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Trends of SARS-CoV-2 antibody prevalence in selected regions across Ghana

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Trends of SARS-CoV-2 antibody prevalence in selected regions across Ghana

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Abstract

To estimate the level of community exposure to SARS-CoV-2 in Ghana, we conducted phased seroprevalence studies of 2729 participants in selected locations across Ghana. Phase I screening (August 2020) covered a total of 1305 individuals screened at major markets/lorry stations, major shopping malls, hospitals and research institutions involved in COVID-19 work. The screening was performed using a strip-in-cassette lateral flow type Rapid Diagnostic Test (RDT) kit that simultaneously and separately detected IgM and IgG antibodies against SARS-CoV-2 nucleocapsid protein. In Phase I, 252/1305 (19%) tested positive for IgM or IgG or both. Exposure rate was significantly higher among individuals tested at markets/lorry stations (26.9%) compared to those at Shopping Malls (9.4%). The 41–60-years age group had the highest exposure rate (27.2%). People with only a basic level or no formal education had a higher exposure rate (26.2%) than those with tertiary level education (13.1%); and higher in informally employed workers (24.0%) than those in the formal sector (15.0%). Phases II and III screening activities in October and December 2020, respectively, showed no evidence of increased seroprevalence, indicating either a reduced transmission rate or loss of antibody expression in a subset of the participants. The Upper East region has the lowest exposure rate, with only 4 of 200 participants (2%) seropositivity. Phase IV screening in February 2021 showed that exposure rates in the upper income earners (26.2%) had almost doubled since August 2020, reflective of Ghana's second wave of symptomatic COVID-19 cases, which began in December 2020. The Phase IV results suggest that seroprevalence levels have become so high that the initial socioeconomic stratification of exposure has been lost. Overall, the data indicates a much higher COVID-19 seroprevalence in the Greater Accra Region than was officially acknowledged, likely implying a considerably lower case fatality rate than the current national figure of 0.84%. Additionally, the high exposure levels seen in the communities suggest that COVID-19 in Ghana still predominantly presents with none-to-mild symptoms. Our results lay the foundation for more extensive SARS-CoV-2 surveillance in Ghana and the West African

62 sub-region, including deploying rapid antigen test kits in concert to determine the actual
63 infection burden since antibody development lags infection.
64

Background

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was first reported in Wuhan, China, in late 2019 [1]. By April 20th 2021 there were 141,058,320 COVID-19 SARS-CoV-2 reported infections with 3,015,314 associated deaths (case fatality ratio (CFR): of 2.1%) globally. Of these, 4,437,846 COVID-19 cases and 118,133 deaths (CFR: 2.7%), representing 3.07% and 3.85% of all reported global cases and deaths, were from the 55 African Union Member States [2]. Ghana, from the first two reported (imported) cases on March 12th 2020, by April 16th 2021 reported a cumulative total of 91,709 confirmed cases with 771 associated deaths (CFR of 0.84%) by this date [3].

The current gold standard method for diagnosis of SARS-CoV-2 infection is by real-time reverse transcription polymerase chain reaction (RT-PCR), which detects viral nucleic acid sequences, and thus the virus, present in the upper respiratory tract (nasopharyngeal or oropharyngeal) swab samples [4-6]. Due to limited resources, tests are prioritised on symptomatic, severe, and/or suspected cases, and occasionally on contacts of confirmed cases. Common symptoms of SARS-CoV-2 infection include fever, dry cough, tiredness and other variable ones with onset between 5 to 14 days after infection [7]. Approximately 80% of infected persons show mild or no symptom [8], however, posing a danger of unmitigated transmission and potential rapid rise in disease onset, severity and death [9]. Additionally, RT-PCR sensitivity may be affected by viral load, virus replication rate, RNA isolation method, and the source or timing of swab collection relative to disease stage [10]. This could lead to false negativity of about 20% [11], indicating that actual infections may be higher than reported per test.

