

Herd Immunity against Severe Acute Respiratory Syndrome Coronavirus 2 Infection in 10 Communities, Qatar

Appendix

Appendix Table 1. Characteristics of CMW communities 2–10 and associations with SARS-CoV-2 seropositivity (detectable antibodies in serologic samples), Qatar*

Characteristic	No. (%)† tested	SARS-CoV-2 seropositive			Univariable regression analysis	
		No.	%‡ (95% CI)	p value	OR (95% CI)	p value§
CMW community 2						
Sex						
M	385 (84.4)	270	70.1 (65.3–74.7)	<0.001	1.00	
F	71 (15.6)	12	16.9 (9.0–27.7)		0.09 (0.04–0.17)	<0.001
Age, y						
<29	301 (66.0)	180	59.8 (54.0–65.4)	0.005	1.00	
30–39	143 (31.4)	99	69.2 (61.0–76.7)		1.51 (0.99–2.31)	0.055
40–49	12 (2.6)	3	25.0 (5.5–57.2)		0.22 (0.06–0.84)	0.027
Nationality						
Other	47 (10.3)	29	61.7 (46.4–75.5)	<0.001	1.00	
Kenyan	60 (13.2)	27	45.0 (32.1–58.4)		0.51 (0.23–1.11)	0.088
Nepalese	296 (64.9)	181	61.1 (55.3–66.7)		0.98 (0.52–1.84)	0.942
Bangladeshi	53 (11.6)	45	84.9 (72.4–93.3)		3.49 (1.34–9.07)	0.010
CMW community 3						
Sex						
M	291 (100.0)	244	83.8 (79.1–87.9)	NA	NA	
F	NA	NA	NA		NA	NA
Age, y						
<29	81 (27.8)	69	85.2 (75.6–92.1)	0.837	1.00	
30–39	109 (37.5)	89	81.7 (73.1–88.4)		0.77 (0.35–1.69)	0.520
40–49	79 (27.1)	68	86.1 (76.5–92.8)		1.08 (0.44–2.60)	0.872
≥50	22 (7.6)	18	81.8 (59.7–94.8)		0.78 (0.23–2.72)	0.700
Nationality						
Other	5 (1.7)	4	80.0 (28.4–99.5)	0.972	1.00	
Indian	99 (34.0)	83	83.8 (75.1–90.5)		1.30 (0.14–12.37)	0.821
Nepalese	187 (64.3)	157	84.0 (77.9–88.9)		1.31 (0.14–12.12)	0.813
CMW community 4						
Sex						
M	460 (86.1)	309	67.2 (62.7–71.5)	0.001	1.00	
F	74 (13.9)	21	28.4 (18.5–40.1)		0.19 (0.11–0.33)	<0.001
Age, y						
<29	257 (48.1)	168	65.4 (59.2–71.2)	<0.001	1.00	
30–39	200 (37.5)	108	54.0 (46.8–61.1)		0.62 (0.43–0.91)	0.014
40–49	38 (7.1)	17	44.7 (28.6–61.7)		0.43 (0.22–0.85)	0.016
≥50	3 (0.6)	2	66.7 (9.4–99.2)		1.06 (0.09–11.85)	0.963
Missing	36 (6.7)	35	97.2 (85.5–99.9)		18.54 (2.50–137.60)	0.004
Nationality						
Other	49 (9.2)	11	22.4 (11.8–36.6)	<0.001	1.00	
Indian	62 (11.6)	33	53.2 (40.1–66.0)		3.93 (1.70–9.07)	0.001
Nepalese	155 (29.0)	89	57.4 (49.2–65.3)		4.66 (2.22–9.79)	<0.001
Bangladeshi	268 (50.2)	197	73.5 (67.8–78.7)		9.59 (4.65–19.77)	<0.001
CMW community 5						
Sex						
M	437 (98.7)	243	55.6 (50.8–60.3)	0.007	1.00	
F	6 (1.4)	0	0.0 (0.0–45.9)		Omitted by model	NA
Age, y						
<29	117 (26.4)	67	57.3 (47.8–66.4)	0.542	1.00	
30–39	193 (43.6)	106	54.9 (47.6–62.1)		0.91 (0.57–1.44)	0.687

