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RESEARCH PAPER

King Salman Humanitarian Aid and Relief Centre (KSrelief) During the COVID-19 Crisis and its Impact on the Seroprevalence of COVID-19 Antibodies in Healthcare Workers in Yemen

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ABSTRACT

PURPOSE: The purpose of this study is to review the humanitarian work done by KSrelief to support the healthcare sector in Yemen during the COVID-19 crisis, and to assess its impacts on the seroprevalence rate of anti-SARS-CoV-2 antibodies among healthcare workers (HCWs) in Yemen.

DESIGN/METHODOLOGY/APPROACH: Data related to the KSrelief humanitarian efforts, particularly the medical aid to the healthcare sector in Yemen, over the 3-year period from 2020 to 2022 was analysed. In addition, a cross-sectional study was conducted among 404 HCWs in Lahj and AL-Dhalea hospitals from 1 June-30 September 2022. A self-administered

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questionnaire was distributed to all voluntary HCWs. A blood test for the presence of anti-nucleocapsid (anti-N) antibodies by anti-SARS-CoV-2 immunoassay using an electrochemiluminescence technique was taken. The impact of the aid efforts on the seroprevalence rate was assessed and correlated, and the lessons learned and what needs to be done to improve the utilisation of the aid efforts are discussed.

STUDY FINDINGS: Up to December 2022, KSrelief implemented 764 projects with budget of US$1,130,771,135. These projects were executed through the Yemeni Ministry of Public Health and covered more than 12 governorates of Yemen. The projects included a vaccination programme, the provision of personal protection equipment (PPE) and other protective gear for HCWs, RT-PCR devices and accessories, and medical and laboratory devices and equipment. The seroprevalence test revealed 94.0% of the healthcare workers with Anti-SARS-CoV-2 antibodies.

RESEARCH LIMITATIONS/IMPLICATIONS: To the best of our knowledge, this is the first study that compares the impact of the humanitarian assistance provided by KSrelief in Yemen during the COVID-19 crisis with the level of seroprevalence of COVID-19 among HCWs in Lahj and AL-Dhalea governorates in Yemen. It is also the first study documenting the seropositivity of SARS-CoV-2 antibodies in HCWs in Yemen. The findings among HCWs in different healthcare settings in the country are non-general; this is because only 2 governorates out of 22 were selected that could be reported among the findings' limitations. In addition, there are some potential information recall biases such as in reporting of previous infection with SARS-CoV-2, the use of PPE, and infection prevention and control (IPC) training.

PRACTICAL IMPLICATIONS: Although the KSrelief efforts are directed at all governorates of Yemen, the impact of these efforts on the seroprevalence rate in other regions needs to be assessed to get an overall view of the correlation between the two. This study revealed that the ultimate great humanitarian assistance and relief measures provided by KSrelief to the healthcare sector in Yemen in the form of medical equipment and supplies to fight the COVID crisis set a true example of universal brotherhood; this can be replicated by other organisations working to decrease human suffering from natural or man-made disasters. Vaccination and reinforcement of IPC measures and training activities for imparting knowledge and appropriate implementation of the IPC protocol are key to preventing morbidity and mortality among HCWs.

ORIGINALITY/VALUE: The lessons learned from the correlation of the seroprevalence study with the aid efforts can be used as a guide by KSrelief themselves as well as by the other organisations working to deliver medical aid to the conflict-ridden countries, to better manage the precious resources and to identify any lacunae's that may hinder full utilisation of the relief efforts.

Although humanitarian assistance to Yemen has been provided by KSrelief since the beginning of the political turmoil, the relief measures were increased exponentially to counter the challenges of the COVID-19 pandemic and the social and economic deprivation due to the ongoing war. This seroprevalence survey was the first to document the seropositivity of SARS-CoV-2 antibodies in HCWs in Yemen after the fifth global COVID-19 wave.

