

Seroprevalence of SARS-CoV-2 Infection Among Working Women and Impact of Workplace Restrictions

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Objective: To determine the prevalence of SARS-CoV-2 virus infection among female workers who were restricted to working from home compared with those who continued to attend in-person work.

Methods: As part of national surveillance program, serum samples for SARS-CoV-2 antibody testing and nasopharyngeal swabs for SARS-CoV-2 PCR were obtained on 1636 female school staff and salon/spa workers who were restricted to work remotely (restricted group) and 1190 female health-care workers who continued in-person work (unrestricted group).

Results: Seropositivity rate was 5.1% among the restricted and 22.7% among the unrestricted group ($P < 0.0001$). Presence of symptoms at baseline (adjusted odds ratio [aOR], 2.88; 95% CI 2.09–3.97), contact with a confirmed case (aOR 2.34; 95% CI 1.37–3.98), and unrestricted work type (aOR 4.71; 95% CI 3.24–6.86) were associated with a higher risk of infection, while increasing age was associated with a lower risk of infection.

Conclusion: Prevalence of SARS-CoV-2 infection as determined by seropositivity was higher among women who were not subject to workplace restrictions.

Keywords: SARS-CoV-2, COVID-19, work-place restrictions, women, infections, Qatar

Introduction

In response to the SARS-CoV-2 pandemic, many countries imposed varying levels of restrictions on gathering and movement of people. Such restrictions included a reduction in number of persons physically present in the workplace, and number of persons congregating in a closed space at any given time.¹ The intent of these restrictions was to reduce the workplace transmission of infection. However, data supporting this approach, particularly quantifiable impact on transmission of infection, are sparse. Workplace conditions and requirements vary significantly according to the work type, setting and local customs and norms. Certain professions require extensive outdoor mobility and contact with other persons, while others require work in solitude without any need for external mobility.² Expatriate workers are an important sector in the population of Qatar and represent about 85% of the whole population.^{1,3–5} Women predominate certain work types and changes in work pattern may significantly alter the infection risk in such settings.

Effect of workplace restrictions upon the incidence or prevalence of SARS-CoV-2 infection in female workers is also unknown. On March 17, 2020, Qatar introduced several public health measures to curb the spread of the pandemic.¹ These measures included restricting travel outside one's usual place of dwelling to essential travel, mandating at least 80% of non-critical staff at government and private organizations to work from home, partially or completely closing down salons, malls, restaurants and schools, and limiting the entry of non-citizens and non-residents into the country.

After noting a sustained reduction in pandemic spread, these restrictions were eased on September 10, 2020, with special provisions and requirements for the salon workers and school staff to be tested for SARS-CoV-2 before joining work in-person and subsequently on an ongoing basis.

Using serologic tests to detect the presence of SARS-CoV-2 antibodies is useful to estimate the prevalence of infection in a population, particularly when a large proportion of cases are asymptomatic and unrecognized.⁶ We undertook this study to determine the incidence and risk of SARS-CoV-2 infection in women who were restricted to working in an indoor setting compared with women who continued to commute to work and attend work in person.

Methods

Study Setting and Participants

The study was conducted in Qatar between March 17, 2020, and September 10, 2020. Two groups were included in the current study: 1) working women who were restricted to working from home, working indoors, or temporarily furloughed (restricted group); and 2) working women who continued to work as usual, with full in-person attendance (unrestricted group). The first group included female school staff and salon/spa workers, while the second group included female health-care workers at Hamad Medical Corporation, the largest integrated public health service network in Qatar which provided approximately 85% of the in-patient hospital bed capacity in Qatar. Among these groups, all persons who underwent serum antibody testing during the study period were included. Serologic testing was voluntary and was offered to all workers in those sectors as part of a national surveillance campaign through the Ministry of Public Health Qatar.

