Thorac Res Pract. 2025;26(3):137-144 DOI: 10.4274/ThoracResPract.2025.2025-1-12

Original Article

Nationwide Assessment of Pulmonary Function Testing Practices and Safety Compliance During the COVID-19 Pandemic

Aslı Görek Dilektaşlı[1], Şermin Börekçi[2], Öznur Akkoca Yıldız[3], Bilun Gemicioğlu[2], Cüneyt Saltürk[4], Sevgi Behiye Saryal[3], Gaye Ulubay[5]

[1]Department of Pulmonary Medicine, Bursa Uludağ University Faculty of Medicine, Bursa, Türkiye
[2]Department of Pulmonary Diseases, İstanbul University-Cerrahpaşa, Cerrahpaşa Faculty of Medicine, İstanbul, Türkiye
[3]Department of Chest Diseases, Ankara University Faculty of Medicine, Ankara, Türkiye
[4]Department of Chest Diseases, Medipol University Faculty of Medicine, İstanbul, Türkiye
[5]Department of Pulmonary Medicine, Başkent University Faculty of Medicine, Ankara, Türkiye

Cite this article as: Dilektasli AG, Börekçi Ş, Akkoca Yıldız Ö, et al. Nationwide assessment of pulmonary function testing practices and safety compliance during the COVID-19 pandemic. *Thorac Res Pract.* 2025;26(3):137-144

Abstract

OBJECTIVE: Coronavirus disease-2019 (COVID-19) presented considerable challenges to health services, particularly for a routine assessment method, the pulmonary function tests (PFTs), which can generate aerosols and require sharing common surfaces. Despite these risks, there is a need to continue testing, especially for vulnerable patient groups.

MATERIAL AND METHODS: An online survey was conducted from June 1 to June 26, 2020, to assess pulmonologists' practices regarding PFTs before and during the pandemic's first peak in Türkiye (March 11-May 20, 2020). The survey included 30 anonymized questions and received ethical committee approval. Statistical analysis was performed using the IBM Statistical Package for the Social Sciences statistical package.

RESULTS: Two hundred and forty-three respondents across 59 cities participated in the study. 93% were pulmonologists. 77.4% of PFT labs have adequate ventilation by having a window enabling room direct air exchange. 27.2% of the PFT labs continued testing during the first peak of the pandemic. 83.3% of the responding centers applied triage before testing. Ongoing tests included spirometry (100%), bronchodilator reversibility testing (62.1%), and carbon-monoxide diffusion testing (16.7%). 49% of the PFT labs conducted fewer than four tests daily, while 21.2% performed more than eight. PFT technicians used personal protective equipment, with 67.7% using eye protection and 75.3 % wearing FFP3 or FFP2 masks.

CONCLUSION: The survey found that pulmonologists have acted quickly and made moderate success in making preparations in PFT labs for the COVID-19 pandemic. Nevertheless, safer practice in PFT units still needs to be implemented.

KEYWORDS: Pulmonary function testing, COVID-19, occupational safety

Received: 31.01.2025 ***Revision Requested:*** 11.02.2025 ***Last Revision Received:*** 12.02.2025
Accepted: 15.02.2025 ***Epub:*** 08.04.2025 ***Publication Date:*** 30.04.2025

INTRODUCTION

The Coronavirus disease-2019 (COVID-19) pandemic has affected global healthcare systems, necessitating rapid adaptations to clinical practices to mitigate transmission risks. The primary transmission routes of Severe acute respiratory syndrome-Coronavirus-2 (SARS-CoV-2), the virus responsible for COVID-19, include respiratory droplets and contact with contaminated surfaces.

Pulmonary function tests (PFTs) are essential non-invasive procedures for assessing respiratory function and diagnosing various pulmonary conditions. However, the execution of PFTs poses unique challenges during the COVID-19 pandemic. The testing process can generate aerosols, potentially facilitating airborne transmission of the virus. Additionally, the PFT environment often involves shared equipment and close interaction between patients and healthcare providers, increasing the risk of contact transmission.[1,2]

Corresponding author: Aslı Görek Dilektaşlı MD, e-mail: asligorekd@gmail.com

Copyright© 2025 The Author. Published by Galenos Publishing House on behalf of Turkish Thoracic Society.
Content of this journal is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

Despite these challenges, the need to continue PFTs remains, particularly for vulnerable populations requiring ongoing respiratory assessment and management. Balancing the continuation of these essential services with the imperative to protect healthcare workers and patients from infection is a significant concern.[3] Implementing stringent infection control measures, such as adequate ventilation, personal protective equipment (PPE), and thorough disinfection protocols, is crucial to minimize transmission risks during PFTs.[4,5]

This study aims to obtain information about the practice patterns of pulmonologists in PFT labs before the pandemic in Türkiye and to evaluate the compliance of pulmonologists in Türkiye with safety practice recommendations for PFTs during the COVID-19 pandemic. The findings can inform the development of clear and comprehensive guidelines by analyzing current practices and identifying potential gaps in adherence to safety protocols. Such guidelines are essential to ensure the continuation of PFT, safeguarding healthcare providers and patients amid ongoing and future public health crises.[6]

MATERIAL AND METHODS

This cross-sectional survey was conducted following approval from the Clinical Research Ethics Board of Başkent University Faculty of Medicine (approval number: KA20/201, date: 01.06.2020). Members of the Turkish Thoracic Society, a nationwide pulmonologist society, who consented to participate, were enrolled between June 1, 2020, and June 26, 2020. Reminders were sent every week.

