2021 Italy	Cohort	16	male to female ratio= 10:6 age= 7.5 (0.5-10.5) mild disease= 100%	Length of hospital stay, days=92 (87–97) Mortality=NR FEV1%= 96 (94–102) FVC%= 95 (87–100) FEV1/FVC= 92 (87–97) O2sats=NR PEFR=NR DLCO= 119 (111–132)
Dobkin, 2021, USA	Cohort	29	male to female ratio= 59:41 age= 13.1 (± 3.9) severe= NR	Length of hospital stay, days=NR Mortality=NR FEV1= 107 (± 12) FVC= 110 (± 16) FEV1/FVC= 86 (± 8) O2sats=99 (± 1) PEFR=NR DLCO=95 (± 17)
Bogusławski, 2022, Poland	Cohort	41	male to female ratio= 18:23 age= 6.8 (0.7-12.9) severe= 7.3% non-severe 92.7%	Length of hospital stay, days=NR Mortality=NR FEV1= 0.49 (−0.76 to 1.86) FVC= 0.3 (−0.89 to 1.96) FEV1/FVC= 0.06 (−0.61 to 0.75) O2sats=NR PEFR=NR DLCO= 0.2 (−0.35 TO 0.73)
Iovine, 2022, Italy	Cohort	589	male to female ratio= 51:49 age= 9.6 (± 4.2) severe= NR	Length of hospital stay, days=NR Mortality=NR FEV1= 100.38 (±11.48) FVC= 99.7 (±11.6) FEV1/FVC= 101 (±7.7) O2sats=NR PEFR=NR DLCO=NR

Ipek, 2022, Turkey	Cohort	34	male to female ratio= 18:16 age= 12.7 (± 3.1) severe= NR	Length of hospital stay, days=7 (±9) Mortality=NR FEV1= 98.67±14.93 FVC= 94.21±13.68 FEV1/FVC= 101.06±24.89 O2sats=NR PEFR=NR DLCO=NR
Ozturk, 2022, Turkey	Cohort	50	male to female ratio= 22:28 age= 15.3 (8-18) severe= 20.0% non-severe=80.0%	Length of hospital stay, days=NR Mortality=NR FEV1= 105.18±15.92 FVC= 110.38±12.33 FEV1/FVC= 94.18±8.76 O2sats=NR PEFR=NR DLCO=89.65±8.76
Palacios, 2022, USA	Cohort	82	male to female ratio= 34:48 age= 15.2 (± 2.3) severe= NR	Length of hospital stay, days=NR Mortality=NR FEV1= 104 (97–111) FVC= 104 (13) FEV1/FVC= NR O2sats= 98 (97–99) PEFR=NR DLCO=89.65±8.76

Risk of bias assessment showed that 6 of 7 studies had low sample size while no other concerns for bias were found in representativeness, exposure, outcomes and statistical test used. Overall, all studies were of good methodological quality (score > 3).

Table 2: Risk of Bias Assessment Using Newcastle Ottawa Scale for Observational Studies

Author, country year,	Representativeness	Sample Size	Exposure	Outcome	Statistical Test	Score
Bottino, 2021 italy	Truly representative of studied population (1)	Not-satisfactory (0)	Objective and accurate data source (1)	Objective and accurate data source (1)	Clearly described and accurate (1)	4 (good)
Dobkin, 2021, USA	Truly representative of studied population (1)	Not-satisfactory (0)	Objective accurate source (1) and data	Objective accurate source (1) and data	Clearly described and accurate (1)	4 (good)
Bogusławski, Poland 2022,	Truly representative of studied population (1)	Not-satisfactory (0)	Objective accurate source (1) and data	Objective accurate source (1) and data	Clearly described and accurate (1)	4 (good)
Iovine, 2022, Itaty	Truly representative of studied population (1)	Not-satisfactory (1)	Objective accurate source (1) and data	Objective accurate source (1) and data	Clearly described and accurate (1)	5 (Good)
Ipek, 2022, Turkey	Truly representative studied population (1)	Not-satisfactory (0)	Objective accurate source (1) and data	Objective accurate source (1) and data	Clearly described and accurate (1)	4 (good)
Ozturk, Turkey 2022,	Truly representative studied population (1) of	Not-satisfactory (0)	Objective accurate source (1) and data	Objective accurate source (1) and data	Clearly described and accurate (1)	4 (good)
Palacios, 2022, USA	Truly representative studied population (1)	Not-satisfactory (0)	Objective accurate source (1) and data	Objective accurate source (1) and data	Clearly described and accurate (1)	4 (good)