Characteristic	No. (%)† tested	SARS-CoV-2 seropositive			Univariable regression analysis	
		No.	%‡ (95% CI)	p value	OR (95% CI)	p value§
40–49	108 (24.4)	54	50.0 (40.2–59.8)		0.75 (0.44–1.26)	0.275
≥50	25 (5.6)	16	64.0 (42.5–82.0)		1.33 (0.54–3.25)	0.536
Nationality						
Other	46 (10.4)	17	37.0 (23.2–52.5)	<0.001	1.00	
Indian	160 (36.1)	73	45.6 (37.7–53.7)		1.43 (0.73–2.81)	0.297
Sri Lankan	63 (14.2)	35	55.6 (42.5–68.1)		2.13 (0.98–4.64)	0.056
Nepalese	174 (39.3)	118	67.8 (60.3–74.7)		3.59 (1.82–7.08)	<0.001
CMW community 6						
Sex						
M	1465 (97.3)	939	64.1 (61.6–66.6)	<0.001	1.00	
F	40 (2.7)	7	17.5 (7.3–32.8)		0.12 (0.05–0.27)	<0.001
Age, y						
≤29	389 (25.8)	258	66.3 (61.4–71.0)	0.114	1.00	
30–39	644 (42.8)	387	60.1 (56.2–63.9)		0.76 (0.59–0.99)	0.045
40–49	374 (24.9)	244	65.2 (60.2–70.1)		0.95 (0.71–1.29)	0.753
≥50	98 (6.5)	57	58.2 (47.8–68.1)		0.71 (0.45–1.11)	0.132
Nationality						
Other	173 (11.5)	63	36.4 (29.2–44.1)	<0.001	1.00	
Indian	649 (43.1)	408	62.9 (59.0–66.6)		2.96 (2.09–4.19)	<0.001
Nepalese	547 (36.3)	366	66.9 (62.8–70.8)		3.53 (2.47–5.05)	<0.001
Bangladeshi	136 (9.0)	109	80.1 (72.4–86.5)		7.05 (4.18–11.89)	<0.001
CMW community 7						
Sex						
M	188 (100.0)	122	64.9 (57.6–71.7)	NA	NA	
F	NA	NA	NA		NA	NA
Age, y						
≤29	91 (48.4)	61	67.0 (56.4–76.5)	0.703	1.00	
30–39	54 (28.7)	32	59.3 (45.0–72.4)		0.72 (0.36–1.44)	0.346
40–49	29 (15.4)	21	72.4 (52.8–87.3)		1.29 (0.51–3.25)	0.588
≥50	11 (5.9)	6	54.5 (23.4–83.3)		0.59 (0.17–2.09)	0.414
Missing	3 (1.6)	2	66.7 (9.4–99.2)		0.98 (0.09–11.28)	0.989
Nationality						
Other	24 (12.8)	6	25.0 (9.8–46.7)	<0.001	1.00	
Indian	42 (22.3)	2	4.8 (0.6–16.2)		0.15 (2.76–81.64)	0.028
Nepalese	122 (64.9)	114	93.4 (87.5–97.1)		42.75 (13.28–137.66)	<0.001
CMW community 8						
Sex						
M	134 (96.4)	92	68.7 (60.1–76.4)	0.023	1.00	
F	5 (3.6)	1	20.0 (0.5–71.6)		0.11 (0.01–1.05)	0.056
Age, y						
≤29	26 (18.7)	16	61.5 (40.6–79.8)	0.330	1.00	
30–39	70 (50.4)	48	68.6 (56.4–79.1)		1.36 (0.53–3.48)	0.517
40–49	33 (23.7)	20	60.6 (42.1–77.1)		0.96 (0.33–2.76)	0.942
≥50	10 (7.2)	9	90.0 (55.5–99.7)		5.63 (0.62–51.37)	0.126
Nationality						
Other	26 (18.7)	7	26.9 (11.6–47.8)	<0.001	1.00	
Indian	64 (46.0)	46	71.9 (59.2–82.4)		6.94 (2.49–19.31)	<0.001
Bangladeshi	25 (18.0)	18	72.0 (50.6–87.9)		6.98 (2.04–23.88)	0.002
Nepalese	24 (17.3)	22	91.7 (73.0–99.0)		29.86 (5.53–161.34)	<0.001
CMW community 9						
Sex						
Men	164 (81.2)	125	76.2 (69.0–82.5)	<0.001	1.00	
Women	38 (18.8)	1	2.6 (0.1–13.8)		0.01 (0.00–0.06)	<0.001
Age (years)						
≤29	30 (14.9)	16	53.3 (34.3–71.7)	0.201	1.00	
30–39	58 (28.7)	33	56.9 (43.2–69.8)		1.16 (0.48–2.80)	0.750
40–49	61 (30.2)	38	62.3 (49.0–74.4)		1.45 (0.60–3.50)	0.414
50+	53 (26.2)	39	73.6 (59.7–84.7)		2.44 (0.95–6.25)	0.064
Nationality						
All other nationalities	28 (13.9)	17	60.7 (40.6–78.5)	0.766	1.00	
Nepalese	85 (42.1)	51	60.0 (48.8–70.5)		0.97 (0.41–2.33)	0.947
Indian	89 (44.1)	58	65.2 (54.3–75.0)		1.21 (0.50–2.90)	0.668
CMW community 10						
Sex						
M	957 (100.0)	620	64.8 (61.7–67.8)	NA	NA	
F	NA	NA	NA		NA	NA

