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Insights for a Next Pandemic: An Assessment of Laboratory COVID-19 Safety

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Abstract: In January 2020, the WHO declared COVID-19 a global pandemic, underscoring the importance of safeguarding measures and mental health support for medical professionals due to its serious impact and widespread reach. This study aimed to assess knowledge gaps in safety guidelines and the use of personal protective equipment (PPE) among staff in medical laboratories, specifically all accredited laboratories actively engaged in COVID-19 testing in Jordan. Data were collected via a blinded, non-stratified electronic questionnaire, with one response submitted from each laboratory through a Google Form. The survey targeted laboratory personnel affiliated with the 40 accredited laboratories handling COVID-19 testing. A validated questionnaire consisting of 25 questions was used to evaluate the knowledge of these laboratories. The findings indicate that workers in certain laboratories exhibited deficiencies in their understanding of safety regulations, quality control, and the proper use of PPE when handling COVID-19 samples. Additionally, the study highlights the increasing impact of the COVID-19 pandemic on individuals' mental health. The demanding laboratory work necessitated by the pandemic can have negative psychological effects on staff. These effects underscore the importance of implementing supportive mental health policies and resources to mitigate psychological impact and enhance the overall well-being of laboratory personnel. Addressing these knowledge gaps, improving safety protocols, and providing adequate mental health support are crucial steps in ensuring the safety and well-being of laboratory staff and enhancing the overall management of future pandemics.

Keywords: Jordan; pandemics; COVID-19 testing; mental health; health policy; laboratory personnel; personal protective equipment; surveys and questionnaires

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Academic Editor: Raphael Grzebieta

Received: 29 April 2024
Revised: 11 December 2024
Accepted: 7 January 2025
Published: 5 February 2025

Citation: Al-Zyoud, W.; Abu Ismail, H.; Althawbih, H.; Odeh, B.; Saket, M.; Al-Kazwini, A.; Al-Hammouri, F.; Dajani, R. Insights for a Next Pandemic: An Assessment of Laboratory COVID-19 Safety. *Safety* **2025**, *11*, 13. https://doi.org/10.3390/safety11010013

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1. Introduction

By the end of January 2020, the WHO had declared 2019-nCoV a global pandemic [1]. COVID-19 is an infectious disease caused by the "severe acute respiratory syndrome coronavirus 2" (SARS-CoV-2) [2,3]. Most instances of COVID-19 are mild to moderate and do not require hospitalization. However, the disease can have serious long-term effects, including pulmonary, cardiovascular, renal, neuropsychiatric, gastrointestinal, and even dermatological complications, which can lead to death, particularly among patients

with chronic diseases and older adults [4,5]. SARS-CoV-2 spreads through respiratory droplets or aerosols and can remain airborne for up to 3 h. On cardboard, the virus can survive for 24 h, while on plastic or stainless steel, it can last up to 3 days [6]. The diagnosis of COVID-19 primarily relies on two laboratory tests. Real-time polymerase chain reaction (RT-PCR) detects targeted RNA, while antibody testing is used to identify SARS-CoV-2 antibodies [7]. Additionally, next-generation sequencing has played a vital role in detecting new variants of SARS-CoV-2, such as alpha, beta, delta, and omicron, including the recently identified BA.2.68 and JN.1 variants [8–12]. Laboratory technicians and healthcare professionals must be knowledgeable about and adhere to safety guidelines during a pandemic. Throughout the pandemic, several cases of infection were reported among healthcare workers, some of which were fatal. The World Health Organization issued a guidebook to protect workers handling suspected COVID-19 cases [13]. One of the safety precautions implemented to prevent the spread of COVID-19 was quarantine. However, quarantine takes a toll on people's psychological well-being, especially within the healthcare industry. The overburdened healthcare system in developing countries has led to concerns, stress, increased heart rates, shortness of breath, headaches, and irritation among health workers due to a lack of sterilization and decontamination supplies (e.g., aerosolized hydrogen peroxide) and personal protective equipment, such as filtering facepiece (FFP1, 2, and 3) respiratory masks, with higher numbers indicating higher particle filtering efficiency [14–16].

According to the Occupational Safety and Health Administration (OSHA), workers at risk of coronavirus exposure are categorized into three levels: very high, medium, and low exposure risk. Very high-risk jobs for COVID-19 in any healthcare sector include doctors, dentists, nurses, paramedics, emergency medical technicians, morgue workers performing autopsies, and laboratory personnel who need a designated biosafety level (BSL) to handle infectious specimens and the biological transmission of the viral vector [17]. Biosafety levels are established in laboratories to determine the protective measures required to safeguard personnel, the environment, and the public. These levels are outlined by Biosafety in Biomedical Laboratories (BMBL). The BMBL's biosafety level designations specify practices, safety criteria, and facility criteria based on biological risk evaluations for each experimental technique. There are four biosafety levels: BSL-1 refers to the study of agents or toxins that rarely cause disease in healthy humans. BSL-2 laboratories examine infectious agents or toxins that can be inhaled, ingested, or absorbed. BSL-3 laboratories study airborne pathogens that can cause fatal infections. BSL-4 laboratories research dangerous diseases for which there is no vaccination or treatment [18]. SARS-CoV-2 cultures should be characterized in a BSL-3 laboratory using BSL-3 procedures [19]. The COVID-19 pandemic has revealed significant issues regarding safety measures and the mental well-being of laboratory workers in Jordan. Despite the existence of guidelines on safety and personal protective equipment, there remains a gap between what is known and how this knowledge is applied among laboratory personnel in accredited laboratories. Additionally, it has become evident that the outbreak has caused psychological trauma to lab technicians, who require more mental support to recover from such experiences. Ensuring a safe environment for laboratory staff, as well as enhancing their ability to respond quickly to pandemics, depends on addressing these issues. This research aims to highlight vital insights and recommendations to improve the safety, well-being, and preparedness of laboratory staff facing the challenges posed by COVID-19 and future infectious disease outbreaks. The study addresses several complications: knowledge gaps in safety guidelines and PPE usage, the impact on laboratory safety, mental health effects, the need for improved safety protocols and training, and overall preparedness for future pandemics. A summary of the variables used in the study is provided in Table 1.