Rapid immunodiagnostic tests (RDTs) can be used to detect either SARS-CoV-2-expressed proteins (antigens) in respiratory tract samples (e.g., sputum, throat swab) or human anti-SARS-CoV-2 specific antibodies in blood or serum within minutes. Rapid antigen tests have utility for rapid detection of transmissible infections but have lower sensitivity than PCR-based methods [12] and have become common for routine SARS-CoV-2 screening at ports

of entry. Some RDTs also detect the presence of antibodies against SARS-CoV-2 in bodily fluids. These are useful for performing population level surveillance of viral exposure. Unlike antigen RDT's which pick up active and often transmissible infection, antibody RDTs tend to pick up the evidence of previous or recent infection and cannot be used to detect active infection [12]. There are more than 280 Conformité Européenne-*in vitro* diagnostics (CE-IVD)-marked COVID-19 antibody detection RDT kits listed with the Foundation for Innovative Diagnostics (FIND) [13]. Currently, lateral flow immunoassays (LFIAs), chemiluminescence immunoassays (CLIAs), or enzyme-linked immunosorbent assays (ELISAs) are commonly used for detection of SARS-CoV-2 IgM and IgG antibodies [14, 15]. Similar to other infections, SARS-CoV-2 elicits an immune response [16], and the presence of the virus-specific antibodies in blood indicates previous or current infection regardless of the presence or absence of symptoms [17, 18]. Generally, IgM or IgG are produced early and later in infection, respectively [19]. It is currently unknown how long SARS-CoV-2 IgM and IgG antibodies persist, however, seroconversion of IgM appears to peak simultaneously with IgG within 2 to 3 weeks after symptoms onset [10, 17, 20-24]

In addition to retrospectively evaluating infection dynamics and the population disease burden, serology tests are useful for vaccine trials, therapeutic antibodies results analyses, and tests for individual and herd immunity. Antibody presence can also help identify COVID-19-recovered individuals and potential donors of convalescent plasma for immunotherapy of critically sick COVID-19 patients [25]. Some seroprevalence studies have used cross-sectional snapshots to evaluate community level exposure of SARS-CoV-2 [26] but to our knowledge, no single study has attempted to track the spatial-temporal dynamics of SARS-CoV-2 exposure in Africa. Ghana reported its first two (imported) cases on March 12th, 2020 [3]. By April 4th, positive cases who had neither travel history nor known contact with confirmed cases, were detected, implying local transmission. To estimate COVID-19 community spread in Ghana, over a 7-month period, we randomly screened for IgM and IgG antibodies against SARS-CoV-2 in people at various public places in Accra (National capital,

where >50% of reported cases occur), Kasoa (a densely-populated town in the Central Region, and a COVID-19 transmission hotspot [27] and which shares a border with Accra), Cape Coast (Central Regional capital), Akropong (a small town in the Eastern Region, a 15-minute drive away from Accra), Navrongo (a small town in the Upper East Region, which hosts a public university and a government Health Research Centre) and Bolgatanga (the Upper East Regional capital) (Figure 1). A questionnaire administered during the study collected demographic data as well and evaluated the COVID-19 knowledge, attitudes and perceptions (KAP) of study participants.