Characteristic	No. (%)† tested	SARS-CoV-2 seropositive			Univariable regression analysis	
		No.	%‡ (95% CI)	p value	OR (95% CI)	p value§
Age, y						
≤29	189 (19.7)	116	61.4 (54.0–68.4)	0.119	1.00	
30–39	392 (41.0)	243	62.0 (57.0–66.8)		1.03 (0.72–1.47)	0.887
40–49	273 (28.5)	190	69.6 (63.8–75.0)		1.44 (0.98–2.13)	0.067
≥50	103 (10.8)	71	68.9 (59.1–77.7)		1.40 (0.84–2.32)	0.199
Nationality						
Other	69 (7.2)	42	60.9 (48.4–72.4)	0.061	1.00	
Bangladeshi	62 (6.5)	37	59.7 (46.4–71.9)		0.95 (0.47–1.92)	0.889
Nepalese	389 (40.6)	238	61.2 (56.1–66.1)		1.01 (0.60–1.71)	0.961
Indian	437 (45.7)	303	69.3 (64.8–73.6)		1.45 (0.86–2.46)	0.162

*CMW, craft and manual worker; NA, not applicable; OR, odd ratio; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

†Percent positive of those tested.

‡Percent of total sample.

§Covariates with p value ≤0.05 in univariable analysis were considered as showing evidence for an association with SARS-CoV-2 seropositivity.

Appendix Table 2. Characteristics of CMWs and associations with SARS-CoV-2 real-time RT-PCR positivity, Qatar*