Table 1. A summary of the variables used in the study.

Category	Variable	Description	Justification
Safety Practices	Knowledge of Safety Guidelines	Understanding of COVID-19 safety protocols by lab staff	WHO COVID-19 safety guidelines [20]
	Use of PPE	Proper use of personal protective equipment	OSHA standards [21]
Laboratory Standards	Biosafety Level (BSL)	Biosafety level classification of labs (BSL-2, BSL-3)	WHO biosafety recommendations [20]
	COVID-19 Testing Capabilities	Types of COVID-19 tests conducted (PCR, antibody tests)	Clinical Chemistry Laboratory standards [22]
Mental Health	Mental Health Impact	Psychological effects of pandemic on lab personnel	Studies on mental health impact of COVID-19 [23]
Demographics	Educational Level	Highest degree obtained by lab personnel	Educational requirements in medical laboratories [24]
	Years of Experience	Professional experience duration of lab personnel	Studies on experience and safety compliance [25]
Laboratory Procedures	Laboratory Procedures	Protocols for handling and processing COVID-19 samples	WHO laboratory procedures for COVID-19 [20]
Quality Control	Quality Control Accreditation	Accreditation status of laboratory quality control tests	Laboratory accreditation standards [26]
Geographical	Geographical Location	Distribution of labs in different Jordanian cities	Demographic studies on healthcare facilities in Jordan [27]

The outlook of this paper is structured into five main sections. Following the introduction, Section 2 outlines the study design, ethical considerations, and the survey tool used to evaluate laboratory safety practices during the COVID-19 pandemic. Section 3 presents the results, including the Ridge regression analysis, and highlights the key factors affecting laboratory safety and efficiency. Section 4 discusses these findings, compares them to existing literature, and identifies important implications for laboratory operations and policies, while also addressing the study's limitations. Finally, Section 5 offers recommendations for enhancing laboratory safety standards, mental health support, and preparedness for future pandemics, while suggesting directions for future research.

2. Methods

2.1. Study Design

A 25-question questionnaire was selected based on its alignment with the study objectives, content relevance to safety guidelines, personal protective equipment (PPE) use, and understanding of COVID-19 safety rules within laboratory settings. The questionnaire was primarily validated by language and statistics experts. It assessed the knowledge of COVID-19 safety regulations among staff from 40 medical laboratories, encompassing all qualified laboratories actively engaged in testing for COVID-19 across Jordan. Additionally, feedback from stakeholders (e.g., laboratory staff, public health authorities) was obtained to refine the questionnaire and enhance data collection processes. The validation of the questionnaire included content and face validity. Additionally, the reliability analysis was conducted using statistical tests, with Cronbach's alpha for this survey calculated at 0.747 to assess the internal consistency of the questionnaire items. The response rate and completeness of responses were monitored to evaluate the questionnaire's acceptability and practicality. Given practical limitations, as Jordan is a small country, the sample size (n = 40, with only one response submitted from each laboratory) was guided by expert recommendations in epidemiological study design and pilot testing, considering this size

sufficient to achieve a reasonable level of statistical confidence in identifying knowledge gaps and safety practices related to COVID-19 handling across all qualified laboratories in Jordan. The study gathered responses from 40 accredited laboratories conducting COVID-19 testing in Jordan, with each laboratory providing one response to capture the perspectives of its staff. This approach was deemed sufficient to reflect the practices and conditions of those facilities, especially since, in Jordan, typically only one or, at most, three staff members are qualified to work with COVID-19 in any given laboratory.

Although the total number of individuals working in these laboratories was not recorded, participation criteria ensured that only personnel directly associated with these facilities participated. Participants were required to hold a professional role in COVID-19 testing, such as medical laboratory technicians, managers, or staff with relevant experience in handling infectious samples. Individuals not actively working in laboratories during the pandemic or without direct involvement in COVID-19 testing procedures were excluded.

2.2. Ethics

The study was based on a descriptive–analytical method and conducted in accordance with the Declaration of Helsinki. The protocol was approved by the Ethics Committee of The Specialty Hospital in Amman, Jordan with project identification code/Issued No.: 5/1/T/113533. All subjects provided informed consent for inclusion before voluntarily participating in the study. The duration of the study and data analysis was from April 2023 to October 2023, while the pilot testing took place from the end of 2021 to mid-2022.