Methods

Study design

This study was a multi-site repeated observational cross-sectional study carried out over a period of 7 months from July 27, 2020 to February 26, 2021. Phase I was performed between 27 July and September 14, 2020 (designated August 2020), followed by additional phases in October 2020, December 2020 and February 2021 to identify changes from the initial rates observed at public places (Figure S1). For ease of reference in the text, and for site anonymity, the sites were assigned codes based on site type and risk factors: markets and lorry stations (ML), malls (M), research centres (R), hospitals (H) and generalised community screening (C). Generalised community screening included attendees at a concert since that reflected individuals who would be otherwise dispersed through the community. A research centre involved in mass COVID-19 testing and a COVID-19 treatment centre were given the respective codes, RC and HC. Phase I participants were invited to volunteer for the study at two shopping malls, three major markets/lorry stations (ML1-3), two research institutes involved in COVID-19 work (R1) and COVID-19 testing (RC), and three major hospitals, one of which was a COVID-19 treatment centre (H1, H2, and HC). Informed consent was obtained from all study participants. Exposure to COVID-19 was detected using a strip-in-cassette lateral flow rapid diagnostic test kit which simultaneously detects IgM and IgG antibodies against SARS-CoV-2 antigens. Phase II screened participants at one market (ML4), one research centre (R1) and two hospitals (H1, H4) while Phase III screened participants at ML1 and across two towns in the Upper East Region (C1). During Phase IV, the exposure levels of upper-income earners were evaluated by screening at 2 malls (M1 and M3) and a repeat screening at H2. In addition, the exposure level in a small town (C3) in the Eastern Region, near Accra, was estimated. Screening at hospitals and research facilities included only staff members and their close contacts; patients at the hospitals were excluded from this study. All tests were performed on-site and participants were subsequently informed of their exposure status and counselled to adhere to COVID-19

mitigation protocols. When IgM was detected, participants were referred for a COVID-19 PCR test.

Testing kit

The 'UNSCIENCE COVID-19 IgG/IgM antibody Rapid Test Kit' (Catalogue# UNCOV-40, Lot Number 20200326) was registered with the Ghana FDA, and the kit validation report was submitted to the Ghana Food and Drug Authority (FDA). For the validation exercise, sera from RT-PCR confirmed COVID-19 cases were used to evaluate several kits' performance since there were no established SARS-CoV-2 antibody detection standards for use at the commencement of this study. This kit had a manufacturer-declared IgG sensitivity and specificity of over 98% (https://covid-19-diagnostics.jrc.ec.europa.eu/devices/detail/634). Using the Ghana Food and Drugs Authority (FDA) validation protocol[36], the UNSCIENCE kit demonstrated a sensitivity of 66% when tested using 100 Ghanaian convalescent COVID-19 patient sera (2-4 weeks after a PCR-positive result). We checked the existence of pre-existing cross-reactive antibodies using sera from 100 PCR-verified COVID-19 negative samples and obtained a specificity of 94%. In the validation exercises, when a test result was not obvious, at least 3 researchers validated the reading. In the rare case of an invalid test (no control line, or wrong location of bands), the test was repeated. A representative set of randomly chosen positive and negative test results are shown in Figure S2. The kit was also adjudged to have a concordance of 72% with the WHO-recommended Wantai ELISA kit (https://www.fda.gov/media/140929/download).

Data management and analysis

A short questionnaire was administered to capture participant demographic data, knowledge of COVID-19 and COVID-19 testing history. The data, including the antibody test results were entered and managed using Research Electronic Data Capture suite (REDCap) [28]. The data were cleaned by checking for completeness, duplication and consistency. Cleaned data were analyzed with Stata 16 (StataCorp, College Station, Texas, USA) and R/RStudio

184 [29, 30]. GraphPad Prism version 8.0.0 [31] was used for some additional analysis and
185 generation of figures. Descriptive analyses were performed and univariate and multivariate
186 logistic regression models were used to assess the association between seroprevalence and
187 risk factors. Multivariable logistic models for seropositivity were obtained by using a
188 backward stepwise procedure. Demographic variables that were associated with
189 seropositivity at the P<0.25 level were included. The overall goodness of fit was assessed
190 using the Wald statistic. Unadjusted and adjusted odds ratios with 95% confidence intervals
191 were computed and presented as parallel dot plots with error bars. Statistical significance
192 was inferred for *p*-values below 0.05.
193