A 30-item online questionnaire, developed by the authors using Google Docs, was administered to participants. The survey consisted of three sections: (1) demographics of the participants and information about pulmonary function test practices before the pandemic period, (2) PFT practices during the first peak of the COVID-19 pandemic, and (3) organizational plans for PFTs in the post-peak phase. The participants' workplaces were categorized as primary, secondary, and tertiary health-care centers.

The physical characteristics and operational details of the PFT laboratories, including ventilation, staffing, procedural volume, and available equipment, were also surveyed. The study evaluated PFT practices during the first peak of the pandemic (March 11-May 20, 2020), including the type and frequency of procedures, cleaning and disinfection methods, and the use of PPE. Respondents also reported their plans for implementing triage, PPE usage, and disinfection methods in the post-peak phase.

Data collection adhered to ethical principles and the Declaration of Helsinki, with voluntary participation and informed consent obtained before survey initiation.

Statistical Analysis

IBM Statistical Package for the Social Sciences statistics for Windows (21.0. Armonk, NY: IBM Corp.) software was used for statistical analysis. We primarily conducted categorical data analysis, reporting percentages and frequencies for categorical variables.

RESULTS

A total of 280 participants completed the survey. After excluding duplicate cases, 243 respondents' responses from 159 different health centers were evaluated for the final analysis. Of the respondents, 58.4% (142) were female. The majority of the participants were pulmonologists (93.0%), followed by pediatricians (2.0%), allergists (1.6%), thoracic surgeons (0.8%), other specialties (2.1%) and PFT technicians (0.4%). Participants represented seven regions of Türkiye, with at least one respondent from 59 of the 81 cities in Türkiye. The largest number of participants were from İstanbul (n=45), followed by Ankara (n=30), İzmir (n=22), and Bursa (n=11). Most participants worked in tertiary care centers (62.5%), with others from secondary and primary care centers, 33.5% and 1.3%, respectively.

Physical Conditions and PFT Practices Before the Pandemic

Details of the participants' PFT practices are presented in Table 1. Adequate room ventilation by having a window enabling room direct air exchange was reported in 77.4% of the PFT labs, while 22.6% lacked windows. Most PFT labs were relatively small, with 40.3% having a surface area larger than 10 m^2, ~35% measuring between 5-10 m^2, and approximately 15% less than 5 m^2. Of those centers, 153 (63.0) had a separate waiting room.

PFTs were most commonly performed by a trained technician in 50.6%, or trained nurses in 44.9%, and by the physician in 4.5% of the enrolled participants' workplaces. Most labs reported one (41.1%) or two (36.2%) staff members, while 22.6% had three or more. The number of PFTs performed daily varied, with 44.2% performing more than 40 tests daily, 26.7% performing 20-40 tests daily, and 30% performing less than 20 daily tests. Spirometry (100%) and bronchodilator responsiveness testing (92.6%) were the most commonly performed procedures in PFT labs, followed by carbon monoxide diffusion testing (47.3%), the 6-minute walking test (43.6%), and body plethysmography or other advanced lung volume measurements (32.1%). Other procedures included bronchoprovocation testing (36.2%) and cardiopulmonary exercise testing (8.5%).

PFT Practices During the First Peak of the Pandemic

During the first peak of the COVID-19 pandemic, 66 (27.2%) of the PFT labs in the participants' healthcare facilities continued testing, primarily in tertiary-care centers (55.4%), followed by secondary (40%) and primary-care centers (4.6%). Specific practices during this period are presented in Table 2.

The number of PFT tests performed daily was reduced, with most labs performing fewer than eight daily tests. Spirometry remained the most frequently performed procedure, while advanced tests, such as plethysmography and bronchoprovocation, were rarely conducted (Table 2). The types of PFT procedures stratified by the grade of the medical service in those PFT labs during the first phase of the pandemic period are summarized in Figure 1.

The use and type of PPE by the staff performing the procedures are presented in Table 3. Appropriate PPE was worn by 45.4% of the staff, with variations across healthcare levels [primary: 66.7%, secondary: 42.3%, and tertiary: 66.7%; (P = 0.151, data

not shown)]. During the first peak, 67.7% used eye protection by goggles or face shields. 75.3% of the technicians used FFP3 or FFP2 masks, whereas 12.2% used FFP3 or FFP2 masks with gown and gloves (Table 3).