2.3. Survey Instrument

Twenty-five separate questions were asked in the laboratories. The raw text of the entire survey was based on the survey [28] after obtaining permission, and all provided Supplementary Materials. Specifying the type of laboratory was among the questions. The survey aimed to determine the most common medical specialties among laboratory technicians. Additionally, respondents were required to indicate whether they held a bachelor's degree, a master's degree, a higher diploma, or a PhD. Another important was the years of experience of the laboratory technician or respondent. Questions 6–12 focused on laboratory details such as biosafety levels (BSLs) and the availability of COVID-19 testing. The survey inquired whether the laboratory conducted follow-up tests for COVID-19, such as next-generation sequencing (NGS) or microbiology. It also addressed specimen transport within the lab and the personal protective equipment (PPE) used for COVID-19 work. The survey examined which parameters were most frequently tested in COVID-19 samples. Questions included whether the laboratory had a centrifuge for COVID-19 samples, if a single employee tested samples from one COVID-19 patient in one day, and if the laboratory had any special restrictions related to COVID-19 tests. Quality control tests are essential for laboratory testing accuracy and precision. Respondents were asked if they had been quarantined, if the pandemic had affected their mental health, and if their work had been impacted.

2.4. Data Collection and Study Popualtion (Participants)

Data were collected via a blinded non-stratified electronic questionnaire, allowing only one response from each laboratory via a Google Form, resulting in 40 total responses. The survey targeted laboratory personnel affiliated with all 40 accredited laboratories handling COVID-19 testing in Jordan. The survey did not employ stratification based on predefined categories such as age, gender, or specific professional roles. Instead, it included a broad range of laboratory personnel who met the inclusion criteria, such as laboratory affiliation, professional role, experience with COVID-19 testing, and geographical location in Jordan, ensuring a diverse and representative sample of the target population.

2.5. Data Analysis

All collected data from the study were converted to digital format. Using IBM SPSS v. 26, these data were then analyzed using ridge regression analysis and nonparametric statistics (2-sided *p*-value test) to develop meaningful insights into knowledge gaps, safety practices, and compliance with COVID-19 guidelines. In this context, ridge regression is a regularized linear regression technique applied to avoid possible multicollinearity among predictor variables. This method adds a penalty to the ordinary least squares objectives, shrinking coefficients and reducing their variance. Consequently, ridge regression stabilizes the estimates and improves generalizability.

$$Loss\ Function = Sum\ of\ Squared\ Residuals + \lambda\ .\ \sum_{j=1}^{p} \beta_j^2$$

where:

λ: the regularization parameter, controlling the strength of the penalty; a higher λ results in smaller coefficients, reducing overfitting by limiting model complexity. Meanwhile, a smaller λ allows coefficients to take larger values, improving fit but increasing the risk of overfitting.

$\sum_{j=1}^{p} \beta_j^2$: the L2 (Ridge regularization) penalty, which discourages large coefficients to prevent overfitting.

3. Results

We used the survey data to conduct a Ridge regression analysis (Figure 1) to identify the factors that predict perceived working efficiency during the COVID-19 pandemic. The estimates derived from the Ridge regression model include the relative importance of each predictor variable, with coefficients indicating the strength of their relationship with perceived working efficiency. The x-axis displays the coefficients for each predictor. These coefficients reflect both the magnitude and direction (positive or negative) of each variable's impact on the outcome. Larger absolute values signify stronger predictors, while coefficients closer to zero suggest a weaker influence. Positive coefficients (represented by bars extending to the right) indicate that an increase in the predictor's value results in an increase in the outcome, whereas negative coefficients (bars extending to the left) indicate that an increase in the predictor's value leads to a decrease in the outcome (Table 2). Among the most influential variables are "Has the laboratory identified tasks that can be performed with reduced or no face-to-face interactions?" and "Did the COVID-19 pandemic affect your mental condition?", which show a significant association with the independent variable. These findings highlight how the pandemic impacted laboratory operations and personnel efficiency.

The following section places our results into further context by comparing the responses of different demographic groups. The results revealed differences in experiences based on gender and scientific specializations. For example, the impact on working efficiency reported by female respondents was more pronounced than that reported by their male counterparts, thus supporting findings from prior research detailed in the discussion.

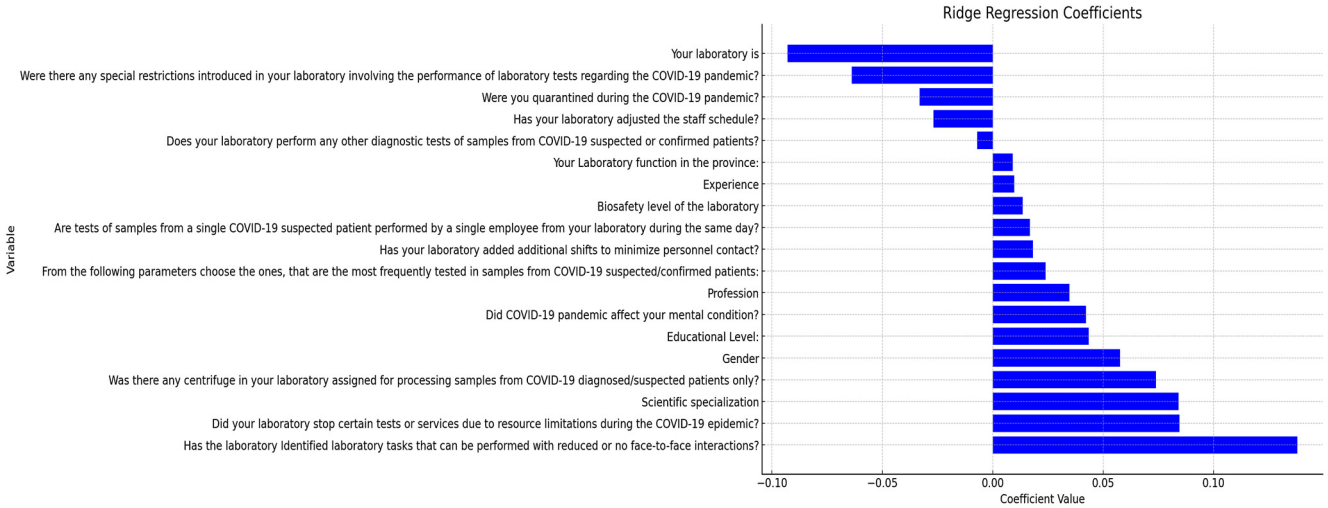


Figure 1. Ridge regression coefficients.