All participants were also tested for SARS-CoV-2 infection using RT-PCR on a nasopharyngeal swab as part of their workplace requirement and national guidelines. A negative test was required for continuing work. Those with a positive test were required to undergo isolation for 10–14 days with a negative test required to resume work.

SARS-CoV-2 Testing

An electrochemiluminescence immunoassay, Roche Elecsys[®] Anti-SARS-CoV-2 (99.5% sensitivity,⁷ 99.8% specificity,^{7,8} Roche, Switzerland, was used to identify antibodies in the serological samples. Reactive for optical density (a proxy for antibody titer) cutoff index 1.0 and non-reactive for cutoff index 1.0, according to manufacturer instructions.⁸ PCR testing of aliquots of Universal Transport Medium UTM) used for nasopharyngeal and oropharyngeal swab collection was utilized to assess current infection (Huachenyang Technology, China).

Aliquots were extracted using the QIA Symphony platform (QIAGEN, USA) and evaluated using the TaqPath[™] COVID-19 Combo Kit (100% sensitivity and specificity;⁹ Thermo Fisher Scientific, USA) on an ABI 7500 FAST (Thermo Fisher, USA). On a Hamilton Microlab STAR (Hamilton, USA), samples were extracted using a custom protocol¹⁰ and tested using the AccuPower SARS-CoV-2 Real-Time RT-PCR Kit (100% sensitivity and specificity)¹¹ on an ABI 7500 FAST, or directly loaded into a Roche cobas[®] 6800 system to be assayed. All laboratory testing was done at the HMC Central Laboratory according to defined procedures.^{12–15} The laboratory is accredited by the College of American Pathologists.

Data Collection

Demographic and clinical information were obtained from the electronic medical records using structured chart reviews. Presence of comorbidities was ascertained based on at least one confirmatory physician note. Severe disease was defined as hospitalization, admission to an intensive care or monitored setting, invasive or non-invasive mechanical ventilation, or death. Presence of symptoms at the time of testing, history of contact with a confirmed case with SARS-CoV-2 infection, and type of accommodation were obtained through in-person interview at time of testing or through a subsequent telephone follow-up.

Statistical Analyses

Baseline characteristics were compared between restricted and unrestricted group using the Mann–Whitney *U*-test or the chi-squared test, as appropriate. Logistic regression was used to calculate the odds ratios and 95% confidence intervals to determine the factors associated with infection (PCR and/or antibody positivity). A stepwise multivariable model was used

and covariates with p-values less than 0.2 in univariable regression analysis were included in the multivariable model. Adjusted odds ratios (aOR) and corresponding 95% confidence intervals were generated. Where p-values were generated, a value of <0.05 was considered statistically significant. Statistical analyses were performed using IBM SPSS Statistics 21.

Ethical Considerations

The study was approved by the Institutional Review Board at Hamad Medical Corporation. A waiver of informed consent was granted since all testing was performed as a part of the national public health response to the pandemic. Patient data was confidentially treated and in compliance with the Declaration of Helsinki (Study number MRC-01-20-982) (Study number MRC-01-20-982).

Results

A total of 2826 women (1636 in the restricted group and 1190 in the unrestricted group) were included in the current study (Figure 1). Among the restricted group, 84/1636 (5.1%) were seropositive at baseline compared with 270/1190 (22.7%) among the unrestricted group ($P < 0.0001$). The median age for the workers in the restricted group was 37 years (IQR 32, 44), while the median age in the unrestricted group was 30 years (IQR 26, 35). A vast majority of workers in both groups had no comorbidities (87.5% among the restricted and 97.5% among the unrestricted group had no comorbidities; $P < 0.0001$). Symptoms were present at baseline in 17.5% of those in the restricted group and 15.5% of those in the unrestricted group ($P = 0.14$). Workers in the unrestricted group were more likely to report contact with a confirmed case and were more likely to reside in shared accommodations with non-family members (Table 1).