Seven (7) studies were included in this systematic review and meta-analysis which are summarized below. The prospective study of Bottino et al. (2021) comprised pediatric patients (n=16, median age 7.5) with a positive result for SARS-CoV-2 RNA (nasopharyngeal aspirate or pharyngeal swab). Lung ultrasounds were done on each individual. Individuals aged 4-6 years had the interrupter method test to determine their airway resistance, whereas individuals aged 6 years and older underwent forced spirometry to examine their lungs' ability to diffuse carbon monoxide. Two semiquantitative enzyme immune assays were utilized to examine any potential relationships between lung changes and the immune response to SARS-CoV-2. There were no noted abnormalities on the diffusing capacity of the lungs for carbon monoxide, airway resistance test, spirometry. Seven patients underwent spirometry and DLCO testing, and none of them had results that were less than 80% of what was expected. IgG against SARS-CoV-2 was also present in all of the subjects. In contrast, no pulmonary problems were found in all samples of adults. The findings implied that pediatric patients may be less likely than adults to experience lung problems from an asymptomatic or mild SARS-CoV-2 infection [1].

Pediatric patients (n=29, mean age 13.1 years) with a history of SARS-CoV2 RNA positive or confirmed close contact and probable symptoms were examined retrospectively in a chart review by Leftin Dobkin and colleagues (2021). According to the findings, patients had ongoing respiratory problems from 1.3 to 6.7 months after the initial illness. Nearly all (96.6%) patients had persistent dyspnea and/or exertional dyspnea at the time of clinic visit. The spirometry test was done on 28 patients. The average percent predicted spirometry findings were as follows: FEV1 107 12%, FVC 110 16%, FEV1/FVC 86 8%, and FEF25%-75% 100 23%. In three individuals, there were obstructive ventilatory abnormalities. No patients had abnormalities in their restricted ventilation. In 14 participants, plethysmography was done, and in 15 subjects, diffusion capacity testing was done. TLC of 108 17%, VC of 120 14%, FRC of 99 20%, and RV of 81 48% are the average percent predicted plethysmography values. Four individuals with RV/TLC exceeding 30%, ranging from 32% to 89%, were found to have air trapping. DLCO/VA was 96 14% and the average percent predicted DLCO was 95 17%. Spirometry and plethysmography were typically normal in the majority of individuals. In addition to this, it has been observed that exertional dyspnea, cough and exercise intolerance were the most common respiratory symptoms after COVID- 19 infection [14].

Ipek and colleagues (2022) included pediatric patients (n=34, age range: 5–18 years) who were admitted at the hospital due to COVID-19 infection and discharged after making a full recovery. As a control group, 33 healthy kids of the same age were enrolled. Through the use of spirometry, pulmonary function tests (PFTs) were carried out. The results showed that the forced vital capacity (FVC%) values of the control and patient groups were 110.6211.71 and 94.2113.68 (p=0.001), forced expiratory volume in the first second (P=0.032), FEV1/FVC% values were 108.508.81 and 101.0624.89 (p=0.034), and forced expiratory flow (FEF) 25-75% values were 106.716.68 and 101.8524. However, a moderately negative link between length of hospital stays and FEF 25-75% was shown by Spearman correlation analysis (r=0.364, p=0.35). After recovering from COVID-19, PFTs in pediatric patients were found to be reduced but still within normal values. The findings had a big impact on how mixed-type lung disease developed [15].