Table 2. Ridge regression analysis.

Category	Variables/Factors	Insights
Strong Positive Predictors	- "Has the laboratory identified tasks that can be performed with reduced or no face-to-face interactions?" - "Did your laboratory stop certain tests or services due to resource limitations during the COVID-19 pandemic?"	Operational adaptations, such as remote work capabilities and resource-driven adjustments, significantly improved the laboratory's response during the pandemic. Flexible operational strategies are critical in crisis management.
Strong Negative Predictors	- "Does your laboratory perform any other diagnostic tests on samples from suspected or confirmed COVID-19 patients?" - "Your laboratory's function in the province"	Laboratories with a broader diagnostic focus or those located in certain provinces faced greater challenges, likely due to resource strain or regional disparities in healthcare infrastructure.
Less Influential Variables	- "Experience" - "Educational Level" - "Gender"	These predictors have minimal impact on the outcome, suggesting that individual-level characteristics were less relevant compared to organizational and structural factors.
Moderately Influential Variables	- "Biosafety level of the laboratory" - "Has your laboratory added additional shifts to minimize personnel contact?"	Higher biosafety standards and shift-based work arrangements moderately contributed to managing pandemic-related pressures but were not the primary drivers of outcomes.

3.1. Demographic Data

Three types of laboratories were surveyed: clinical, molecular, and those that are both clinical and molecular. These laboratories are managed by trained medical technologists who conduct tests on biological samples from patients. Molecular testing is becoming increasingly common in clinical laboratories, primarily to detect changes in the sequencing or expression levels of key genes involved in diseases. Over two-thirds of the laboratories surveyed were classified as both clinical and molecular, as shown in Table S1. Most of the

laboratories were located in Amman (71.4%), Irbid (16.3%), Aqaba and Zarqa (4.1%), and Madaba and Mafraq (2.0%), as demonstrated in Table S2.

3.2. Respondents' Educational Level

Medical sciences-related specializations were preferred by females over males (60% vs. 40%). These results are displayed in Figure S1. Laboratory technicians represented the highest percentage of respondents at 82.5%, while managers had the lowest at 17.5%. These results are illustrated in Figure 2.

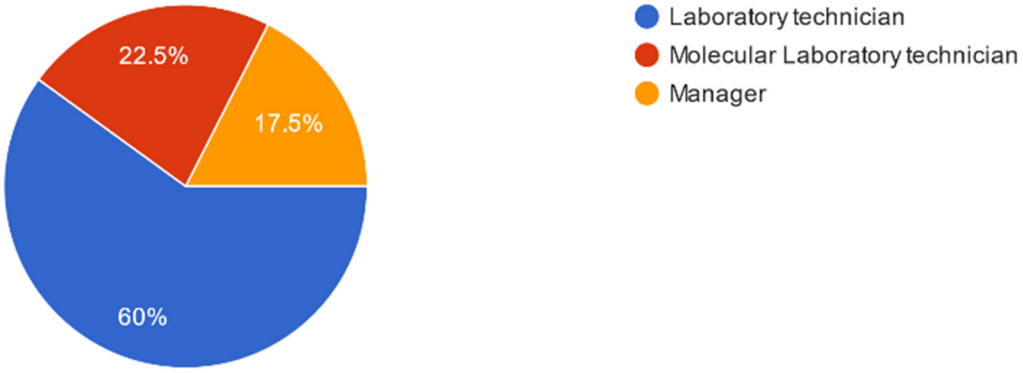


Figure 2. The professions of the respondents.

Medical laboratories specialization had the highest response rate at 62.6%, followed by biotechnology and genetic engineering at 22.5%. These results are shown in Table 3.

Table 3. Respondents' scientific specialization.

Scientific Specialization	Frequency	Percentage (%)
Medical laboratories	25	62.5
Biotechnology and genetic engineering	9	22.5
Pharmacy	1	2.5
Medicine	2	5.0
Chemistry	1	2.5
Microbiology	2	5.0
Total	40	100.0

A question was asked to determine the educational level of the respondents. Table S3 shows that respondents holding a bachelor's degree constituted the highest percentage at 72.5%. The final question in this subcategory addressed the years of experience working in a laboratory. Figure S2 indicates that respondents with 0 to 2 years of experience made up the highest percentage at 55%, compared to 45% for those with over 3 years of experience, which reflects a close ratio. Experience is essential in this sector.

3.3. Laboratory-Related Responses

This subcategory focused on laboratory tests, biosafety levels, COVID-19 infection tests, and tests for COVID-19 cases. BSL-2 was the most frequently reported biosafety cabinet level, noted by 40% of respondents, indicating that the laboratories are following WHO recommendations. The percentages are displayed in Table S4. The second part of this subcategory reveals that laboratories performing both PCR tests and rapid antibody tests for COVID-19 accounted for the highest percentage at 85%, with a statistically significant difference as shown in Table 4.