Among those in the restricted group who were seropositive ($n = 84$), 1 (1.2%) was positive by RT-PCR concurrently on a nasopharyngeal swab specimen, while 29 (34.5%) had a previously documented positive RT-PCR. Among those in the restricted group who were seronegative ($n = 1552$), 25 (1.6%) were positive by RT-PCR concurrently on a nasopharyngeal swab specimen. Among those in the unrestricted group who were seropositive ($n = 270$), 9 (3.3%) were positive by RT-PCR concurrently on a nasopharyngeal swab specimen, while 148 (54.8%) had a previously documented positive RT-PCR. Among those in the unrestricted group who were seronegative ($n = 920$), 12 (1.3%)

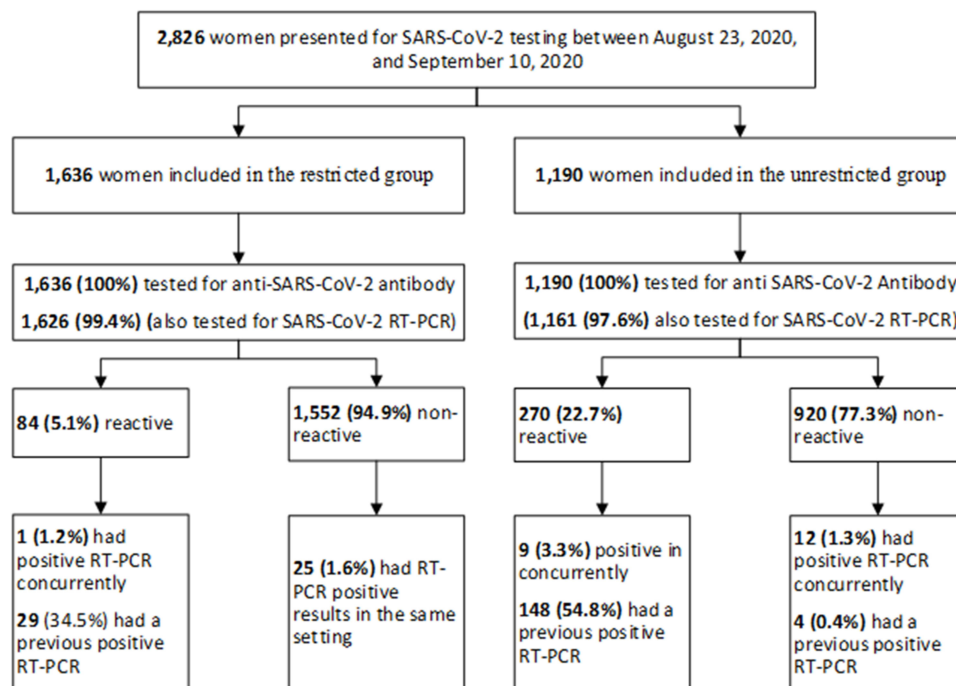


Figure 1 Study flowsheet.

Table 1 Baseline Characteristics of Working Women with Work Restrictions (Restricted Group) vs Working Women with No Work Restrictions (Unrestricted Group)