KEYWORDS: *KSrelief; Humanitarian Assistance; Seroprevalence; COVID-19; Healthcare Workers*

INTRODUCTION

As of 12 January 2023, the world had experienced five consecutive waves of SARS-CoV-2 infection with a total of 660,746,894 confirmed cases, including 6,692,538 deaths (WHO, 2022a). With its already collapsing healthcare system due to poverty and the ongoing political crisis, Yemen suddenly faced a huge challenge with the beginning of the COVID-19 epidemic in March 2020. Being an undeveloped country, Yemen has fewer per capita hospital beds as well as a persistent shortage of medical supplies and healthcare workers (HCWs) (Zawiah *et al*., 2020). King Salman Humanitarian Aid and Relief Centre (KSrelief) is the foremost organisation providing multi-faceted humanitarian assistance, including a much-needed lifeline to the healthcare system of Yemen even before the detection of the first case of COVID-19 in Yemen. KSrelief is an international aid organisation established by the Kingdom of Saudi Arabia (KSA) under the patronage of the custodian of the

two holy mosques, King Salman Bin Abdulaziz Al Saud, to provide aid and relief efforts to crisis-afflicted communities (KSrelief, 2017). In Yemen, the relief efforts are directed towards the public in general and HCWs who worked tirelessly to combat the COVID-19 menace in particular.

The COVID-19 epidemic put a huge burden on the HCWs as well as on the already crumbling healthcare facilities in Yemen. The HCWs had to deal with an enormous number of patients, many of whom were hospitalised for a long time, leading to chronic exposure thereby increasing their risk of contracting the disease. Physical and mental stress due to extended working hours further compounded the problem. All these factors led to decreased compliance with infection prevention and control (IPC) protocols recommended by the World Health Organization (WHO), and further increased the likelihood of contracting and transmitting the infectious virus (WHO, 2021).

To reduce the transmission of coronavirus among the public and for the protection of HCWs from COVID-19, a robust implementation of the "hierarchy of controls" required for IPC in healthcare settings, as well as the wider application of public healthcare preventive measures, are essential (WHO, 2020a; PHO, 2022).

Even though KSrelief has provided an extensive amount of medical aid, many hospitals in Yemen lack basic infrastructure; this leads to the under-utilisation of medical supplies (Mae and Angelo, 2021). Lack of training and knowledge regarding IPC measures, as well as non-compliance and hesitancy on part of the HCWs, further negatively impacts the good work done by the KSrelief, leading to an increase in transmission rate of the SARS-CoV-2 virus, and delayed diagnosis and treatment of COVID-19.

This study aims to review the humanitarian work done by KSrelief in supporting the healthcare system in Yemen during the COVID-19 crisis, as well as assessing the impact and ramifications of these efforts on the level of seroprevalence of SARS-CoV-2 virus among the HCWs in the Lahj and Al-Dhalea governorates of Yemen.

METHOD

The study was carried out in two parts. The first part analyses data related to the relief efforts carried out by KSrelief. The second part of the study assesses the impact of KSrelief efforts on COVID-19 seropositivity in the HCWs in Yemen; it also describes the method used to analyse the rate of seroprevalence.

Data Collection Related to the Humanitarian Assistance Provided by KSrelief to the Health Care Sector in Yemen

Detailed data related to the humanitarian assistance provided by KSrelief to the healthcare system in Yemen during a 3-year period from 2020-2022 was analysed. The data were collected from the Ministry of Health and Population in Aden that documents KSrelief efforts in Yemen, and from the reports generated by the KSrelief field team.

Seroprevalence Survey

Design and Settings

A cross-sectional seroprevalence study was conducted among the HCWs in Lahj and AL-Dhalea hospitals from June to September 2022. Data generated from KSrelief were correlated with the findings from the seroprevalence study to assess its possible impacts and ramifications.

Participants and Sampling

The participants in this study were HCWs working in the hospitals located in the Lahj and AL-Dhalea governates of Yemen. The HCWs include doctors, dentists, nurses, x-ray technicians, laboratory personnel, pharmacists, respiratory therapists, and nutritionists, as well as auxiliary personnel such as social workers, clerks, housekeeping, and laundry staff. The HCWs who did not agree to participate and those who did not complete the questionnaire were excluded from the study. Due to the scarcity of data on the seroprevalence of anti-SARS-CoV-2 antibodies among HCWs in Yemen, and to maximise the sample size, we made an assumption of a prevalence rate of 50%, with a 95% confidence interval and 5% margin of error to calculate the sample size (Dasgupta *et al*., 2002). With a test sample of 384, we added an additional 5% to compensate for possible missing samples, thereby arriving at a sample size of 404 HCWs.