Table 4. COVID-19 infection tests available in laboratories.

Does Your Laboratory Provide COVID-19 Infection Tests?				
	Frequency	**Percentage (%)**	**Standardized Test Statistic**	**Asymptotic Sig. (2-Sided Test)**
Yes, molecular test only (PCR)	3	7.5	5.850	0.000
Yes, antibody test only	3	7.5		
Yes, both molecular and antibody tests	34	85.0		
No, my laboratory doesn't provide tests for COVID-19 infection	0	0		
Total	40	100.0		

The following question was designed to emphasize the availability of diagnostic tests for suspected or confirmed COVID-19 patients. It aimed to determine whether the laboratory conducts follow-up studies after COVID-19 testing, such as next-generation sequencing (NGS) or microbiology. The follow-up tests conducted after COVID-19 testing were statistically significant (Table 5).

Table 5. Availability of diagnostic tests in laboratories.

Does Your Laboratory Perform Any Other Diagnostic Tests of Samples from COVID-19 Suspected or Confirmed Patients, Such as NGS or Microbiology?				
	Frequency	**Percentage (%)**	**Standardized Test Statistic**	**Asymptotic Sig. (2-Sided Test)**
Yes	31	77.5	3.320	0.001
No	9	22.5		
Total	40	100.0		

3.4. Equipment and Transportation of Biohazard Pouches

Respondents were asked about the protocol for transporting specimens in the laboratory and the PPE used when working with COVID-19. Were biohazard pouches used to transport materials from COVID-19-suspected patients? The results revealed a significant difference in the knowledge of transportation methods for biohazard specimens. Three respondents were unaware of the methods for transporting hazardous materials. These results are shown in Table S5 and Figure S3. Table 6 demonstrates that 92.5% of laboratories have access to PPE for COVID-19 work, while 7.5% lack protective equipment for handling COVID-19 positive samples, which could pose a problem.

Table 6. Using PPE with COVID-19 samples.

Does Your Hospital/Employer Provide Personal Protective Equipment During Work with COVID-19-Positive Samples?				
	Frequency	**Percentage (%)**	**Standardized Test Statistic**	**Asymptotic Sig. (2-Sided Test)**
Yes, in sufficient quantity	27	67.5	5.218	0.000
Yes, but in a limited quantity	10	25.0		
No	3	7.5		
Total	40	100.0		

Surgical masks and goggles were the most commonly used PPE in laboratories conducting COVID-19 sample tests (Figure S4). COVID-19 samples are tested for blood count, coagulation, electrolytes, and cardiac markers, with the most requested test being C-reactive protein (CRP) (Figure S5).

3.5. Procedures in the Laboratory for COVID-19 Samples

The first question in this subcategory inquired whether there was a centrifuge in the laboratory specifically assigned for processing samples from suspected or diagnosed COVID-19 patients. This was to determine if the samples were tested according to standard procedures and placed in a dedicated area accessible only to personnel wearing protective equipment. Table S6 and Figure S6 indicate that responses regarding a designated centrifuge for COVID-19 samples were significant, with 55% of laboratories having a centrifuge to keep positive and negative samples separate.

Was it significant that a single employee performed tests on a single COVID-19 patient on the same day? The answer was "Yes". When a single employee conducts the tests, it implies that this individual prepared the sample alone after donning the protective equipment. If the answer to the question is "No", the material is divided among different laboratory rooms. The results are shown in Table S7.

High-risk inhalation tests required special safety equipment, and the results were significant. Table S8 and Figure S7 reveal that no special regulations were followed for COVID-19 in general, which disregarded safety rules. Did resource limitations cause laboratories to halt certain tests or services during the COVID-19 pandemic? This indicates a need for increased resources from the responsible parties. The results in Table 7 show that only 35% of laboratories ceased their services due to resource limitations.

Table 7. Resource limitation in laboratories.

Did Your Laboratory Cease Certain Tests or Services Due to Resource Limitations During the COVID-19 Epidemic?					
		Frequency	**Percentage (%)**	**Standardized Test Statistic**	**Asymptotic Sig. (2-Sided Test)**
Valid	Yes	14	35.0	−1.739	0.082
	No	26	65.0		
	Total	40	100.0		

3.6. Quality Control Accreditation

Accreditation of quality control tests is essential for laboratory precision. Table S9 shows that 85% of laboratories possess internally accredited quality control tests. what is the difference between internal and external quality control accreditation? Table S10 indicates that 65% of laboratories have external QC accreditation. However, 30% of respondents were unsure if their laboratory conducted external QC tests.

3.7. Mental Health of the Respondents

This subcategory may be one of the most significant aspects of the study. This section inquired whether respondents had been quarantined during the pandemic and whether they believed their work efficiency had decreased. The question 25 aimed to determine if the pandemic had affected the respondents' mental well-being. Approximately 65% of respondents reported being quarantined, with 22.5% citing workplace infection as the reason, as shown in Table 8.

In Table 9, it is shown that there is no significant difference in working efficiency between laboratories, as the outcomes were similar. In Table 10, it is shown that the mental health of over 80% of the respondents has been affected by the COVID-19 pandemic. Conditions such as anxiety and depression may have worsened.

Table 8. Respondents' quarantine status.