Forty-seven (71.2%) respondents reported a reduction in the total number of staff working in the PFT laboratories. Routine COVID-19 triage, before entering the PFT unit, was implemented in 83.3% of the labs, but cleaning and disinfection practices varied. Only 48.5% of respondents reported having clear information about cleaning methods (Table 2). A total of 17 (25.8%) of the included centers used ultraviolet (UV) lamps in the PFT laboratories (primary, secondary, and tertiary levels,(n = 17, 26.2%); (n = 0, 0%); (n = 4, 15.4%). We observed that tertiary healthcare settings used UV lamps more than secondary healthcare facilities (76.5% vs. 23.5%, p<0.0001). 81.8% of the respondents reported flexibility in scheduling work hours, whereas 66.7% reduced the staff available in their PFT units.

Five labs (7.6%) performed PFTs on COVID-19 patients. The reported indications were the evaluation of dyspnea in the post-COVID phase in three patients, pulmonary fibrosis in one patient, and evaluation of disability in one patient in the post-COVID phase. Of those centers that continued performing PFTs in the pandemic phase, one PFT staff was diagnosed with COVID-19 during the first phase of the pandemic among the total respondents.

Survey Participants' Organizational Plans for Pulmonary Function Tests in the Post-peak Phase

All respondents (100%) planned to resume PFT in the post-peak phase using PPE. Table 3 presents participants' PPE preferences for the post-peak phase, showing a similar distribution with the first peak period. A total of 160 respondents (65.8%) were planning to apply triage screening, and 72 respondents (29.6%) were planning to use UV lamps in their PFT units in the post-peak phase (data not shown).

Main Points

- The pandemic created challenges for pulmonary function tests (PFTs) due to their potential for aerosol generation and increased transmission risks. This study aimed to evaluate the pre-pandemic and pandemic-era PFT practices among pulmonologists in Türkiye, focusing on adherence to safety recommendations and identifying gaps for guideline improvement.
- Two hundred and forty-three responses were analyzed from 59 different cities in Türkiye, with participants predominantly pulmonologists (93%) and most working in tertiary care centers (62.5%).
- PFT labs had varied ventilation, staffing, and space configurations, with only 40.3% meeting recommended size standards and 22.6% lacking adequate ventilation.
- During the pandemic's first peak, only 27.2% of PFT labs continued operations, primarily in tertiary care centers. Spirometry remained the most performed test, while significant reductions were noted in complex procedures like plethysmography and bronchoprovocation testing.
- Infection control measures varied, with only 45.4% of staff using full PPE consistently and 83.3% implementing routine Coronavirus disease-2019 triage.

DISCUSSION

This study provides a detailed analysis of PFT lab practices in Türkiye before and during the COVID-19 pandemic. To the best of our knowledge, this study is the first nationwide assessment; it captures the infrastructure, operational procedures, staff characteristics, and pandemic adaptations of PFT labs across a diverse range of healthcare facilities and geographic regions in Türkiye. The results reveal critical insights into the status of

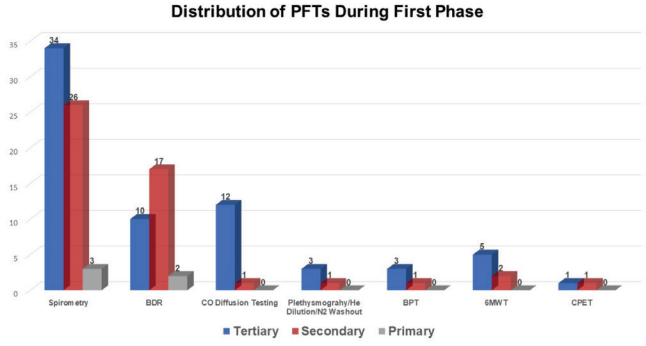

Figure 1. Distribution of pulmonary function tests during the first peak of the pandemic stratified by healthcare center levels

PFTs: pulmonary function tests

Table 1. Pulmonary function test practices of the pulmonary functions test labs before the pandemic period in Türkiye

	n (%)
Number of technicians/nurses working in the PFT lab	
1	100 (41.1)
2	88 (36.2)
≥3	55 (22.6)
Number of PFT tests performed per day	
<10	26 (10.7)
10-20	47 (19.3)
20-40	65 (26.7)
>40	105 (44.2)
Performed procedures in the PFT lab	
Spirometry	
Bronchodilator response testing	243 (100)
Carbon monoxide diffusion testing	225 (92.6)
Body plethysmography/helium dilution/nitrogen washout tests	115 (47.3)
Bronchoprovocation test	78 (32.1)
6-minute walking test	88 (36.2)
Cardiopulmonary exercise testing	106 (43.6)
The total surface area of the PFT lab	45 (8.5)
<5 m^2	36 (14.8)
5-10 m^2	109 (34.9)
>10 m^2	98 (40.3)
A separate waiting room is available for the PFT lab	153 (63.0)

PFT: pulmonary function tests

PFT labs and highlight areas requiring improvement to enhance safety and efficiency during overwhelming conditions such as the pandemic.