	Restricted Group	Unrestricted Group	p-value
	N=1636	N=1190	
Median age (IQR) years	37 (32, 44)	30 (26, 35)	<0.0001
Nationality, N (%)			<0.0001
Indian	814 (49.8)	37 (3.1)	
Filipino	228 (13.9)	455 (38.2)	
Nepalese	122 (7.5)	353 (29.7)	
Sri Lankan	136 (8.3)	12 (1.0)	
Kenyan	29 (1.8)	167 (14.0)	
Egyptian	57 (3.5)	2 (0.2)	
British/Irish	42 (2.6)	1 (0.1)	
Tunisian	8 (0.5)	38 (3.2)	
Others	200 (12.2)	125 (10.5)	
Number of comorbidities			<0.0001
None, N (%)	1432 (87.5)	1160 (97.5)	
1–2, N (%)	190 (11.6)	30 (2.5)	
≥3, N (%)	14 (0.9)	0	
Comorbidities, N (%)			
Diabetes	42 (2.6)	3 (0.3)	<0.0001
Hypertension	73 (4.5)	8 (0.7)	<0.0001
Cardiovascular disease	9 (0.6)	1 (0.1)	0.04
Chronic kidney disease	3 (0.2)	0	0.19
Chronic lung disease	46 (2.8)	12 (1.0)	0.001
Chronic liver disease	6 (0.4)	0	0.04
Cancer diagnosis	3 (0.2)	1 (0.1)	0.44
Immune disorders	43 (2.6)	1 (0.1)	<0.0001
Symptomatic at baseline, N (%)	287 (17.5)	184 (15.5)	0.14
Contact with confirmed case, N (%)	22 (1.3)	68 (5.7)	<0.0001
Accommodation status, N (%)			<0.0001
Single housing	21 (1.3)	3 (0.3)	
Family housing	1552 (94.9)	45 (3.8)	
Shared with non-family members	63 (3.9)	1142 (96.0)	
Median Education (IQR) years	16 (16, 16)	16 (12, 16)	0.23
Seropositive, N (%)	84 (5.1)	270 (22.7)	<0.0001

(Continued)

Table 1 (Continued).

	Restricted Group	Unrestricted Group	p-value
	N=1636	N=1190	
RT-PCR positive, N (%)	55 (3.4)	173 (14.7)	<0.0001
Either/both positive, N (%)	109 (6.7)	286 (24.0)	<0.0001

were positive by RT-PCR concurrently on a nasopharyngeal swab specimen, while 4 (0.4%) had a previously documented positive RT-PCR (Figure 1).

A comparison of baseline characteristics of workers in the restricted and unrestricted group with evidence of infection SARS-CoV-2 either by RT-PCR or serological test is provided in Table 2. In a multivariable logistic regression model, presence of symptoms at baseline (OR 2.88; 95% CI 2.09–3.97), contact with a confirmed case (OR 2.34; 95% CI 1.37–3.98), and being in the unrestricted group (OR 4.71; 95% CI 3.24–6.86) were associated with a higher risk of seropositivity, while increasing age (OR 0.81 per 10 year increase; 95% CI 0.68, 0.97) was associated with lower risk of seropositivity (Table 3).

Discussion

The SARS-CoV-2 pandemic has significantly impacted nearly all facets of public life. The pandemic forced many countries, including Qatar, to implement varying degrees of restrictions on the way people gathered, traveled, and worked.¹ While some of these restrictions were based on evidence, others had little evidence to support them. The impact of work-place restrictions upon the risk of SARS-CoV-2 infection in the female work force has not been described before.

We compared two groups of working women. First group were those who were restricted to working from home or were in professions where their place of work was closed and thereby their movements were restricted. This restricted group included school staff and salon/spa workers since schools were required to switch to online teaching and salons and spas were closed during the study period. The second group comprised female health-care workers at Hamad Medical Corporation. This unrestricted group was required to attend work in-person throughout the study period due to the nature of their work, and therefore commuted to work on a regular basis. We found that the overall infection rate SARS-CoV-2 RT-PCR among the restricted group was significantly lower than that of the unrestricted group (6.6% vs 24.0% respectively). The reason for this is quite intuitive, since individuals in the unrestricted group had more contact with others and were more likely to be exposed to an infected person. While such exposure could have occurred within or outside the workplace, we and others have previously reported that SARS-CoV-2 infections among health-care workers are more likely to be associated with community exposure rather than work-related exposure.^{12,14,16–18} In line with our findings, an Italian investigation found that workers with minimal exposure had significant low infection in the early months of 2020, from May to June.² Workers in the unrestricted group were >4 times more likely to report contact with a confirmed case, though for the current study we did not ascertain where such contact occurred. Workers in the unrestricted group, which were exclusively health-care workers, were nearly 3 times more likely to have SARS-CoV-2 infection than workers in the restricted group. Though not conclusive, these results collectively suggest that mobility likely played a significant role in acquisition of infection among workers in the unrestricted group.