Were You Quarantined During the COVID-19 Pandemic?				
	Frequency	**Percentage (%)**	**Standardized Test Statistic**	**Asymptotic Sig. (2-Sided Test)**
Yes, because of COVID-19 infection	14	35.0	0.791	0.429
Yes, because of private contact with an infected person (outside of my workplace)	3	7.5		
Yes, because of workplace-related contact with infected person	6	15.0		
Yes, because of performance of tests on biological samples from COVID-19 positive patient	3	7.5		
No, until now I have not been aware of having any direct contact with the SARS-CoV-2 virus	14	35.0		
Total	40	100.0		

Table 9. Working efficiency status.

Do You Think Your Working Efficiency Is Lowered in Relation to the COVID-19 Pandemic?				
	Frequency	**Percentage (%)**	**Standardized Test Statistic**	**Asymptotic Sig. (2-Sided Test)**
Yes	22	55.0	0.474	0.635
No	18	45.0		
Total	40	100.0		

Table 10. COVID-19 effect on the mental conditions.

Did COVID-19 Pandemic Affect Your Mental Condition?				
	Frequency	**Percentage (%)**	**Standardized Test Statistic**	**Asymptotic Sig. (2-Sided Test)**
Yes	33	82.5	3.953	0.000
No	7	17.5		
Total	40	100.0		

3.8. Employe-Related Responses

The questions 21-22 in the survey focused primarily on job-related issues, such as changes to staff schedules and additional shifts due to the epidemic. Do the laboratory's tasks require face-to-face contact with patients? Most responses (85%) indicated that the staff schedule was adjusted, while 15% remained unchanged, possibly due to the curfew (Table 11). Table 12 shows that 75% of the surveyed laboratories added a new shift (shift C). Table 13 indicates that 70% of the laboratories reported reduced or no face-to-face interactional laboratory tasks.

Table 11. Adjusting the staff schedule in laboratories.

	Frequency	**Percentage (%)**	**Standardized Test Statistic**	**Asymptotic Sig. (2-Sided Test)**
Yes	34	85.0	4.269	0.000
No	6	15.0		
Total	40	100.0		

Table 12. Addition of shift "C" in laboratories.

Has Your Laboratory Added Additional Shifts to Include Shift C to Minimize Personnel Contact?				
	Frequency	**Percentage (%)**	**Standardized Test Statistic**	**Asymptotic Sig. (2-Sided Test)**
Yes	30	75.0		
No	10	25.0	3.004	0.003
Total	40	100.0		

Table 13. Identification of laboratory tasks to reduce face-to-face interactions.

Has the Laboratory Identified Laboratory Tasks That Can Be Performed with Reduced or No Face-to-Face Interactions?				
	Frequency	**Percentage (%)**	**Standardized Test Statistic**	**Asymptotic Sig. (2-Sided Test)**
Yes	28	70.0		
No	12	30.0	2.372	0.018
Total	40	100.0		

4. Discussion

The findings of this study provide valuable insights into the current state of laboratory safety practices and the mental health impacts among laboratory personnel during the COVID-19 pandemic in Jordan. The various measures used in our study investigated the impact of the pandemic on laboratory operations and the efficiency of personnel. Our Ridge regression analysis revealed that perceived working efficiency was significantly influenced by several factors. Among the most influential factors were the identification of duties that could be performed with minimal face-to-face contact, the cessation of certain tests or services due to resource constraints, and the psychological effects of the pandemic. Several key points have emerged from the data, highlighting both strengths and areas needing improvement.

4.1. Demographic Data, Including Ender, Job Experience, and Specializations

Laboratories are equipped for both clinical and molecular testing because both types of tests are essential for diagnosing and treating a wide range of medical conditions. Molecular testing is becoming increasingly important in healthcare, which may lead to more laboratories adopting a hybrid model to provide a comprehensive array of tests. This trend also reflects industry consolidation in healthcare. Laboratories should focus on offering various testing services to reduce costs and enhance efficiency. These findings underscore the importance of integrated laboratory services, incorporating both clinical and molecular testing. Most of the laboratories studied in Jordan were located in Amman and Irbid, the country's two largest and most populous cities. This concentration may be due to higher demand for laboratory services in these areas. Factors such as trained staff accessibility, funding, and healthcare facilities may influence laboratory distribution in Jordan. Further research is needed to understand the factors driving laboratory locations within the country. Certain regions of Jordan exhibit a high density of laboratories. The survey revealed that females preferred specializations related to medical sciences more than males. This result aligns with previous findings indicating that females are more likely to pursue careers in medical fields [29]. Personal interests and experiences, along with societal expectations and cultural norms, may influence this preference. Additionally, females may have more educational and career opportunities in the medical field, potentially accounting for the difference in preferences. Gender pay disparities and access to opportunities could also

contribute, as well as encouragement towards medical careers. Overall, these findings suggest that gender may influence the choice of medical specialties. The study's results indicated that laboratory technicians constituted 82.5% of the total respondents. Given their role in handling COVID-19 specimens, it is not surprising that they represented the largest group. Managers made up the smallest proportion of respondents, accounting for just 17.5% of the total. The direct involvement of laboratory technicians in the COVID-19 response likely explains their higher participation in the study. The responses showed that 62.6% of participants specialized in medical laboratories, followed by 22.5% in biotechnology and genetic engineering. Their expertise in diagnosing illnesses may explain the significant number of respondents with specializations in medical laboratories, making them more likely to engage in research relevant to their field. The increasing relevance of biotechnology and genetic engineering in modern healthcare may also contribute to the growing percentage of respondents specializing in these areas. The results indicated that the highest proportion of respondents, 72.5%, held a bachelor's degree, likely due to the requirements for many medical roles. Consequently, individuals with bachelor's degrees may be more likely to work in positions involving medical science research. Respondents' educational levels may be influenced by factors such as available educational opportunities, career aspirations, and job requirements. Approximately 55% of respondents reported having 0–2 years of laboratory experience, while a smaller group of 45% had 3 years of experience. Factors such as job availability, individual career goals, and job demands may influence the distribution of respondents according to their years of experience.