In the study by Öztürk and colleagues published in 2022, pulmonary function tests and chronic respiratory symptoms in children with COVID-19 (n=50, mean age 183.5 months) were examined. Three months following infection, patients underwent pulmonary function tests and were assessed for the persistence of pulmonary symptoms. In 28% of patients, persistent respiratory symptoms were still present three months after the infection; the most frequent symptoms were cough, tightness in the chest, dyspnea, and exertional dyspnea. One patient had a restrictive abnormality, whereas three had an obstructive one. Four individuals exhibited reduced lung carbon monoxide diffusing capacity (DLCO). The individuals with chronic respiratory symptoms had a significant decline in FEV1/FVC and an increase in pulmonary clearance index. 12.5% of patients with non-severe disease and 50% of patients with severe disease reported having persistent respiratory symptoms. The group with severe illness had significantly decreased DLCO as well. It was determined that the severity of acute COVID-19 in children does not correlate with the persistence of respiratory symptoms. Peripheral airways may be impacted because it may persist regardless of how severe the inflammation is from COVID-19 [7].

The observational study by Bogusawski et al. (2023) comprised children (n=41, median age 3.75 years) who had been diagnosed with COVID-19 pneumonia. Three months after being discharged, all children attended follow-up appointments, and if any abnormalities were noted, a second visit was planned for the following three months. Pulmonary function tests (PFTs), lung ultrasound (LUS) utilizing a standardized procedure, physical examination, and medical history all made up the clinical assessment. Results from PFTs were contrasted with those of healthy kids. Seven (17.1%) children reported having persistent symptoms, with impaired exercise tolerance (57.1%), difficulty in breathing (42.9%), and cough (42.9%) being the most predominant. Small subpleural consolidations (29%) and coalescent B-lines (37%) were the two LUS anomalies that were most common. When compared to the second follow-up visit, the amount of LUS anomalies was substantially larger at the initial visit (p = 0.03). PFT findings did not significantly differ between the study group's two follow-up visits or between the study group and healthy children. It was determined that after COVID-19 pneumonia, children can face long-term consequences. Most of the time, these are minor and go away with time [16].

A total of 589 patients (n=433, mean age 9.6 years) with prior proven SARS-CoV-2 infection were included in the prospective, longitudinal, single-center investigation by Iovine et al. (2023), where spirometry was carried out. Only 14 patients (3.2%) had a forced expiratory volume in the first second (FEV1) 80%, and none of the patients had a reduced forced vital capacity (FVC). In particular, following the administration of salbutamol, the mean value of the expected percentage of FEV1 was 100.3% with a mean variation of +2.3%. On the other hand, the mean value of the anticipated FVC was 99.7%, with a mean variation of +0.2%

after salbutamol. Furthermore, the mean pre-salbutamol FEV1/FVC value was 101%. The mean spirometry measurements taken fell within the acceptable range. Patients with and without respiratory symptoms during infection had similar spirometry results, with no statistically significant differences. Spirometry results did not alter according to how long had passed between infection and enrollment, either. Hence, lung function does not seem to be compromised for a very long time after infection in children. As a result, in the pediatric population, lung function based on spirometry readings does not seem to be compromised for a very long-time following infection [17]. Palacios et al. (2022) described long-term respiratory effects after SARS-CoV-2 infection in pediatric populations. In this single-center, retrospective cohort of patients seen in a COVID- 19 pulmonary clinic in 2021, adolescents were evaluated if they had persistence in respiratory symptoms of 4 weeks or beyond. Generally, spirometry results were within normal limits in 77% of the study, with approximately 15% (n = 14) presenting with obstructive deficits and five patients with restrictive deficits attributed to a previous history of asthma disease. The median FEV1% was 104 (97–111) while the mean FVC% was 104 (±13) [18].

Meta-analysis of Pulmonary Function Test Findings

Six of seven studies were included in the meta-analysis. The study by Bogusławski et al. 2022 was not included since actual % values of PFT findings are not reported.

The pooled Forced Expiratory Volume (FEV1%) indicates the severity of obstruction in lung diseases among patients included in the studies. The pooled value is equal to 101.5% (92.0% to 111.0%) which indicates normal functioning. All the studies showed consistent findings and are homogenous (I^2=0%).

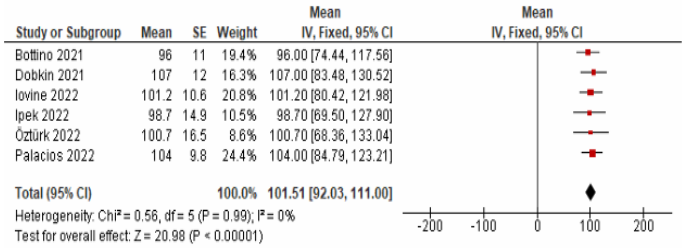

Figure 3: Pooled FEV1% values in the six studies

The pooled Forced Vital Capacity (FVC%) indicates the amount of air that can be forcibly exhaled from the lungs. The pooled value is equal to 100.9% (91.3% to 110.5%) which indicates normal functioning. All the studies showed consistent findings and are homogenous (I^2=0%).