Most workers in the restricted group lived in family accommodations, while the workers in the unrestricted group predominantly lived in accommodation which was shared with non-family members. Sharing living space with non-family members has been shown to be a risk factor for acquiring SARS-CoV-2 infection and our data support the previous findings.^{13,16,19,20}

Presence of symptoms and contact with a confirmed case were independently associated with a higher risk of infection. These findings can help policymakers and public health officials identify a high-risk subgroup of persons who may need to be tested more frequently or more aggressively furloughed to prevent further spread of infection. Future modeling studies can help quantify such risk and help create a risk-based prediction model or algorithm for early

Table 2 Baseline Characteristics of Restricted and Unrestricted Staff with Any Evidence of SARS-CoV-2 Virus

	RT-PCR-SARS-CoV-2 Positivity			Anti-SARS-CoV-2 Positivity		
	Restricted Group	Unrestricted Group	p-value	Restricted Group	Unrestricted Group	p-value
N (%)	55 (3.4)	173 (14.7)	<0.0001	84 (5.1)	270 (22.7)	<0.0001
Missing N, (%)	10	29		0	0	
Seropositive, N (%)	30 (54.5)	157 (90.8)	<0.0001			
RT-PCR positive, N (%)				30 (35.7)	157 (59.2)	<0.0001
Nationality, N (%)			<0.0001			<0.0001
Indian	13 (23.6)	4 (2.3)		40 (47.6)	6 (2.2)	
Filipino	9 (16.4)	53 (30.6)		10 (11.9)	88 (32.6)	
Nepalese	11 (20.0)	83 (48.0)		4 (4.8)	111 (41.1)	
Sri Lankan	4 (7.3)	1 (0.6)		8 (9.5)	1 (0.4)	
Kenyan	1 (1.8)	20 (11.6)		1 (1.2)	35 (13.0)	
Egyptian	5 (9.1)	0		6 (7.1)	0	
British/Irish	1 (1.8)	0		2 (2.4)	0	
Tunisian	0	4 (2.3)		0	6 (2.2)	
Others	11 (20.0)	8 (4.6)		13 (15.5)	23 (8.5)	
Number of Comorbidities, N (%)			<0.0001			<0.0001
None	41 (74.5)	166 (96.0)		69 (82.1)	261 (96.7)	
1–2	13 (23.6)	7 (4.0)		14 (16.7)	9 (3.3)	
≥3	1 (1.8)	0		1 (1.2)	0	
Comorbidities, N (%)						
Diabetes	4 (7.3)	1 (0.6)	0.003	5 (6.0)	0	<0.0001
Hypertension	3 (5.5)	3 (1.7)	0.13	5 (6.0)	3 (1.1)	0.009
Cardiovascular disease	0	1 (0.6)	0.57	0	1 (0.4)	0.58
Chronic lung disease	1 (1.8)	3 (1.7)	0.97	3 (3.6)	4 (1.5)	0.23
Chronic liver disease	1 (1.8)	0	0.08	0	0	
Neurological disease	1 (1.8)	0	0.08	1 (1.2)	0	0.07
Cancer diagnosis	2 (3.6)	0	0.01	1 (1.2)	0	0.07
Immune disorders	1 (1.8)	0	0.08	1 (1.2)	0	0.07
Rheumatological disease	0	0		1 (1.2)	0	0.07
Symptomatic at baseline, N (%)	20 (36.4)	81 (46.8)	0.17	26 (31.0)	89 (33.0)	0.73
Contact with confirmed case, N (%)	10 (18.2)	31 (17.9)	0.97	10 (11.9)	32 (76.2)	0.99

(Continued)

Table 2 (Continued).