Sampling Technique

The data regarding the number and distribution of hospitals and the HCWs in Lahj and Al-Dhalea governorates were obtained from the respective health offices. We used a probability proportional to size (PPS) sampling method to register the required number of HCWs. From the final sample size of 404, 267 HCWs (66%) from Lahj and 137 HCWs (34%) from Al-Dhalea governorates who were working during the period of study were enrolled in the study.

Data Collection

A self-administered questionnaire based on the "WHO surveillance protocol for COVID-19 infection among HCWs" was distributed to the enrolled HCWs (WHO, 2020b).

The questionnaire was constructed to include multiple domains. The first domain included demographic information such as age, sex, healthcare setting, duration in service, and occupational category. The second domain comprised of three questions related to exposure to the SARS-CoV-2 virus, for example, the frequency of exposure, time of occurrence, and the type of setting as a source of infection. The third domain constituted questions related to the main COVID-19 clinical manifestations, as well as its confirmation with a reverse transcriptase-polymerase chain reaction (RT-PCR) test. The fourth domain consisted of questions related to any pre-existing co-morbidities in the participants, such as asthma, heart disease, hypertension, kidney disease, diabetes mellitus, and immune deficiency. The fifth set was composed of six questions based on the application of the

"hierarchy of controls" of the IPC protocol. The last domain is related to the information related to the uptake of COVID-19 vaccinations and the level of acceptance or hesitancy to receive the vaccine in the future.

Responses were measured in two variables, either "Yes" (score of 1) or "No/not remember" (score-0).

A 5ml venous blood sample of the participants was assessed for the presence of anti-nucleocapsid (anti-N) antibodies of SARS-CoV-2 using a fully automated immunoassay analyser based on the electrochemiluminescence immunoassay (ECLIA) technique, which is certified by WHO. The test has a specificity of 99.81% (CI 95%: 99.6-99.9%) and specificity of 99.5% (CI 95%: 98.63-99.85%) (Roche Diagnostics, 2022; WHO, 2022b). We used Elecsys® Anti-SARS-CoV-2 by Roche Diagnostics, an *in vitro* qualitative serologic test for the detection of antibodies (including IgG) to SARS-CoV-2.

The entered data were coded and analysed using the statistical software platform-SPSS version 23 (IBM Corp., Armonk, New York).

RESULTS

KSrelief Humanitarian Assistance Findings

Up to 31 December 2022, KSrelief carried out 764 humanitarian assistance projects totalling US$1,130,771,135, in Yemen. These projects were implemented through the Yemeni Ministry of Public Health and other relevant Yemeni Ministries covering more than 12 governorates. Some of these projects were directed towards Yemen's health care system during the COVID-19 crisis and included five batches of relief measures. The much needed health care relief included supply of PPE and other protective gear for HCWs, PCR devices and accessories, medical devices, and a vaccination programme against COVID-19. During the pandemic, and in collaboration with the WHO, KSrelief provided 6 mobile clinics and 81 ambulances to transport critical cases to the nearest health care centre (WHO, 2020c).

Table 1 summarises most of these humanitarian aids during COVID-19. In May 2020, at the start of the pandemic, the first and second batches of urgent measures were initiated to support and improve the capabilities of the Yemeni Ministry of Health and Population to counter the outbreak of SARS-CoV-2 in Yemen (KSrelief, 2020a; KSrelief, 2020b). The PCR testing machines and kits were provided to the National Center for Central Public Health Laboratories to speed up the diagnosis of COVID-19 in the local population (KSrelief, 2020c). The health care facilities were supplied with the necessary laboratory testing equipment. To limit the effects of COVID-19, the HCWs were provided with PPE and other protective equipment that were either not available or were in short supply in many hospitals (KSrelief, 2020d; KSrelief, 2020e).