In our study, before the pandemic, PFTs were primarily conducted by trained technicians (50.6%) or nurses (44.9%), with test volumes often exceeding 40 tests daily. Spirometry and bronchodilator response testing were the most commonly performed procedures, reflecting their central role in pulmonary diagnostics globally.[7-10] The COVID-19 pandemic has significantly impacted PFT services worldwide, necessitating adaptations to minimize infection risk while maintaining essential diagnostic services.[11,12]

Table 2. Pulmonary function test practices of the pulmonary functions test labs during the first peak of the pandemic phase

	n (%)
Number of PFT tests performed per day	
<2	14 (21.2)
2-4	19 (28.8)
4-8	19 (28.8)
8-16	11 (16.7)
>16	3 (4.5)
Performed procedures in the PFT lab	
Spirometry	
Bronchodilator reversibility testing	66 (100.0)
Carbon monoxide diffusion testing	41 (62.1)
Body plethysmography/helium dilution/nitrogen washout tests	11 (16.7)
Bronchoprovocation test	3 (4.5)
6-minute walking test	4 (6.0)
Cardiopulmonary exercise testing	8 (12.1)
Triage performed	2 (3.0)
Cleaning/disinfection method	55 (83.3)
No information about the method used	
Ethanol >70%	32 (48.5)
Sodium hypochlorite at 0.1-0.5% in 1:10 dilution	13 (19.7)
Sodium hypochlorite at 0.1-0.5% in 1:100 dilution	11 (16.7)
	10 (15.2)

PFT: pulmonary function tests

During the pandemic's first peak, only 27.2% of the PFT labs in participants' healthcare facilities continued testing, with most operational labs located in tertiary-care centers (55.4%), followed by secondary-care facilities and a limited number of primary-care centers (4.6%). Test volumes decreased markedly, with most labs performing fewer than eight daily tests. Our findings demonstrate a marked reduction in the number of PFT tests performed daily, with most laboratories conducting fewer than eight tests daily. This decline aligns with global recommendations to limit non-urgent testing during the pandemic to reduce patient exposure and conserve healthcare resources.[5,13-16] Despite its potential for aerosol generation, spirometry remained the most frequently performed procedure (100.0%), with bronchodilator reversibility and diffusion testing conducted in 62% and 17% of cases during the post-peak phase. These findings underscore the critical role of spirometry in diagnosing and monitoring chronic respiratory conditions like asthma and chronic obstructive pulmonary disease (COPD), even during the restrictive conditions imposed by the COVID-19 pandemic. The continued prioritization of spirometry highlights its ability to provide critical diagnostic information quickly, with fewer resources and minimal patient contact compared to more complex procedures.

In contrast, more complex and time-intensive procedures, such as plethysmography (4.5%) and bronchoprovocation testing (4.0%), were rarely conducted during the first peak period. These advanced tests are not only resource-intensive but also carry a higher risk of aerosol generation, particularly in the case of bronchoprovocation, where patients are required to inhale substances that may provoke coughing. Of those 66 centers continuing testing, 12% continued six-minute walking testing. Cardiopulmonary exercise testing (3.0%), which requires prolonged patient interaction and may generate aerosols, was performed infrequently, further emphasizing the focus on safety during this period. The limited use of these procedures likely reflects adherence to international guidelines, emphasizing

Table 3. Personal protective equipment was used in the first peak of the pandemic period (n = 66) and planned to be used in the post-peak phase (n = 242)

	First peak of the pandemic period n (%)	Post-peak phase n (%)
Type of PPE used during PFT		
FFP2/FFP3 + face-shield + gown + gloves	30 (45.4)	110 (45.4)
FFP2/FFP3 + face-shield + gloves	1 (1.5)	10 (4.1)
FFP2/FFP3 + gown + gloves	8 (12.2)	19 (7.9)
FFP2/FFP3 + gloves	4 (6.2)	5 (2.1)
Surgical mask + face-shield + gown + gloves	4 (6.2)	12 (5.0)
Surgical mask + face-shield + gloves	11 (16.2)	36 (14.8)
Surgical mask + gown + gloves	3 (4.6)	19 (7.9)
Surgical mask and gloves	5 (7.7)	4 (1.7)
Hesitant	-	27 (11.1)
Total	66	242

PFT: pulmonary function tests, PPE: personal protective equipment

minimizing non-essential diagnostic procedures to reduce exposure risks for patients and healthcare providers.[5,13,16]

By December 2023, the COVID-19 pandemic had resulted in over 17.1 million confirmed cases and more than 100.000 deaths in Türkiye.[17] Globally, the pandemic prompted strict public health measures, including suspending non-urgent medical services, such as routine diagnostic testing and outpatient consultations.[18] These measures, supported by global and local respiratory societies, led to the closure or significant reduction of PFT laboratory operations.[13,19-21] PFTs, including spirometry and diffusion capacity measurements, were considered high-risk procedures due to their aerosol-generating potential and associated risks of SARS-CoV-2 transmission.[5,10,13,15,19,21]

Modeling studies anticipated the need for sustained restrictions on PFTs for the long term, up to 18-24 months, to prevent resurgences in infection rates.[16,22] To adapt, PFT labs implemented stringent protocols, including mandatory PPE use, pre-visit screening, enhanced disinfection measures, and innovative technologies like personal spirometers.[16,22,23] Despite these adaptations, significantly reduced testing capacities posed challenges for managing chronic respiratory diseases, which rely on objective lung function assessments for diagnosis, monitoring, therapeutic evaluation, and prognosis.[24] The inability to perform routine PFTs risked delays in diagnosis and suboptimal management of conditions such as asthma, COPD, and interstitial lung diseases, potentially leading to long-term health consequences. Maintaining access to PFT services remained critical as healthcare systems navigated these disruptions. PFT provides essential insights into disease severity and progression, making its restoration vital for optimal patient outcomes and preserving high-quality care in chronic respiratory disease management.