Characteristic	No. (%)† tested	SARS-CoV-2 RT-PCR positive			Univariable regression analysis		Multivariable regression analysis‡	
		No.	%§ (95% CI)	p value	OR (95% CI)	p value¶	OR (95% CI)	p value#
Sex								
M	1,844 (91.5)	100	5.4 (4.4–6.6)	0.395	1.00		NA	
F	172 (8.5)	12	7.0 (3.7–11.9)		1.31 (0.70–2.43)	0.396	NA	NA
Age, y								
<29	785 (38.9)	39	5.0 (3.6–6.7)	0.486	1.00		NA	
30–39	787 (39.0)	44	5.6 (4.1–7.4)		1.13 (0.73–1.76)	0.581	NA	NA
40–49	351 (17.4)	25	7.1 (4.7–10.3)		1.47 (0.87–2.46)	0.148	NA	NA
≥50	93 (4.6)	4	4.3 (1.2–10.6)		0.86 (0.30–2.46)	0.778	NA	NA
Nationality								
Other**	149 (7.4)	15	10.1 (5.7–16.1)	0.002	1.00		1.00	
Nepalese	918 (45.5)	46	5.0 (3.7–6.6)		0.47 (0.26–0.87)	0.016	0.43 (0.22–0.82)	0.011
Bangladeshi	265 (13.1)	9	3.4 (1.6–6.3)		0.31 (0.13–0.74)	0.008	0.44 (0.17–1.12)	0.085
Filipino	112 (5.6)	4	3.6 (1.0–8.9)		0.33 (0.11–1.03)	0.055	0.49 (0.15–1.63)	0.242
Indian	572 (28.4)	38	6.6 (4.7–9.0)		0.64 (0.34–1.19)	0.157	0.69 (0.33–1.45)	0.329
CMW community								
6††	832 (41.3)	42	5.0 (3.7–6.8)	<0.001	1.00††		1.00††	
1	92 (4.6)	0	0.0 (0.0–3.9)		Omitted by model	NA	Omitted by model	NA
8	39 (1.9)	0	0.0 (0.0–9.0)		Omitted by model	NA	Omitted by model	NA
4	363 (18)	10	2.8 (1.3–5.0)		0.53 (0.26–1.07)	0.078	0.63 (0.30–1.36)	0.240
2	424 (21.0)	32	7.5 (5.2–10.5)		1.54 (0.95–2.47)	0.077	1.60 (0.91–2.79)	0.099
3	266 (13.2)	28	10.5 (7.1–14.9)		2.21 (1.34–3.65)	0.002	2.44 (1.45–4.08)	0.001

*CMW, craft and manual worker; Ct, cycle threshold; NA, not applicable; OR, odd ratio; RT-PCR, real-time reverse transcription PCR; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

†Percent of total sample.

‡Pseudo-R² value in the multivariable logistic regression model is 3.4%.

§Percentage real-time RT-PCR positive of those tested.

¶Covariates with p value ≤0.2 in univariable analysis were included in multivariable analysis.

#Covariates with p-value ≤0.05 in multivariable analysis were considered predictors of real-time RT-PCR positivity.

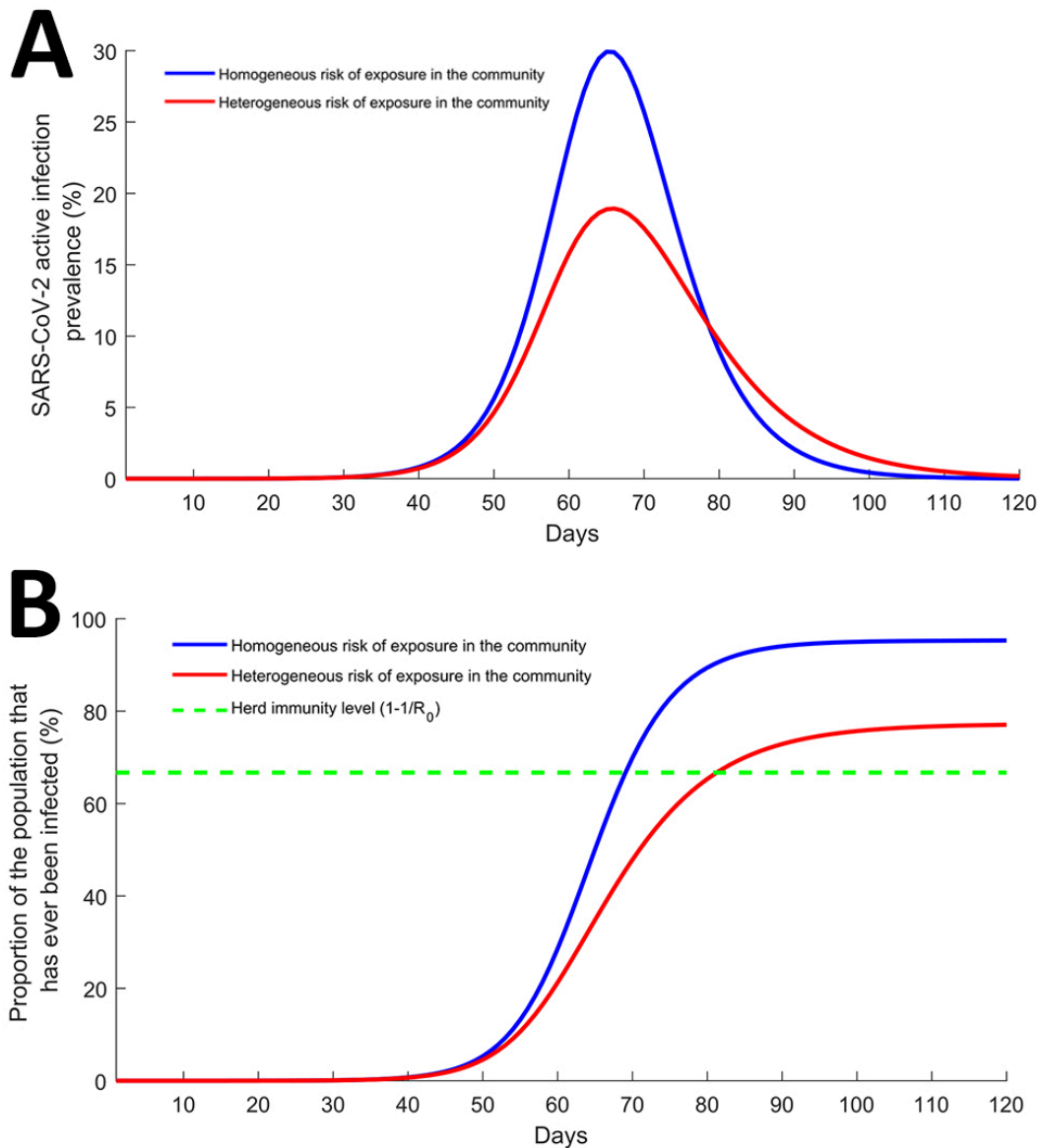
**Includes all other nationalities that contributed <5% of the sample in each community. These are Egyptian, Ghanaian, Indonesian, Jordanian, Kenyan, Lebanese, Nigerian, Pakistani, Sri Lankan, Tunisian, and Ugandan.