Results

Study sites and participant characteristics

A total of 2729 participants were screened for this study (Figure S1), including 1305 in Phase I (10 sites: August, 2020), 395 in Phase II (4 sites: October, 2020), 393 in Phase III (2 sites: December, 2020) and 636 in Phase IV (4 sites: February 2021) . Altogether, four markets/lorry stations (ML-1 was visited twice), three malls (M1, twice), two research institutes (R, twice), two sets of small towns locations (C1 and C3) and four hospitals (H1 and H2, twice) were screened across all Phases. During Phase III, 200 individuals were also screened from Navrongo and Bolgatanga in the Upper East Region (C1), which had the lowest reported COVID-19 cases in Ghana at the time the study began. Attendees (81) at a free Afrochella concert in Accra were also screened during Phase III (C2), potentially representing a general cross-section of the GAR population.

During Phase I, 946 individuals were sampled in public spaces, including 616 at markets/lorry stations and 330 at malls, while 359 were sampled in healthcare (254) and research (105) facilities (Table 1). There was a slightly higher number of female participants than males. The modal age range was 21–40 years, and over 40% of the participants had a tertiary education. Tertiary education was defined as having a post-secondary qualification such as a diploma, degree or above. Most respondents worked in the informal sector, with low or mid-level socioeconomic status. Over 90% of participants had good knowledge of COVID-19 symptoms, transmission routes and preventative measures (Figure S3). Such knowledge did not, however, correlate with participants' seropositivity status or mask-wearing prior to recruitment. Only 7% of participants had previously received a COVID-19 PCR test (Figure S4). Similar participant characteristics were observed in Phases II, III and IV with smaller numbers of participants.

218 **Table 1: Socio-demographic characteristics of participants (N=2729)**

	Phase 1 (n=1305)		Phase 2 (n=395)		Phase 3 (n=393)		Phase 4 (n=636)	
Characteristics	**number**	**Percentage**	**number**	**Percentage**	**number**	**Percentage**	**number**	**Percentage**
Exposure risk groups								
Shopping malls (M)	330	25.3					356	56.0
Markets/Lorry stations (ML)	616	47.2	152	38.5	115	36.5		
COVID testing/treatment centres (RC/HC)	105	8.0						
Other Health Research centres/Hospital R/H	254	19.5	243	61.5			81	12.7
Navrongo/Bolgatanga (C1)					200	63.5		
Afrochella Concert (C2)					78	19.8		
Akropong (C3)							199	31.3
Gender								
Male	591	45.3	124	31.4	177	45.0	295	46.4
Female	714	54.7	271	68.6	216	55.0	341	53.6
Age group (in years)								
<21	63	4.8	13	3.3	63	16.0	44	6.9
21-40	769	58.9	216	54.7	251	63.9	362	56.9
41-60	365	28.0	119	30.1	57	14.5	167	26.3
60+	89	6.8	13	3.3	7	1.8	62	9.7

	Phase 1 (n=1305)		Phase 2 (n=395)		Phase 3 (n=393)		Phase 4 (n=636)	
Characteristics	**number**	**Percentage**	**number**	**Percentage**	**number**	**Percentage**	**number**	**Percentage**
Missing	19	1.5	34	8.6	15	3.8	1	0.2
Educational level								
None/Basic	402	30.8	128	32.4	117	29.8	202	31.8
Secondary	245	18.8	54	13.7	148	37.7	139	21.9
Tertiary	616	47.2	133	33.7	106	27.0	279	43.9
Missing	42	3.2	80	20.3	22	5.6	16	2.5
Employment type								
Formal	520	39.8	171	43.3	72	18.3	257	40.4
Informal	655	50.2	175	44.3	190	48.3	261	41.0
Student	59	4.5	21	5.3	114	29.0	48	7.5
Unemployed	44	3.4	19	4.8	11	2.8	70	11.0
Missing	27	2.1	9	2.3	6	1.5	0	0.0
Socio-economic status								
Lowest	524	40.2	170	43.0	158	40.2	249	39.2
Middle	259	19.8	122	30.9	78	19.8	124	19.5
Higher	522	40.0	103	26.1	157	39.9	263	41.4