Using the data collected from this survey, it is evident that most PFT laboratories in Türkiye are relatively small, with only 40.3% having a surface area greater than 10 m^2, while approximately 15% are less than 5 m^2. This limited space presents a significant challenge in adhering to physical distancing recommendations, a critical component of infection control during the COVID-19 pandemic. The World Health Organization advised maintaining a minimum physical distance of 3 feet [~1 meter (m)] between individuals, while the Centers for Disease Control and Prevention (CDC) in the USA recommended a more conservative distance of 6 feet (~2 meters), reflecting differences in national guidelines.[5,25] Recent studies have further suggested that activities such as coughing or shouting, common during respiratory testing, can propel aerosols beyond 2 meters, emphasizing that distancing rules should account for factors such as ventilation, occupancy, and exposure time.[26-28] In this context, the small size of many PFT labs, particularly those less than 5 m^2, is inadequate to maintain even the minimum recommended distance between patients and healthcare personnel. The proximity required for test supervision, combined with the physical constraints of these smaller labs, significantly heightens the risk of airborne transmission in the absence of additional protective measures. The effect of a larger PFT lab size and more frequent air changes to reduce airborne particulate concentrations by dilution and faster clearance during and after PFT was shown by Li et al.[2] The Pulmonary Service Design Guide suggests that standard rooms designated for PFT ideally have dimensions of at least 12.0 feet (~3.65 m) x 10.0 feet (~3.05 m), corresponding to a surface area of 11-12 m^2.[29] For an extended PFT lab (e.g., for stress testing), the recommended minimum dimensions are 12.6 feet (~3.81 m) and 19.6 feet (~5.94 m), corresponding to a surface area of 24-25 m^2.[29] These dimensions ensure sufficient space to accommodate PFT equipment, a workstation for the PFT technician, a chair, sink, equipment storage, trash, sharps container and other necessary items.[29]

Inadequate room size also exacerbates challenges related to ventilation, as smaller spaces often have poorer airflow dynamics and are more prone to aerosol accumulation. Direct air exchange, such as opening windows or doors, while helpful, is insufficient for ensuring adequate ventilation in such confined areas. Computational fluid dynamics models have demonstrated that in small rooms, factors such as airflow turbulence, air conditioner inlet velocity, and droplet dispersion patterns can lead to hotspots of aerosol concentration, further increasing infection risks.[27,28] In a recent analysis, we have shown that infectious particle dispersion in a hospital examination room is predicted by various factors: airflow turbulence, air conditioner inlet velocity, droplet size, evaporation, surface adherence, and room design, highlighting the need for computational fluid dynamics model-based layout planning and ventilation optimization to reduce infection risks.[27] Consequently, PFT labs with a surface area less than 5 m^2 may fail to provide a safe environment for both patients and staff, highlighting the need for stricter design and ventilation standards for these facilities.

Given these findings, ensuring adequate space and proper airflow is essential for maintaining infection control in PFT labs. Larger rooms combined with optimized ventilation systems such as HEPA filtration or UV germicidal irradiation, are more likely to meet the distancing and air quality requirements necessary to minimize infection risks during respiratory testing.[5] However, our study revealed that 22.6% of PFT labs lacked windows, which are critical for enabling direct air exchange and supporting natural ventilation. The absence of such basic ventilation measures highlights the need for more stringent design and operational guidelines to address ventilation inadequacies, especially in smaller, enclosed spaces.

Proper ventilation plays a pivotal role in mitigating aerosol transmission, particularly in settings where aerosol-generating procedures, such as spirometry, are performed. The CDC provides examples of air exchange rates, appropriate droplet pause periods, and the time required for airborne contaminant removal to ensure a safe testing environment. Ventilation rates are measured in terms of air changes per hour (ACH), which indicates the airflow rate relative to room size. A ventilation rate of six air changes per hour (6 ACH) implies that the room's air volume is replaced six times per hour by the ventilation system. However, this does not mean the entire air volume is replaced each time; instead, the new air mixes with the existing air, causing dilution over time. At a rate of 6 ACH, approximately 95% of airborne contaminants are removed within 30 minutes, demonstrating the critical importance of maintaining adequate

ventilation rates to reduce infection risks in PFT labs.[5,13,30] We believe oncoming international standards for a PFT lab should explicitly address these spatial and ventilation requirements, emphasizing the integration of advanced air filtration technologies, adherence to recommended air exchange rates, and the provision of larger testing spaces. This is particularly crucial for facilities in resource-limited settings, where space and infrastructure constraints often hinder compliance with optimal infection control practices. By addressing these factors, PFT labs can enhance the safety of both patients and staff while maintaining the essential diagnostic capabilities necessary for respiratory care.