The third batch of COVID-19 medical aid from KSrelief included healthcare items, protective masks for the health care staff, and ICU ventilators that were delivered to the National Drug Program of the Yemen to combat the pandemic in several governorates (KSrelief 2020f).

The fourth and the fifth batches of COVID-19 medical assistance comprised of N95 protective masks, gloves, infusion and syringe pumps, ventilators, disinfectants and sterilisers, and thermal cameras for epidemiological surveillance (KSrelief, 2020g).

Apart from these measures, artificial ventilators were provided as part of special medical assistance to combat the spread of the SARS-CoV-2 virus in the Republic of Yemen (KSrelief, 2020h).

In September 2020, an additional sixth batch of COVID-19 relief aid was delivered, including examination beds, regular and portable ventilators, thermometers, electronic blood pressure monitors, blood glucose meters with test strips, an ambulance, stethoscopes and sterilisers (KSrelief, 2020i).

An additional five PCR testing devices and other medical aid was provided in October 2020 to support and improve the capabilities of the Ministry to combat the ongoing outbreak of the COVID-19 pandemic (KSrelief, 2020d). Some of the projects were conducted under WHO guidance by the Ministry of Public Health and Population in Yemen in collaboration with KSrelief and Emirati aid (WHO, 2020c).

Table 1: Projects Implemented by the KSrelief to Combat COVID-19 in Yemen

Time	Items	Purpose
April 2020	81 ambulances and 6 mobile clinics in collaboration with the WHO and United Arab Emirates.	Ensures the ease of transferring patients to health facilities and hospitals for necessary medical care
May 2020	First batch of its COVID-19 response medical assistance needed healthcare worker protection items. Protective clothing and masks, detection devices for patients, laboratory supplies, medicines, peripheral venous catheters, and patient beds	Combat the pandemic in several governorates
May 2020	Polymerase Chain Reaction (PCR) tests	Help to speed up diagnosis of COVID-19 in the local population
May 2020	Second batch healthcare worker protection items, including protective masks, infusion pumps, syringe pumps and thermal cameras	Combat the pandemic in several governorates
June 2020	Personal protection equipment (PPE) and supplies, and laboratory tests	To help limit the effects of COVID-19 on the population
June 2020	Third batch healthcare worker protection items, including protective masks, infusion pumps, syringe pumps and thermal cameras	Combat the pandemic in several governorates COVID-19 response medical assistance to the National Drug Program
August 2020	Fourth and fifth batches of its COVID-19 response medical assistance	Securing urgently needed medical equipment and preventive supplies to fight coronavirus in Yemen

(continued)

Table 1: Projects Implemented by the KSrelief to Combat COVID-19 in Yemen *(continued)*

Time	Items	Purpose
August 2020	Artificial ventilators as part of special medical assistance to combat the spread of the new Coronavirus	
September 2020	Examination beds, regular and portable ventilators, thermometers, electronic blood pressure monitors, blood glucose meters with test strips, an ambulance, stethoscopes, and sterilisers	
October 2020	Five Polymerase Chain Reaction (PCR) COVID-19 testing devices and other medical sector	

Source: Constructed by authors

Seroprevalence Results

The mean age of the 404 participants was 33 (±SD 9.0) years. Around two-thirds (65.3%) of the HCWs were males and only 34.7% were females. The majority of participants were nurses (51.2%) while physicians (11.6%) comprised the lowest proportion among the HCWs (Table 2).

Table 2: Association Between Demographics and the SARS-CoV-2 Seropositivity (n=404)

Variables	Categories	Total	Negative	Positive	P-value
		No. (%)	No. (%)	No. (%)	
Sex	Male	264 (65.3)	18 (6.8)	246 (93.2)	0.180
	Female	140 (34.7)	5 (3.5)	135 (96.5)	
Age	≤ 25 years	52 (12.9)	3 (2.0)	49 (98.0)	0.724
	25-44 years	294 (72.8)	18 (6.2)	276 (93.8)	
	≥45 years	58 (14.4)	2 (3.4)	56 (96.6)	
Years of Experience	1 year	12 (3.0)	0 (0.0)	12 (100.0)	0.687
	2 to 5 years	190 (47.0)	11 (5.8)	179 (94.2)	
	>5 years	202 (50.0)	12 (6.0)	190 (94.0)	
Occupational Category	Physicians	47 (11.6)	4 (8.5)	43 (91.5)	0.648
	Nurses	207 (51.2)	12 (5.8)	195 (94.2)	
	Applied medicine	92 (22.8)	5 (5.4)	87 (94.2)	
	Supporting services	58 (14.4)	2 (3.4)	56 (96.6)	