††CMW community 6, which had the largest sample size, was chosen as a reference.

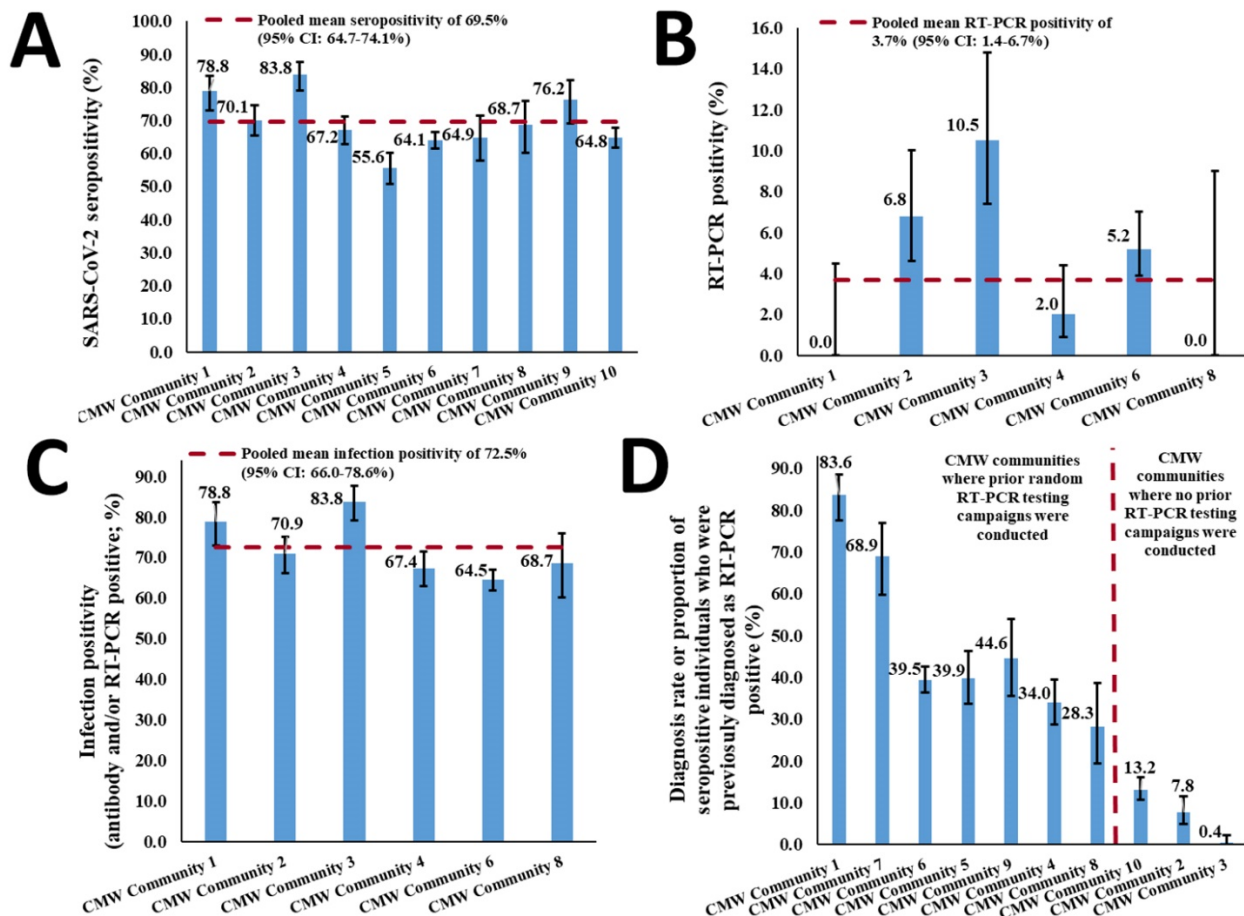
Appendix Table 3. Characteristics of 14 SARS-CoV-2 antibody-negative men who had a real-time RT-PCR positive result for SARS-CoV-2 at some point before this study was conducted, Qatar*