	RT-PCR-SARS-CoV-2 Positivity			Anti-SARS-CoV-2 Positivity		
	Restricted Group	Unrestricted Group	p-value	Restricted Group	Unrestricted Group	p-value
Accommodation status, N (%)			<0.0001			<0.0001
Single housing	0	0		0	1 (0.4)	
Family housing	55 (100.0)	3 (1.7)		1 (1.2)	265 (98.1)	
Shared with non-family members	0	170 (98.3)		83 (98.8)	4 (1.5)	
Median age (IQR) years	36 (30, 40)	30 (26, 35)	<0.0001	35.5 (31, 43)	29 (26, 34.3)	<0.0001
Median Education (IQR) years	16 (16, 16)	14 (10, 16)	0.40	16 (16, 16)	14 (11.5, 16)	0.39
Median CT value (IQR)	24 (19, 32)	25 (20, 31)	0.65	22 (18, 30)	25 (20, 31)	0.36
Median anti SARSCov-2 antibody (IQR)	51.6 (18.6, 118.0)	58.9 (22.0, 110.0)	0.95	46.7 (14, 92.6)	48.1 (15.4, 94.4)	0.84
Need for hospitalization, N (%)	3 (5.5)	2 (1.2)	0.06	2 (2.4)	3 (1.1)	0.39
Pneumonia, N (%)	2 (3.6)	1 (0.6)	0.08	1 (1.2)	1 (0.4)	0.38

Table 3 Factors Associated with SARS-CoV-2 Infection Among Female Workers

	RT-PCR-SARS-CoV-2 Positivity		Anti-SARS-CoV-2 Positivity	
	Odds Ratio (95% CI)	p-value	Odds Ratio (95% CI)	p-value
Age 10-year increase	0.84 (0.67–1.06)	0.14	0.81 (0.68–0.97)	0.03
Nationality (vs Indian)				
Filipino	2.41 (1.26–4.59)	0.008	0.94 (0.59–1.50)	0.81
Nepalese	7.47 (3.92–14.22)	<0.0001	1.78 (1.11–2.85)	0.02
Sri Lankan	1.44 (0.51–4.08)	0.50	0.91 (0.43–1.95)	0.81
Kenyan	2.68 (1.22–5.90)	0.01	0.99 (0.56–1.76)	0.98
Egyptian	6.34 (2.15–18.72)	0.001	2.03 (0.79–5.22)	0.14
British/Irish	1.06 (0.13–8.71)	0.96	0.92 (0.21–4.0)	0.91
Tunisian	1.03 (0.29–3.73)	0.96	0.46 (1.66–1.26)	0.13
Others	1.40 (0.67–2.93)	0.37	0.84 (0.50–1.42)	0.53
Symptomatic at baseline	4.81 (3.30–7.0)	<0.0001	2.88 (2.09–3.97)	<0.0001
Contact with confirmed case	3.72 (2.10–6.56)	<0.0001	2.34 (1.37–3.98)	0.002
Unrestricted group (vs restricted)	2.90 (1.86–4.51)	<0.0001	4.71 (3.24–6.86)	<0.0001
Comorbidities (vs none)				
1–2	1.97 (1.12, 3.47)	0.02	1.37 (0.83–2.25)	0.22
≥3	3.93 (0.46–33.6)	0.21	1.99 (0.25–15.93)	0.52

identification and isolation/quarantine of highest risk persons. Notably, restricting some employees from working outdoors can protect vulnerable populations by reducing their chances of exposure to the infected workers, particularly those who are asymptomatic. Accumulating evidences showed that transmission can happen from young asymptomatic or mildly symptomatic cases who are freely mobile in the population.^{14,21–23}

We also found that 64.7% of workers in the restricted group and 59.2% in the unrestricted group were incidentally detected during serologic or PCR screening. Many of these persons are asymptomatic at the time of infection and can lead to further spread of infections. Previous mathematical modeling from Qatar demonstrated that in the absence of government enforced interventions, including work restriction, the epidemic would have been far worse and progressed to 10-fold higher number of infections than the current numbers.⁵