4.2. Biosafety Level and Transportation of Biohazard Pouches

The results reveal that biosafety cabinet levels 2 and 3 are the most frequently used types of cabinets, accounting for more than 70% of responses. This finding aligns with the World Health Organization's (WHO) recommendation and previous reports that biosafety cabinet level 2 should be used when working with coronaviruses [25,30]. The high proportion of respondents using this type of cabinet suggests that many laboratories are adhering to these recommendations and taking precautions to safeguard their staff and the community from potential exposure to hazardous materials. However, 25% of respondents emphasize the importance of following guidelines and recommendations from organizations like the WHO to ensure the safety of both the community and laboratory staff. On another note, most laboratories (85%) conduct both rapid antibody tests and PCR tests for COVID-19. The statistical significance of this finding indicates that the observed difference is unlikely to be due to chance. It is important to note that none of the 40 accredited laboratories included in this study offered either PCR or antibody tests for COVID-19. Testing options must be varied to ensure accurate diagnosis and treatment of COVID-19. More than three-quarters of the laboratories appear to conduct follow-up tests following COVID-19 testing, and this difference is statistically significant. This is a positive outcome, demonstrating additional steps taken for diagnosing and treating COVID-19. Next-generation sequencing (NGS) [31] and microbiology are two types of follow-up tests that can provide useful information about the strain of the virus and help guide treatment decisions. Biohazard specimens must be safely transported to prevent accidental exposure and contamination, and most laboratories recognize the importance of safe transportation of hazardous materials. Professional training and awareness sessions could further ensure the proper handling and transport of hazardous materials. The study shows that laboratories have access to PPE for COVID-19 positive samples, which is a positive outcome, as the use of personal protective equipment (PPE) is crucial for halting the virus's spread and safeguarding healthcare workers from accidental exposure. However, the difference in access to PPE is statistically significant, suggesting that some laboratories

may not be well equipped to handle COVID-19 positive samples. It is concerning that 7.5% of laboratories have no access to PPE when dealing with these samples, as this endangers both workers and the general public. To ensure the safety of healthcare workers and the effectiveness of COVID-19 testing, it may be necessary to address this issue and equip these laboratories appropriately. Masks and goggles are the most commonly used PPE in laboratories handling COVID-19 samples. The prevalence of these two items suggests that laboratories prioritize them when dealing with COVID-19 specimens. These data may influence best practices for COVID-19 testing and enhance the safety and efficiency of the testing process. Additionally, the C-reactive protein (CRP) test was found to be the most frequently requested parameter, and it has also been reported that CRP may serve as an early marker to predict the severity of COVID-19 [32].

4.3. Special Restrictions or Procedures to Deal with COVID-19 Samples

Many laboratories have designated a centrifuge specifically for processing COVID-19 samples. This is crucial, as it helps to prevent the mixing of positive and negative samples, which could lead to incorrect diagnoses and further spread of the infection. Data indicate that more than half of the laboratories surveyed (55%) house a centrifuge in a designated area for this purpose. Many laboratories prioritize precision and safety in the processing of COVID-19 samples. Statistically significant results are observed when one employee conducts tests on one patient in one day. This demonstrates that a single worker can independently prepare the sample and perform the test while wearing protective gear. Most respondents (80%) have implemented special restrictions or procedures for laboratory testing related to COVID-19. Although most respondents reported taking necessary safety measures for workers, the fact that 20% stated they had no such restrictions in place is concerning. Worker safety should be a priority in laboratories during a pandemic. During the COVID-19 pandemic, only a small percentage of laboratories (35%) ceased providing certain tests or services due to a lack of resources [33]. Most laboratories have managed to continue offering services despite the pandemic [34].

Limited resources have impacted many laboratories, potentially affecting their operations and the communities they serve. Providing additional resources may be necessary for these laboratories to maintain their services and testing capabilities.

4.4. Quality Control (QC), Quarantine, Working Efficiency, and Mental Health

The results indicate that 85% of laboratories have approved internal quality control tests. These tests ensure accuracy, which is a positive outcome that aligns with previous reports [35,36].

Establishing accredited quality control tests can provide research facilities with trust and confidence. Approximately 65% of laboratories have external quality control accreditation, which is a positive statistic, as external QC accreditation can guarantee laboratory quality. What are the reasons 15% of laboratories do not have accredited quality control tests? What measures can be taken to help them adopt such tests?

However, 30% of respondents were unsure whether their laboratory had external QC accreditation, which is concerning. Laboratories must be aware of their accreditations. This uncertainty may hinder research because some laboratories lack clarity on their external QC accreditations. The laboratories surveyed implemented measures to reduce contact between patients and technicians for safety. Around 75% of the laboratories surveyed added a new shift (shift C) to their operations, and 85% altered their staff schedules. Additionally, 70% of surveyed laboratories reduced the risk of transmission by minimizing face-to-face tasks. These results suggest that the laboratories surveyed prioritized employee safety during the COVID-19 pandemic. A portion of the survey revealed that the COVID-19 pandemic

significantly impacted the respondents' mental health. Sixty-five percent of respondents had to quarantine during the pandemic, with 22.5% being due to workplace infection and 42.5% due to personal contact. Notably, there was no difference in laboratory work efficiency related to the pandemic.