Source: Constructed by authors

Anti-SARS-CoV-2 antibodies were detected in 94.0% of subjects; however, 93.7% had not been tested for COVID-19 by an RT-PCR test even though a significant number had some COVID-19 manifestations (Figure 1).

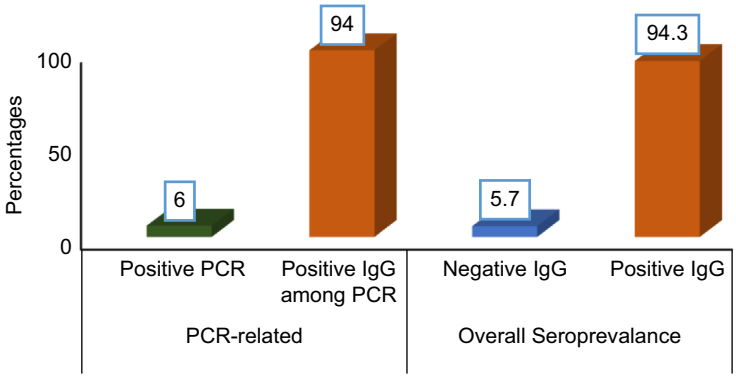

Figure 1: PCR level and Seroprevalence of SARS-CoV-2 Antibodies Among HCWs
Source: Constructed by authors

Symptoms of COVID-19 and Prevalence of Positive Tests

The current results showed a high percentage of asymptomatic seropositive HCWs (72%) as compared to the seronegative group (28.0%). Most of the individuals had COVID-19 symptoms without being confirmed by an RT-PCR test, however, a P-value of >0.05 indicated insignificant differences. Most of the COVID-19 symptoms were observed in the seropositive individuals and were noted in the following descending order of frequency: cough (94.6%), shortness of breath (94.5%), loss of sense of smell or taste (93.3%), and fever/chills (93%), as seen in Table 3.

Table 3: Association Between Symptoms of COVID-19 Infection and Prevalence of Positive Tests

Variables	Category	Total	Negative	Positive	P-value
		No. (%)	No. (%)	No. (%)	
Shortness of breath	YES	55 (14)	3 (5.5)	52 (94.5)	0.535
	No	349 (86)	20 (5.7)	329 (94.3)	
Cough	YES	93 (23)	5 (5.4)	88 (94.6)	0.881
	No	311 (77)	18 (5.8)	293 (94.2)	
Loss of smell or taste	YES	104 (26)	7 (6.7)	97 (93.3)	0.596
	No	300 (74)	16 (5.3)	284 (94.7)	
Fever/chills	YES	93 (23)	6 (7)	80 (93)	0.477
	No	311 (77)	17 (5.3)	301 (94.7)	
Fatigue and weakness	YES	88 (22)	6 (7)	80 (93)	0.536
	No	316 (88)	17 (5.3)	301 (94.7)	

(continued)

Table 3: Association Between Symptoms of COVID-19 Infection and Prevalence of Positive Tests *(continued)*

Variables	Category	Total No. (%)	Negative No. (%)	Positive No. (%)	P-value
Headache	YES	86 (21)	7 (8)	81 (92)	0.301
	No	318 (79)	16 (5.1)	300 (94)	
Back and joint pain	YES	98 (24)	7 (7.1)	91 (92.9)	0.973
	No	306 (76)	16 (5.2)	290 (94.8)	
Runny nose	YES	60 (15)	6 (10)	54 (90)	0.119
	No	344 (75)	17 (4.9)	327 (95.1)	
Diarrhoea or vomiting	YES	33 (8)	2 (6.1)	31 (93.9)	0.881
	No	371 (92)	21 (5.7)	350 (94.3)	