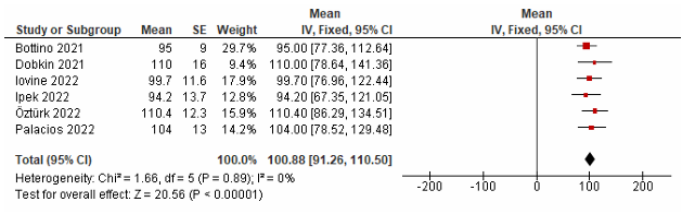

Figure 4: Pooled FVC% values in the six studies.

The pooled FEV1/FVC ratio helps distinguish obstructive and restrictive lung disease. The pooled value is equal to 93.7% (85.7% to 101.8%) which indicates normal functioning since FEV1 and FVC are also in normal range. All the studies showed consistent findings and are homogenous (I2=0%).

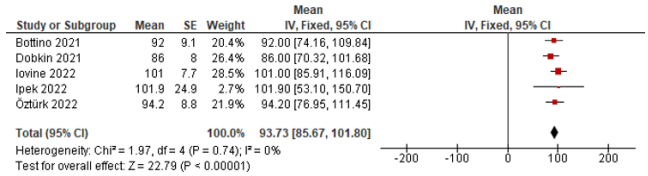

Figure 5: Pooled FEV/FVC% values in the five studies.

Discussion

When evaluating lung diseases, spirometry is the most objective way to assess pulmonary function. Huang et al. discovered that in the early convalescent period, adult patients with COVID-19 pneumonia had worse FEV1/FVC ratios and lower diffusion capacities [19]. Based on PFTs used following the resolution of COVID-19, Fumagelli et al. indicated in that the disease essentially produced a restrictive pattern [9]. At the respiratory function test, Lv et al. found that adult patients with critical illness had increased small airway disease and restricted ventilation disorder [20].

The clinical course of SARS-CoV-2 infection in children and adolescents, it is often less severe than in adults [21]. Long-COVID is the collective term for any symptoms that last or develop four weeks or beyond following an acute SARS-CoV-2 infection [22]. Results of the systematic review are consistent showing that lung function in the pediatric population, as seen in spirometry values, does not seem to be compromised for a very long time after infection. These are typically minor and resolve with time. However, Ipek et al. (2022) emphasized that pediatric patients' lung function deteriorates as their stay in the hospital for COVID-19 lengthens [15].

There are a number of theories that could account for the results in the current study, which seems to show that SARS-CoV-2 infection does not initially appear to be associated with deteriorated pulmonary function in the general pediatric population [17]. Compared to adults, children have fewer chronic diseases and comorbidities. Furthermore, children may exhibit a less vigorous but more focused immune response than adults and be less likely to experience respiratory consequences from an asymptomatic or moderately symptomatic SARS-CoV-2 infection [23-25]. A naturally larger lymphocyte count and a high proportion of natural killer (NK) cells may also contribute to the explanation for the less severe disease in children. What has been found may potentially be explained by the hypothesis that innate immune cells preserve an immunological memory defining the so-called trained immunity. In comparison with adults, differing ACE-2 receptor expression in children may play a protective function against infection susceptibility and lung injury, according to a number of data. Increased expression of this receptor and enzyme in young patients' pneumocytes has been postulated to have a preventive effect against lung injury [26, 27]. Also, as seen in the study of Bottino et al. (2021), pediatric participants had SARS- CoV-2 Ig G positive tests; thus, most SARS-CoV-2-infected children produce virus-specific IgG antibodies [13, 28, 29].

There were no significant variations between the spirometry results of patients with pulmonary symptoms during infection and those without symptoms.17 With this, the illness that causes pulmonary symptoms (such as difficulty in breathing, cough, or colds) does not increase the risk of developing reduced pulmonary function in the future. A recent study by Leftin et al. in this regard demonstrated in a cohort of 29 patients that pulmonary function is normal not only in patients with respiratory symptoms during infection but also in patients who continue to experience respiratory symptoms such as cough, dyspnea, or exertion intolerance at a distance from the infection [14].