Strengths of our study include a large national sample with extensive validated data captured from the National COVID-19 database and supplemented by individual chart reviews and surveys. Certain limitations also need to be noted. The analyses were retrospective in nature. While all participants provided a serum sample for antibody testing, a few did not provide concurrent nasopharyngeal swabs for RT-PCR (10 in the restricted and 29 in the unrestricted group). Some individuals may not have presented for testing previously even in the presence of symptoms. Finally, we did not assess the impact of vaccination, since vaccines were authorized for use after the end of the study period.

Conclusion

In conclusion, female workers who were not restricted from in-person work attendance were significantly more likely to be infected with SARS-CoV-2 than female workers who were restricted from attending in-person work. While not always possible due to the nature of some work, certain restrictions in mobility and in-person attendance during rapidly expanding pandemics can help curtail a proportion of new infections.

Ethics Statement

The study was approved by HMC Institutional Review Boards.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work. Dr. Moza Alishaq had access to all data at all times and takes responsibility for the accuracy of data.

Disclosure

All authors declare no competing interest and have no financial disclosures relevant to this paper.

References

1. Al Kuwari HM, Abdul Rahim HF, Abu-Raddad LJ, et al. Epidemiological investigation of the first 5685 cases of SARS-CoV-2 infection in Qatar, 28 February–18 April 2020. *BMJ Open*. 2020;10(10):e040428. doi:10.1136/bmjopen-2020-040428
2. Della Valle P, Fabbri M, Madotto F, et al.; The MUSTANG–OCCUPATION–COVID-19 Study Group. Occupational exposure in the Lombardy Region (Italy) to SARS-CoV-2 infection: results from the MUSTANG–OCCUPATION–COVID-19 study. *Int J Environ Res Public Health*. 2021;18(5):2567. doi:10.3390/ijerph18052567