Source: Constructed by authors

Association Between Adherence to the WHO Recommended Standard IPC Protocol and Seropositivity

The WHO advocated important standard IPC protocols for COVID-19 are those recommended protocols of hand hygiene, use of alcohol-based hand rub or soap, and use of personal protective equipment (PPE). As illustrated in Table 4, no statistically significant difference (P>0.05) was observed when SARS-CoV-2 seropositivity and adherence to IPC protocol were associated with each other. The overall level of adherence was calculated by adding the sum of all scores of the four main elements of the IPC standard precautions that should be followed by the HCWs in any healthcare setting. Using a 75 percentile as a cut-off level, a higher "poor level of adherence" (52%) was observed as compared to the "good level of adherence" to the IPC (48.0%); however, a statistically significant difference between SARS-CoV-2 seropositivity was not found.

Most of the HCWs (82.2%) indicated unavailability or insufficient quantity of PPE. Consequently, the rate of seropositivity was high (81.4%) in those who indicated unavailability or insufficient quantity of PPE as compared to those (18.6%) who mentioned that the PPE was available in sufficient quantity; however, the differences were not statistically significant (P=0.082). Relating to the participation of the HCWs for IPC training sessions, closer to two-thirds (61.9%) of the HCWs did not receive any training on the application of IPC at their site of work. Statistically, however, not much difference was noted in the rate of seropositivity among those who had participated in the IPC training (96.0%) and among those who did not receive any training (93.0%; P=0.221).

Table 4: Adherence to Infection Prevention and Control and Personal Protective Measures in Association with The Seropositive Tests

Variables	Category	Total	Negative	Positive	P-value
		No. (%)	No. (%)	No. (%)	
Follow IPC standard precautions	Yes	314 (77.7)	16 (5.0)	298 (95.0)	0.333
	No	90 (22.3)	7 (8.0)	83 (92.0)	
Follow 5 recommended moments of hand hygiene.	Yes	273 (67.6)	13 (5.0)	260 (95.0)	0.244
	No	131 (32.4)	10 (8.0)	121 (92.0)	
Use of alcohol-based hand rub or soap	Yes	341 (84.4)	19 (6.0)	322 (94.0)	0.807
	No	63 (15.6)	4 (6.5)	59 (93.5)	
Use of PPE	Yes	289 (71.5)	14 (5.0)	275 (95.0)	0.243
	No	115 (28.5)	9 (8.0)	106 (92.0)	
Availability of PPE in sufficient quantity	Yes	72 (17.8)	1 (4.3)	71 (18.6)	0.082
	No	332 (82.2)	22 (95.7)	310 (81.4)	
Attended IPC Training	Yes	154 (38.1)	6 (4.0)	148 (96.0)	0.221
	No	250 (61.9)	17 (7.0)	233 (93.0)	
The overall level of adherence to IPC	Poor	210 (52.0)	16 (69.6)	194 (50.9)	0.082
	Good	194 (48.0)	7 (30.4)	187 (49.1)	

Source: Constructed by authors

DISCUSSION

The present study analyses the humanitarian assistance and relief efforts provided by KSrelief during the COVID-19 crisis, and assesses its impact on the seroprevalence of COVID-19 antibodies in health care workers in Yemen. Also, the study investigates the seroprevalence of anti-SARS-CoV-2 antibodies among a representative group of HCWs and hospital administrative personnel in Lahj and AL-Dhalea governorates of Yemen, and correlates these findings to the data generated by KSrelief.

Our findings indicate a high prevalence (94.3%) of anti-SARS-CoV-2 antibodies among HCWs and auxiliary hospital staff. The study was conducted from 1 June-30 September 2022, after the peak of the COVID-19 pandemic in Yemen (WHO, 2022a). A far lower SARS-CoV-2 seroprevalence (27.5%) was reported in a previous study in the southern major Yemeni city of Aden during the first peak of the pandemic between November and December 2020 (Bin-Gouth *et al*., 2022).