Person no.	Age, y	Date in 2020 of real-time RT-PCR	Ct value	Date in 2020 of antibody test	Symptoms
1	36	May 13	35.5	Aug 2	Not recorded
2	28	May 4	34.1	Aug 3	Not recorded
3	25	May 4	35.1	Aug 3	Not recorded
4	26	Apr 28	22.0	Aug 8	Not recorded
5	40	Jun 6	35.5	Jul 23	Not recorded
6	33	Jun 9	23.7	Jul 27	Not recorded
7	27	May 12	35.8	Jul 28	Not recorded
8	34	May 13	Unknown	Jul 28	Not recorded
9	31	May 23	27.4	Aug 20	Not recorded
10	31	May 6	19.6	Aug 20	Not recorded
11	33	May 7	18.0	Aug 20	Not recorded
12	39	Jul 11	32.9	Aug 20	Not recorded
13	44	Aug 5	35.2	Aug 20	Asymptomatic
14	34	May 8	32.0	Aug 24	Not recorded

*Ct, cycle threshold; RT-PCR, real-time reverse transcription PCR; SARS-CoV-2; severe acute respiratory syndrome coronavirus 2.



Appendix Figure 1. Herd immunity and heterogeneity in risk for exposure to the infection. SARS-CoV-2 active infection prevalence (A) and the proportion of the population that has ever been SARS-CoV-2 infected (B) in a community in which the risk for exposure is homogeneous versus in a community in which the risk for exposure is heterogeneous. In both of these scenarios, the basic reproduction number R_0 was assumed equal to 3 (1,2). These simulations were generated by using a classic age-structured susceptible-exposed-infectious-recovered mathematical model (3). Heterogeneity in the second modeled scenario was introduced through variable exposure risk by age. SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.



Appendix Figure 2. Measures of SARS-CoV-2 A) seropositivity (antibody positivity), B) real-time RT-PCR positivity, C) infection positivity (antibody or real-time RT-PCR positive), and D) diagnosis rate, among only male craft and manual workers (CMW) across the CMW communities. Panels B and D show results for only the 6 communities for whom real-time RT-PCR testing was performed. Error bars indicate 95% CIs. CMW, craft and manual workers; RT-PCR, real-time reverse transcription PCR; SARS-CoV-2, severe acute respiratory syndrome coronavirus 2.

References

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