During the COVID-19 pandemic, for protecting pulmonary function laboratory staff essential precautions included comprehensive training on PPE usage and strict adherence to infection control protocols.[5,13,19,21] Full PPE—comprising a long-sleeved disposable fluid-repellent gown, N95/FFP2/FFP3 respirator mask, goggles/full-face shield, and disposable gloves—was mandatory for staff conducting tests due to the high aerosol generation during PFTs.[5,13] It was recommended to establish dedicated clean and contaminated areas for donning and doffing PPE, with proper hand hygiene maintained throughout. Separate PPE was recommended for each patient, and guidelines for reusing masks emphasized safe storage and limited reuse under specific conditions.[13,31] Our survey results showed that infection control practices during the COVID-19 pandemic showed significant inconsistencies. Only 45.4% of staff consistently used appropriate PPE, which included items as FFP2/FFP3 masks, gowns, gloves, and face shields, as recommended by international and national guidelines.[5,13] These discrepancies highlight significant barriers to implementing standard infection control measures in high-risk, aerosol-generating environments such as PFT laboratories. The observed variations across healthcare levels, with higher adherence rates in primary and tertiary care settings compared to secondary care ($P = 0.151$), further emphasize systemic challenges in resource distribution and training.

Moreover, cleaning and disinfection practices were varied, with nearly half of the respondents (48%) reporting no information about cleaning protocols (Table 2). UV disinfection through germicidal irradiation, a practice supported by evidence for rapidly reducing viral load in clinical settings, was utilized in only 25.8% of centers. Tertiary healthcare settings were more likely to utilize UV lamps compared to secondary care facilities (76.5% vs. 23.5%, $P < 0.0001$, data not shown). This disparity may reflect resource availability, infrastructure differences, or prioritization of advanced technologies in higher-tier facilities.

Interestingly, the survey revealed flexibility in staff scheduling (81.8%) and a reduction in staff availability in 66.7% of PFT units. These adaptations, while addressing workforce limitations during the pandemic, likely added to the challenges of ensuring consistent infection control. Notably, during the first pandemic peak, only five laboratories (7.6%) performed PFTs on COVID-19-positive patients, with indications including the evaluation of dyspnea, pulmonary fibrosis, and post-COVID-19 disability. Among these, one staff member contracted COVID-19, underscoring the critical need for rigorous protective measures.

Comparing PPE usage between the pandemic peak and post-peak phases, a shift was observed. During the first peak, 45.4% of staff used the full recommended PPE set (FFP2/FFP3 mask, face shield, gown, and gloves), with hesitant adherence reported in other configurations (Table 2). In the post-peak phase, the same proportion (45.4%) adhered to full PPE use, with an increase in the use of other configurations and some hesitation in adopting recommended practices (Table 3). This consistency raises concerns about sustainability and uniformity in infection control measures over time.

The findings reinforce the importance of comprehensive training, adequate supply chains, and clear, evidence-based protocols to mitigate risks to healthcare workers in PFT laboratories. Establishing dedicated donning and doffing areas, adhering to rigorous hand hygiene practices, and maintaining consistent disinfection protocols are vital components. Enhanced efforts to bridge gaps in infection control practices across healthcare levels are imperative to safeguard both healthcare workers and patients in these high-risk settings.

In our study, we observed that screening and triage processes were implemented in 83.3% of the PFT labs during the first phase of the pandemic, a practice strongly recommended by several guidelines, to reduce the risk of COVID-19 transmission.[5,7,13,14,21,32] However, our findings reveal inconsistencies in the application of specific measures, such as body temperature checks or tele-screening, which were variably recommended by guidelines. Notably, most guidelines, emphasized the importance of pre-test COVID-19 screening, such as a documented negative swab test 48-72 hours before testing, particularly for suspected cases.[5,7,13,21,33] This variation in implementation reflects the challenges faced by PFT labs in adhering to evolving guidelines during a rapidly changing public health crisis.

In conclusion, our study underscores the profound impact of the COVID-19 pandemic on PFT services, with substantial reductions in testing volume, procedural prioritization, and widespread adoption of screening protocols. These adaptations align with international recommendations to balance patient safety with the need to maintain essential diagnostic capabilities. Future efforts should focus on standardizing triage and safety protocols across PFT labs to enhance resilience and preparedness for similar public health emergencies.

The findings align with recommendations from the Turkish Thoracic Society and international guidelines, emphasizing the need for strict triage, limited testing, and robust infection control measures during the pandemic.[5,7,13,20,21] For example, routine PFTs were discouraged, and essential procedures such as spirometry and diffusion capacity tests were prioritized. Similarly, full PPE and thorough disinfection protocols were highlighted as critical to minimizing transmission risks.[5,7,13] Notably, pulmonologists demonstrated rapid and moderate-to-good success in implementing adaptations for COVID-19. However, significant gaps in infrastructure, infection control protocols, and staff training persist, indicating a need for continued investment and standardization. However, this

study reveals discrepancies in implementing these measures, particularly in secondary and primary care centers, where resource constraints may be more pronounced.