Our finding reflects an increase in the rate of seroprevalence in Yemen after the recent fifth SARS-CoV-2 wave at the global level (WHO, 2022c). However, the high seroprevalence in Yemen could be due to the inadequate implementation of the confinement measures because of the political turmoil and war in the country. Another reason might be due to natural infection rather than due to the vaccination. This is because the vaccination coverage against COVID-19 in Yemen is extremely low. As of 2 January 2023, only 1,242,982 vaccine doses were administered in a country of

32 million people. The present study was conducted after the fifth SARS-CoV-2 pandemic wave that might have caused a further increase in the rate of seropositivity (WHO, 2022a). The HCWs being a high-risk group of acquiring SARS-CoV-2 infection given their direct role in patient care provides yet another reason for high seroprevalence (El-Raey *et al*., 2021). Furthermore the unavailability and lack of appropriate PPE, inadequate training and decreased compliance in the implementation of the IPC measures adds to the high seropositivity rate (Zawiah *et al*., 2020). This was clearly noticed in the responses of the participants where only 38.1% of the HCWs received IPC training, 48.0% showed an overall level of adherence to the IPC protocol, and a mere 22.3% followed the appropriate IPC standard precautions. Moreover, a significant number of the HCWs reported unavailability or inadequate supply of PPE, and 28.5% of participants did not use PPE even during their contact with COVID-19 patients. All these conducts illustrated that any intervention to reduce the outbreak of disease cannot be fulfilled in an environment where there is laxity in implementation and compliance of the IPC protocol by the HCWs.

Being a third world country, Yemen has poor medical infrastructure (Mohamed Ibrahim *et al*., 2021). The data generated after analysing the tremendous amount of medical aid supplied by the KSrelief we believe one of the reasons for high seroprevalence rate in spite of such a huge effort, is the under-utilisation of the medical supplies by the hospitals as well as the HCWs. This may be due the lack of knowledge, training, and hesitancy to use the medical aid, particularly PPE.

A recent study from Malaysia identified that HCWs with inadequate knowledge and training related to the use of PPE were twice as likely to be infected with COVID-19 than those with adequate knowledge and training (Mohamad *et al*., 2022). Another study from Somalia concluded that 61.4% of the HCWs had a low compliance rate related to the implementation of IPC measures; the primary reason for such a high rate is due to a low risk perception among the HCWs (Nor *et al*., 2022). Moreover, other studies showed that the perception of the organisational and environmental factors related to the IPC measures significantly affected compliance and attitude, leading to low utilisation of PPE (Mae and Angelo, 2021).

A small percentage of our HCWs (23.5%) reported receiving the COVID-19 vaccine. However, no significant differences were noted in the seropositivity between those who received and those who did not receive the vaccine. This could suggest that the HCW became seropositive prior to vaccination and the role of the vaccine was obscured by the immunity induced by natural infection. Moreover, it could also reflect the decreased level of awareness among the HCWs related to the importance of vaccine in reducing the severity of the disease.

Yemen is facing many challenges in developing reliable epidemiological report on COVID-19. This is due to a weak epidemiological surveillance system, lack of an adequate number of RT-PCRs as well as serological tests, lack of community cooperation with the epidemiological surveillance teams, and, above all, the weak security system due to the political conflict.

KSrelief, an humanitarian assistance organisation working under the patronage of His Highness King Salman bin Abdulaziz Al Saud of the KSA, has implemented 764 programmes and projects in

Yemen during the past 5 years to alleviate the suffering of the people of Yemen during the ongoing political conflict. Moreover, the relief measures were increased tremendously during the COVID-19 pandemic (Zawiah *et al*., 2020). The Kingdom of Saudi Arabia announced an economic package worth US$3 billion in humanitarian support (World Bank, 2022). The country faced additional challenges due to the SARS-CoV-2 waves that doubled the suffering of the people infected with COVID-19. The medical aid supplied by KSrelief helped to alleviate the people's suffering, as well as providing a much-needed lifeline to the health care system of Yemen.

Strengths and Limitations

To the best of our knowledge, ours is the first study that assesses the impact of the humanitarian assistance provided by KSrelief in Yemen during the COVID-19 crisis with the level of seroprevalence of COVID-19 among the HCWs in Lahj and AL-Dhalea governorate in Yemen. Also, ours is the first study to document the seropositivity of SARS-CoV-2 antibodies in HCWs in Yemen after the fifth global COVID-19 wave. Although the humanitarian assistance to Yemen was provided by KSrelief since the beginning of the political turmoil, the relief measures were increased exponentially to counter the challenges of the COVID-19 pandemic, and the social and economic deprivation due to the ongoing war.