According to these findings, the mental health of survey respondents was significantly affected by the pandemic. Surveys show an increase in stress, anxiety, depression, and insomnia in the US since the onset of the pandemic. Some individuals have increased their use of alcohol or drugs under the mistaken belief that it will help them cope with their pandemic-related anxieties [37]. In fact, these substances can exacerbate anxiety and despair.

4.5. Limitations

Finally, there are some limitations to this study. First, the sample size is limited, which means that the findings may not be generalizable to other regions or countries. Additionally, the study does not investigate other factors that might influence the safety practices of laboratory workers. Lastly, the study relies on participants' self-reported data, which may not be entirely accurate due to inherent bias; however, this type of bias is often unavoidable in such studies.

5. Conclusions

The study aimed to assess the awareness of safety regulations among laboratory technicians in Jordanian laboratories in relation to public health emergencies like COVID-19. The Ridge regression analysis identified critical predictors that influenced laboratory responses. The results emphasize the importance of operational adaptability to work remotely or with minimal face-to-face contact, efficient resource prioritization and allocation, infrastructure and biosafety improvements, and minimizing workforce strain. These findings directly inform recommendations aimed at enhancing laboratory preparedness and resilience in future crises.

From a broader perspective, several important conclusions have been identified:

1. Awareness of Safety Regulations: This study shows that there is room for improvement in the understanding and application of safety regulations among laboratory staff in Jordan. Despite having certified laboratories, safety guidelines were generally lacking, as was the proper use of personal protective equipment when handling COVID-19 samples. This highlights the necessity for more professional training and educational programs to enhance safety knowledge and practices among laboratory workers.
2. Impact of the Pandemic on Mental Health: Our study indicates that the impact of the COVID-19 pandemic on mental health among healthcare workers, including laboratory staff, is significant. In this context, working in the laboratory may be the most demanding activity during the pandemic due to fears of infection and work-related pressures. Thus, mental health support, along with supportive policies and resources, is essential for promoting well-being.
3. Implications for Safety Standards: The gaps noted in knowledge and practice regarding safety highlight the need to strengthen safety standards and protocols among certified laboratories in Jordan. Critical steps include developing rigorous training programs for safety, providing adequate personal protective equipment (PPE), and regularly assessing safety compliance. These measures are vital for mitigating the risks associated with infectious materials, such as COVID-19 samples. Efforts to foster a safety culture and implement regulations should involve collaborative efforts from regulatory bodies, healthcare institutions, and laboratory management.

4. Call to Action: Prioritizing calls to action is essential to developing initiatives that raise safety awareness, provide mental health support, and improve safety norms in laboratories across Jordan. By doing so, we can enhance safety practices in a manner that protects the well-being of laboratory technicians and establishes the necessary safety standards for an effective response to future pandemic situations.

In conclusion, this study emphasized the need for the gradual development of safety awareness, regulatory compliance, and mental health support to enhance safety practices and protect health workers in laboratory systems. This is essential for an effective pandemic response and preparedness. If these elements are successfully implemented, the potential for stronger safety practices will help safeguard laboratory workers and improve overall safety standards, ultimately contributing positively to effective pandemic response and preparedness.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/safety11010013/s1, Figure S1: The percentages of the two subcategories of gender; Figure S2: Years of experience among laboratory technicians; Figure S3: The use of biohazard pouches; Figure S4: Sorts of PPEs used during work with COVID-19 samples; Figure S5: The most frequently tested parameters in COVID-19; Figure S6: Percentage of the usage of centrifuge devices dedicated only to COVID-19 samples; Figure S7: Percentage of introducing special regulations in laboratory testing COVID-19; Table S1: Sorts of laboratories; Table S2: The location of the studied laboratories; Table S3: The percentages of the educational level of the respondents; Table S4: Biosafety levels used in laboratories; Table S5: Method of transportation of the material from COVID-19 patients; Table S6: The usage of centrifuge devices dedicated only to COVID-19 samples; Table S7: Performing tests on a single sample by a single employee on the same day; Table S8: Introducing special regulations in the laboratory tests regarding COVID-19; Table S9: Internal QC accreditation in laboratories; Table S10: Having external QC accreditation.

Author Contributions: Conceptualization, W.A.-Z. and B.O.; methodology, H.A.I., M.S., R.D. and B.O.; software, H.A. and W.A.-Z.; validation, A.A.-K., F.A.-H. and R.D.; formal analysis, W.A.-Z. and H.A.; investigation, H.A.I. and B.O.; resources, M.S. and W.A.-Z.; data curation, W.A.-Z. and H.A.; writing—original draft preparation, W.A.-Z. and H.A.I.; writing—review and editing, W.A.-Z.; visualization,; supervision, A.A.-K., F.A.-H., M.S. and R.D.; project administration, A.A.-K., F.A.-H. and R.D.; funding acquisition, not applicable. All authors have read and agreed to the published version of the manuscript.

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

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Specialty Hospital with Project identification code/Issued No.: 5/1/T/113533. All subjects provided informed consent for inclusion before participating in the study.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data are contained within the article and Supplementary Materials.

Acknowledgments: The authors thank every medical laboratory that participated in this study.

Conflicts of Interest: The authors declare no conflict of interest.

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