Certain limitations can also be seen in the study. The data gathered were limited to a short study period, given that the history of COVID-19 disease is confined to only the past 3 years. Another limitation of this study pertains to the assessment of pulmonary function based on spirometry results and may have effort related results. Some patients are very young and uncooperative, while others have intellectual disability, hence may not able to perform the tests. Furthermore, because the presence of respiratory tract infection may alter spirometry results, spirometry for patients with cough, colds, fever or respiratory distress may not be feasible during the time of the follow-up and may have been postponed to their next clinic visit. The time of assessment are different. Although the pulmonary function test follows specific guidelines given by the clinical guidelines of pulmonary societies, it is essential to establish standard evaluation times to enable comparison between different populations.

The majority of the participants included in the studies were patients showing only signs or symptoms of a moderate or asymptomatic infection, with only 1 study included participants who had confirmed COVID- 19 pneumonia. Also, the study groups were relatively small in the studies. Thus, the findings cannot be applied to all children who recovered from a SARS-CoV-2 infection, especially those afflicted by pediatric multisystem inflammatory syndrome or severe symptoms. Results should be interpreted carefully, making sure that other parameters and objective data will be considered. Furthermore, baseline pulmonary function values are not available in the studies. Comparing pre- and post-infection pulmonary function tests might give more meaningful results to the study. To support the current findings, larger studies examining lung function will be required in the future.

Conclusions

Consistent with the findings of all studies included in this meta-analysis, pulmonary function assessed using spirometry values, oxygen saturations, and diffusing capacity of the lungs for carbon monoxide (DLCO) values remain to be normal three months after COVID-19 infection in the pediatric population. The majority of the studies included asymptomatic to moderate infection, with only 1 study included participants who had confirmed COVID-19 pneumonia. Hence, results may not be generalized. Further studies are recommended to determine if lung function during the early stage of infection predicts significant lung injury caused by COVID-19.

References

1. World Health Organization (2022) WHO Coronavirus (COVID-19) Dashboard. WHO : https://www.who.int/emergencies/diseases/novel-coronavirus-2019.,
2. Alborote WH, Lozada MC, Bautista K (2021) Pulmonary manifestations and management of COVID-19 pediatric patients admitted in a tertiary government hospital. Acta Medica Philippina 55: 157-163.
3. Reyes-Pagcatipunan, Marimel (2023) Clinical and Laboratory Profile, Management and Outcome of Pediatric SARS-CoV-2 Infection Admiited at the Philippine General Hospital. UP-Philippine General Hospital.
4. Anastasio F, Barbuto S, Scarnecchia E, Paolo Cosma, Alessandro Fugagnoli, et al. (2021) Medium-term impact of COVID-19 on pulmonary function, functional capacity and quality of life. Eur Respir J 58: 2004015.
5. Lalwani M, Taksande AB (2023) Pulmonary Function Test as a Diagnostic Tool for Post-COVID-19 Effects. Cureus 15: e34751.
6. Torres-Castro R, Vasconcello-Castillo L, Alsina-Restoy X, L Solis-Navarro, F Burgos, et al. (2021) Respiratory function in patients post-infection by COVID-19: a systematic review and meta-analysis. Pulmonology 27: 328-337.
7. Öztürk GK, Beken B, Doğan S, Akar HH (2022) Pulmonary function tests in the follow-up of children with COVID-19. Eur J Pediatr 181: 2839-2847.
8. Fonseca A, Lima R, Ladeira I, Guimarães M (2021) Evaluation of pulmonary function in post-COVID- 19 patients - when and how should we do it?. J Bras Pneumol 47: e20210065.
9. Fumagalli A, Misuraca C, Bianchi A, et al. Pulmonary function in patients surviving to COVID- 19 pneumonia. Infection 49: 153-157.
10. Azharul IM, Md Mamunur R, Masuda AF, Masrura H, Md Azizur R (2021) Complete pulmonary function profiles of 267 post COVID patients with exertional dyspnea in Bangladesh. Respirology 26: 59-60.
11. Lewis KL, Helgeson SA, Tatari MM, Mallea JM, Baig HZ, et al. (2021) COVID-19 and the effects on pulmonary function following infection: A retrospective analysis. E Clinical Medicine 39: 101079.
12. Soydaş SA, Ocak E, Gençoğlu MY, Uytun S, Tabakçı SÖ, et al. (2022) Respiratory functions in the follow-up of children with COVID-19 infection. European Respiratory Journal 60: 4250.
13. Bottino I, Patria MF, Milani GP, Carlo Agostoni, Paola Marchisio, et al. (2021) Can Asymptomatic or Non-Severe SARS-CoV-2 Infection Cause Medium-Term Pulmonary Sequelae in Children?. Front Pediatr 9: 621019.
14. Leftin Dobkin SC, Collaco JM, McGrath-Morrow SA (2021) Protracted respiratory findings in children post-SARS-CoV-2 infection. Pediatr Pulmonol 56: 3682-3687.
15. Ipek S, Gungor S, Gullu UU, Betul Kizildag, Mehmet Yasar Ozkars, et al. (2022) Evaluation of Pulmonary Functions After Discharge in Pediatric Patients with COVID-19: A Prospective Study. Sisli Etfal Hastan Tip Bul 56: 318-322.
16. Bogusławski S, Strzelak A, Gajko K, Joanna Peradzyńska, Jolanta Popielska, et al. (2023) The outcomes of COVID-19 pneumonia in children- clinical, radiographic, and pulmonary function assessment. Pediatr Pulmonol 58: 1042-1050.
17. Iovine E, Di Mattia G, Nenna R, et al. Lung function after SARS-CoV-2 infection: A prospective cohort study in children. Pediatr Pulmonol 58: 2009-2016.