3. Alajmi J, Jeremijenko AM, Abraham JC, et al. COVID-19 infection among healthcare workers in a national healthcare system: the Qatar experience. *Int J Infect Dis.* 2020;100:386–389. doi:10.1016/j.ijid.2020.09.027
4. Butt AA, Kartha AB, Masoodi NA, et al. Hospital admission rates, length of stay, and in-hospital mortality for common acute care conditions in COVID-19 vs. pre-COVID-19 era. *Public Health.* 2020;189:6–11. doi:10.1016/j.puhe.2020.09.010
5. Ayoub HH, Chemaitelly H, Seedat S, et al. Mathematical modeling of the SARS-CoV-2 epidemic in Qatar and its impact on the national response to COVID-19. *J Glob Health.* 2021;11:05005. doi:10.7189/jogh.11.05005
6. Biggs HM, Harris JB, Breakwell L, et al; CDC Field Surveyor Team (2020). Estimated community seroprevalence of SARS-CoV-2 antibodies - two Georgia counties, April 28–May 3, 2020. *MMWR.* 2020;69(29):965–970. doi:10.15585/mmwr.mm6929e2
7. Muench P, Jochum S, Wenderoth V, et al. Development and validation of the elecsys anti-SARS-CoV-2 immunoassay as a highly specific tool for determining past exposure to SARS-CoV-2. *J Clin Microbiol.* 2020;58. doi:10.1128/JCM.01694-20
8. The Roche Group. Roche's COVID-19 antibody test receives FDA emergency use authorization and is available in markets accepting the CE mark. Available from: <https://www.roche.com/media/releases/med-cor-2020-05-03.htm>. Accessed June 5, 2020.
9. Thermo fisher scientific TaqPath™ COVID-19 CE-IVD RT-PCR Kit instructions for use. Available from: https://assets.thermofisher.com/TFSAssets/LSG/manuals/MAN0019215_TaqPathCOVID-19_CE-IVD_RT-PCR%20Kit_IFU.pdf. Accessed December 2, 2020.
10. Kalikiri MKR, Hasan MR, Mirza F, et al. High-throughput extraction of SARS-CoV-2 RNA from nasopharyngeal swabs using solid-phase reverse immobilization beads. *medRxiv.* 2020. doi:10.1101/2020.04.08.20055731
11. Kubina R, Dziejdz A. Molecular and serological tests for COVID-19 a comparative review of SARS-CoV-2 coronavirus laboratory and point-of-care diagnostics. *Diagnostics.* 2020;10:434. doi:10.3390/diagnostics10060434
12. Alishaq M, Jeremijenko A, Nafady-Hego H, et al. SARS-CoV-2 infection in mortuary and cemetery workers. *Int J Infect Dis.* 2021;105:621–625. doi:10.1016/j.ijid.2021.03.012
13. Alishaq M, Jeremijenko A, Nafady-Hego H, et al. SARS-CoV-2 PCR and antibody positivity among school staff at the beginning and end of the first school term. *BMC Public Health.* 2021;21(1):2070. doi:10.1186/s12889-021-12134-4
14. Alishaq M, Jeremijenko A, Al-Kanaani Z, et al. Prevalence and risk factors for SARS-CoV-2 infection and seroprevalence among clinical and non-clinical staff in a national healthcare system. *PLoS One.* 2021;16(9):e0257845. doi:10.1371/journal.pone.0257845
15. Alishaq M, Nafady-Hego H, Jeremijenko A, et al. Risk factors for breakthrough SARS-CoV-2 infection in vaccinated healthcare workers. *PLoS One.* 2021;16(10):e0258820. doi:10.1371/journal.pone.0258820
16. Jeremijenko A, Chemaitelly H, Ayoub HH, et al. Herd immunity against severe acute respiratory syndrome coronavirus 2 infection in 10 communities, Qatar. *Emerg Infect Dis.* 2021;27(5):1343–1352. doi:10.3201/eid2705.204365
17. Coyle PV, Chemaitelly H, Ben Hadj Kacem MA, et al. SARS-CoV-2 seroprevalence in the urban population of Qatar: an analysis of antibody testing on a sample of 112,941 individuals. *iScience.* 2021;24(6):102646. doi:10.1016/j.isci.2021.102646
18. Sikkema RS, Pas SD, Nieuwenhuijse DF, et al. COVID-19 in health-care workers in three hospitals in the south of the Netherlands: a cross-sectional study. *Lancet Infect Dis.* 2020;20(11):1273–1280. doi:10.1016/S1473-3099(20)30527-2
19. Abu-Raddad LJ, Chemaitelly H, Ayoub HH, et al. Characterizing the Qatar advanced-phase SARS-CoV-2 epidemic. *Sci Rep.* 2021;11(1):6233. doi:10.1038/s41598-021-85428-7
20. Al-Thani MH, Farag E, Bertolini R, et al. SARS-CoV-2 infection is at herd immunity in the majority segment of the population of Qatar. *Open Forum Infect Dis.* 2021;8(8). doi:10.1093/ofid/ofab221
21. Rothe C, Schunk M, Sothmann P, et al. Transmission of 2019-nCoV infection from an asymptomatic contact in Germany. *N Engl J Med.* 2020;382(10):970–971. doi:10.1056/NEJMc2001468
22. Kim ES, Chin BS, Kang CK, et al. Clinical course and outcomes of patients with severe acute respiratory syndrome coronavirus 2 infection: a preliminary report of the first 28 patients from the Korean Cohort Study on COVID-19. *J Korean Med Sci.* 2020;35(13):e142. doi:10.3346/jkms.2020.35.e142
23. Bai Y, Yao L, Wei T, et al. Presumed asymptomatic carrier transmission of COVID-19. *JAMA.* 2020;323(14):1406–1407. doi:10.1001/jama.2020.2565

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