The findings in this report are subject to some limitations, including the non-generalisation of the findings among HCWs in different healthcare settings in the country as only 2 governorates in Yemen out of 22 were selected. Although the KSrelief efforts were directed to all the governorates of Yemen, the impact of these efforts on the seroprevalence rate in other regions needs to be assessed to get an overall view of the correlation between the two. The serologic test conducted in our study is qualitative rather than quantitative; therefore, it does not determine the quantitative value or the rate of increase in the levels of antibodies to SARS-CoV-2. Moreover, there are several potential information recall biases, such as in reporting of previous infection with SARS-CoV-2, the use of PPE, and IPC training. Finally, the seroprevalence survey was not designed to assess the anti-spike antibodies due to vaccination.

CONCLUSIONS

Despite the huge medical aid supplied by KSrelief, seroprevalence of SARS-CoV-2 is very high among HCWs working in hospitals in the two governorates of Yemen. Under-utilisation of the aid efforts might be one of the reasons for such a high rate of seropositivity. Inadequate implementation of IPC protocol and control measures and decreased uptake of COVID-19 vaccine have played a major role in the spread of SARS-CoV-2 viral infection among HCWs. Vaccination and reinforcement of IPC measures and training activities for imparting the knowledge and appropriate implementation of the IPC protocol are key to preventing morbidity and mortality among HCWs. The high seroprevalence suggests that natural immunity induced by infection is giving rise to a long-lasting herd immunity that may exceed efficacy of multiple vaccine doses. Antibodies

detected in this study do not confer immunity *per se*, but reflect previous exposure to infection that subsequently leads to immunity. The high seropositivity among HCWs may also reflect the level of seroprevalence among the general population given the inadequate implementation of confinement measures during the pandemic. Ensuring adequate IPC training will hopefully lead to behavioural change, will be crucial to prevent any breach in IPC protocol, and therefore minimise the risk of exposure as well as transmission of COVID-19 in healthcare facilities.

The basic medical infrastructure in Yemen needs to be upgraded so as to better utilise the medical aid. Any hesitancy or misconceptions regarding use of PPE among HCWs should be addressed.

KSrelief's grassroots workers need to be directed to facilitate the implementation and utilisation of the medical efforts in order to employ its full potential for the benefits of the HCWs and the general public. Moreover, any lacunae that negatively effect the adequate deployment of the aid efforts should be conveyed to the relevant authorities in Yemen. A multi-modal approach needs to be implemented to improve the basic medical infrastructure in Yemen from the grassroots level.

Ultimately, the great humanitarian assistance and relief measures provided by KSrelief to the health care sector in Yemen in the form of medical equipment and supplies to fight the COVID crisis sets a true example of universal brotherhood that can be replicated by other organisations working to decrease human suffering from natural or man-made disasters.

The lessons learned from the correlation of the seroprevalence study with the aid efforts can be used as a guide by KSrelief themselves, as well as by the other organisations working to deliver medical aid to conflict-ridden countries, to better manage precious resources and to identify any lacunae that may hinder full utilisation of relief efforts.

Ethical Consideration and Informed Consent

The protocol related to the seroprevalence study was approved by the Ethics Research Committee (ERC) of the Faculty of Medicine and Health Sciences, University of Aden. Verbal and written consent was obtained from all participants who agreed to participate voluntarily in the study after explaining the objectives, importance, and benefits of the research. They were assured that the collected data would be handled with a high level of confidentiality, and would only be used for research purposes.

Risks and Benefits for Subjects

This study poses minimal risk to participants involving the collection of a small amount of blood. The direct benefit to the participant is the potential detection of COVID-19 infection, which would then allow for appropriate monitoring and treatment. The primary benefit of the study is indirect in that the data collected will help to improve and guide efforts to understand the transmission of COVID-19 and to prevent its further spread.

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