Despite its strengths, this study has several limitations. The primary and secondary care centers were underrepresented, which may limit the generalizability of findings. It is possible that doctors with a strong interest in PFTs were more likely to volunteer for the study, while those who believe there is limited adherence to standards may have chosen not to participate, potentially introducing bias into the results. Additionally, self-reported data are inherently subject to bias, and the cross-sectional design prevents an evaluation of changes over time. The waiting period between PFT procedures were not assessed, even though it is important to allow at least 20-minute interval between tests to enable airborne particle clearance was shown.[2] Furthermore, specific patient outcomes related to these practices were not evaluated, which could provide additional insights into the effectiveness of implemented measures. Age data of the respondents were not collected, which is a limitation of our study. Age-related differences could potentially influence compliance with safety recommendations. Moreover, this study did not assess infection control standards in PFT laboratories before the pandemic, limiting the ability to compare pre-pandemic and pandemic-era protective measures.

The study underscores the urgent need for standardized guidelines and training programs to ensure consistent infection control practices across all healthcare settings. Investments in infrastructure, such as better ventilation systems and larger lab spaces, are essential for safer PFT practices. Future research should explore longitudinal changes in PFT practices and evaluate patient outcomes to guide policy and practice improvements.

CONCLUSION

In conclusion, this study provides valuable insights into the status and challenges of PFT labs in Türkiye before and during the COVID-19 pandemic. While pulmonologists and healthcare staff have made commendable efforts to adapt to the crisis, continued efforts are needed to address existing gaps and build resilience against future public health emergencies.

Ethics

Ethics Committee Approval: This cross-sectional survey was conducted following approval from the Clinical Research Ethics Board of Başkent University Faculty of Medicine (approval number: KA20/201, date: 01.06.2020).

Informed Consent: Data collection adhered to ethical principles and the Declaration of Helsinki, with voluntary participation and informed consent obtained before survey initiation.

Footnotes

Authorship Contributions

Surgical and Medical Practices: A.G.D., Ş.B., Ö.A.Y., B.G., C.S., G.U., Concept: A.G.D., Ş.B., Ö.A.Y., B.G., C.S., S.B.S., G.U., Design: A.G.D., Ş.B., Ö.A.Y., B.G., C.S., S.B.S., G.U., Data Collection or Processing: A.G.D., Ş.B., Ö.A.Y., B.G., C.S., S.B.S., G.U., Analysis or Interpretation: A.G.D., Ş.B., Ö.A.Y., B.G., G.U., Literature Search: A.G.D., Ş.B., Ö.A.Y., B.G., C.S., S.B.S., G.U., Writing: A.G.D., Ş.B., G.U.

Conflict of Interest: The author of this article, Aslı Görek Dilektaşlı, is a member of the Editorial Board of the Thoracic Research and Practice. However, she did not involved in any stage of the editorial decision of the manuscript. The other authors declared no conflict of interest.

Financial Disclosure: The authors declared that this study received no financial support.

REFERENCES

1. van der Valk JPM, In 't Veen JCCM. SARS-CoV-2: The Relevance and prevention of aerosol transmission. *J Occup Environ Med*. 2021;63(6):e395-e401. **[Crossref]**
2. Li J, Jing G, Fink JB, et al. Airborne particulate concentrations during and after pulmonary function testing. *Chest*. 2021;159(4):1570-1574. **[Crossref]**
3. Borg BM, Osadnik C, Adam K, et al. Pulmonary function testing during SARS-CoV-2: An ANZSRS/TSANZ position statement. *Respirology*. 2022;27(9):688-719. **[Crossref]**
4. Santos JLF, Zanardi P, Alo V, et al. Pulmonary edema in COVID-19 treated with furosemide and negative fluid balance (NEGBAL): a different and promising approach. *J Clin Med*. 2021;10(23):5599. **[Crossref]**
5. McGowan A, Laveneziana P, Bayat S, et al. International consensus on lung function testing during the COVID-19 pandemic and beyond. *ERJ Open Res*. 2022;8(1):00602-2021. **[Crossref]**
6. Palacios S, Krivchenia K, Eisner M, et al. Long-term pulmonary sequelae in adolescents post-SARS-CoV-2 infection. *Pediatr Pulmonol*. 2022;57(10):2455-2463. **[Crossref]**
7. ARTP. ARTP working groups on standards of care and recommendations for lung function departments (2007): lung function service provision. **[Crossref]**
8. Sylvester KP, Clayton N, Cliff I, et al. ARTP statement on pulmonary function testing 2020. *BMJ Open Respir Res*. 2020;7(1):e000575. **[Crossref]**
9. Graham BL, Steenbruggen I, Miller MR, et al. Standardization of spirometry 2019 update. An official American Thoracic Society and European Respiratory Society technical statement. *Am J Respir Crit Care Med*. 2019;200(8):e70-e88. **[Crossref]**
10. Ulubay G, Köktürk N, Görek Dilektaşlı A, et al. Türk Toraks Derneği ulusal spirometri ve laboratuvar standartları [Turkish Thoracic Society national spirometry and laboratory standards]. *Tuberk Toraks*. 2017;65(2):117-130. **[Crossref]**
11. Drummond M. Sleep labs, lung function tests and COVID-19 pandemic - Only emergencies allowed! Pulmonology. 2020;26(4):244-245. **[Crossref]**
12. Hull JH, Lloyd JK, Cooper BG. Lung function testing in the COVID-19 endemic. *Lancet Respir Med*. 2020;8(7):666-667. **[Crossref]**
13. Gemicioğlu B, Börekçi Ş, Dilektaşlı AG, Ulubay G, Azap Ö, Saryal S. Turkish Thoracic Society experts consensus report: recommendations for pulmonary function tests during and after COVID-19 pandemic. *Turk Thorac J*. 2020;21(3):193-200. **[Crossref]**
14. ATS American Thoracic Society. Pulmonary function laboratories: advice regarding COVID-19. 2020. **[Crossref]**