18. Palacios S, Krivchenia K, Eisner M, Young B, Ramilo O, et al. (2022) Long- term pulmonary sequelae in adolescents post-SARS-CoV-2 infection. Pediatric pulmonology 57: 2455-2463.
19. Huang Y, Tan C, Wu J, et al. Impact of coronavirus disease 2019 on pulmonary function in early convalescence phase. Respir Res 21: 163.
20. Lv D, Chen X, Wang X, Linghong Mao, Jiao Sun, et al. (2020) Pulmonary function of patients with 2019 novel coronavirus induced-pneumonia: a retrospective cohort study. Ann Palliat Med 9: 3447-3452.
21. Sudre CH, Murray B, Varsavsky T, Mark S Graham, Rose S Penfold, et al. (2021) Attributes and predictors of long COVID. Nat Med 27: 626-631.
22. 22. NIH (2020) COVID-19 rapid guidelines: managing the long-term effects of COVID-19. London: National Institute for Health and Care Excellence (NICE).
23. Sinaei R, Pezeshki S, Parvaresh S, Sinaei R (2021) Why COVID-19 is less frequent and severe in children: a narrative review. World J Pediatr 17: 10-20.
24. 24. Felsenstein S, Hedrich CM (2020) SARS-CoV-2 infections in children and young people. Clin Immunol 220: 108588.
25. Zimmermann P, Curtis N (2020) Why is COVID-19 less severe in children? A review of the proposed mechanisms underlying the age-related difference in severity of SARS-CoV-2 infections. Arch Dis Child 106: 429-439.
26. Nikolopoulou GB, Maltezou HC (2022) COVID-19 in Children: Where do we Stand?. Arch Med Res 53: 1-8.
27. Cristiani L, Mancino E, Matera L, Raffaella Nenna, Alessandra Pierangeli, et al. (2020) Will children reveal their secret? The coronavirus dilemma. Eur Respir J 55: 2000749.
28. Weisberg SP, Connors TJ, Zhu Y, Matthew R Baldwin, Wen-Hsuan Lin, et al. (2021) Distinct antibody responses to SARS-CoV-2 in children and adults across the COVID-19 clinical spectrum. Nat Immunol 22: 25-31.
29. Corr M, Christie S, Watson C, Julieann Maney, Derek Fairley, et al. (2020) Seroprevalence of SARS-CoV-2 antibodies in children of United Kingdom healthcare workers: a prospective multicentre cohort study protocol. BMJ Open 10: e041661.

Copyright: © 2025 Patricia Joy B Lunas. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.