15. Ramos JA. Pulmonary function testing precautions in a time of COVID-19. *Cleve Clin J Med*. 2020 May 5. doi: 10.3949/ccjm.87a.ccc006. [Epub ahead of print]. **[Crossref]**
16. Stanojevic S, Beaucage F, Comondore V, et al. Resumption of pulmonary function testing during the COVID-19 pandemic: a position statement from the Canadian Thoracic Society and the Canadian Society of Respiratory Therapists. *Can J Respir Crit Care Sleep Med*. 2022:6(2):78-81. **[Crossref]**
17. WHO. The current COVID-19 situation (Türkiye). Cited: 2024 December 25. **[Crossref]**
18. WHO. WHO Coronavirus (COVID-19) dashboard. Cited: 2025 16 Jan. **[Crossref]**
19. Franczuk M, Przybyłowski T, Czajkowska-Malinowska M, et al. Spirometry during the SARS-CoV-2 pandemic. Guidelines and practical advice from the expert panel of Respiratory Physiopathology Assembly of Polish Respiratory Society. *Adv Respir Med*. 2020;88(6):640-650. **[Crossref]**
20. Milanese M, Corsico AG, Bellofiore S, et al. Suggestions for lung function testing in the context of COVID-19. *Respir Med*. 2021;177:106292. **[Crossref]**
21. Crimi C, Impellizzeri P, Campisi R, Nolasco S, Spanevello A, Crimi N. Practical considerations for spirometry during the COVID-19 outbreak: Literature review and insights. *Pulmonology*. 2021;27(5):438-447. **[Crossref]**
22. Kouri A, Gupta S, Yadollahi A, et al. Addressing reduced laboratory-based pulmonary function testing during a pandemic. *Chest*. 2020;158(6):2502-2510. **[Crossref]**
23. Dilektaşlı AG, Guclu OA, Ozturk N, Coskun F, Karadag M. Home spirometry is a valid and effective tool for tracking recovery in pulmonary function tests of COVID-19 pneumonia survivors. *Eur Respir J*. 2024;64(Suppl 68):PA5270. **[Crossref]**
24. GBD Chronic Respiratory Disease Collaborators. Prevalence and attributable health burden of chronic respiratory diseases, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet Respir Med*. 2020;8(6):585-596. **[Crossref]**
25. Jones NR, Qureshi ZU, Temple RJ, Larwood JPJ, Greenhalgh T, Bourouiba L. Two metres or one: what is the evidence for physical distancing in covid-19? *BMJ*. 2020;370:m3223. **[Crossref]**
26. Somsen GA, van Rijn C, Kooij S, Bem RA, Bonn D. Small droplet aerosols in poorly ventilated spaces and SARS-CoV-2 transmission. *Lancet Respir Med*. 2020;8(7):658-659. **[Crossref]**
27. Yüce BE, Kalay OC, Karpat F, et al. Investigation of infectious droplet dispersion in a hospital examination room cooled by split-type air conditioner. *J Environ Health Sci Eng*. 2024;22(2):471-482. **[Crossref]**
28. Tsang TW, Mui KW, Wong LT. Computational fluid dynamics (Cfd) studies on airborne transmission in hospitals: a review on the research approaches and the challenges. *Journal of Building Engineering*. 2023;63:105533. **[Crossref]**
29. VA. Pulmonary medicine service design guide, department of veterans affairs. 2011. **[Crossref]**
30. WHO. Infection prevention and control during health care when Coronavirus disease (COVID-19) is suspected or confirmed: interim guidance. 2021. **[Crossref]**
31. Ağalar C, Engin DÖ. Protective measures for COVID-19 for healthcare providers and laboratory personnel. *Turkish J Med Sci*. 2020;50(9):578-584. **[Crossref]**
32. Gochicoa-Rangel L, Torre-Bouscoulet L, Salles Rojas A, et al. Functional respiratory evaluation in the COVID-19 era: the role of pulmonary function test laboratories. *Rev Invest Clin*. 2020;73(4). **[Crossref]**
33. Khan S, Tsang KK, Mertz D, et al. A regional Canadian expert consensus on recommendations for restoring exercise and pulmonary function testing in low and moderate-to-high community prevalence coronavirus disease 2019 (COVID-19) settings. *Infect Control Hosp Epidemiol*. 2021;42(12):1535-1537. **[Crossref]**