Anti-SARS-CoV-2 seropositivity in Phase I

In Phase I, SARS-CoV-2 IgG, IgM or both antibodies were detected in 19% of all participants (Figure 2A), with the highest rate amongst participants sampled in markets/lorry stations (27%). Among health workers, those at COVID-19 treatment/testing sites had higher exposure rates compared to their colleagues who were not directly handling COVID-19 patients or samples. There was no significant difference in seropositivity across genders (Figure 2B). When stratified by age categories, the highest level of seroprevalence (27.1%) was observed in the 41–60 years age group (Figure 2C). Participants with higher educational backgrounds (Figure 2D), those employed in the formal sector (Figure 2E) and those with higher economic standing (Figure 2F) had lower exposure levels than participants with lower educational background, informal sector workers and poor economic background. Only 20.9% of seropositive participants reported having had COVID-19-like symptoms (Figure 3).

Logistic regression analysis was performed on data from Phase I to identify factors that correlated with increased risk of SARS-CoV-2 exposure (Figure 4). Univariate modelling showed that socio-demographic factors were significantly associated with increased or decreased exposure. These were: being sampled at either markets and lorry stations (Odds ratio, OR:3.6, 95% confidence interval, CI: 2.4-5.4) or a COVID-19 treatment/testing centre (OR: 2.4, 95% CI:1.3-4.4,), being employed in the informal sector (OR: 1.8, 95% CI:1.3-2.4) having a high education (OR: 0.4, 95% CI:0.3-0.6) or having a high income (OR:0.6, 95% CI:0.5-0.9). In a multivariate model, sampling location, participant educational level and income/socioeconomic status remained significantly associated with COVID-19 exposure status; participants were significantly more likely to have COVID-19 antibodies if they were sampled in markets/lorry stations (adjusted odds ratio, aOR: 2.5, 95% CI: 1.5-4.2), and COVID-19 testing/treatment centre (aOR:3.6, 95%CI:1.7-7.5). Participants who had basic or no formal education (aOR: 0.8, 95% CI: 0.5-1.3) had a higher risk of COVID-19 seropositivity. Unemployed individuals (aOR: 0.7, 95% CI: 0.2-2.1) (Table 2, Figure 4), those

246 with high educational level (aOR: 0.8, 95%CI: 0.5-1.3) and high socioeconomic status (aOR:
247 0.8, 95%CI: 0.6-1.2) had reduced risk of COVID-19 seropositivity, but these associations
248 were not statistically significant (Table 2, Figure 4).

249 **Table 2: Summary of participant seropositivity status (N=2729)**

	August 2020 (n=1305)		Oct 2020 (n=395)		Dec - 2020 (n=393)		Jan- Feb 2021 (n=636)	
	Number Sampled	Antibody Positivity %	Number Sampled	Antibody Positivity %	Number Sampled	Antibody Positivity %	Number Sampled	Antibody Positivity %
Sampling location (Code)								
Shopping malls (M)	330	9.4					356	25.3
Markets/Lorry stations (ML)	616	26.9	152	19.7	115	23.5		
COVID testing/treatment Centres (RC/HC)	105	20.0						
Health Research Centres/Hospital (R/H)	254	13.4	243	14.0			81	22.2
Navrongo/Bolgatanga (C1)					200	2.0		
Afrochella Concert (C2)					78.0	15.4		
Akropong (C3)							199	18.6
Gender								
Male	591	18.1	124	14.5	131	1.7	10.7	22.7
Female	714	20.3	271	17.0	184	2.8	11.1	22.9
Age group (in years)								
4-21	63	17.5	13	0.0	63	11.1	44	9.1
21-40	769	16.1	216	11.1	251	11.6	362	24.9
41-60	365	27.1	119	21.8	57	10.5	167	22.8
60+	89	18.0	13	38.5	7.0	14.3	62	21.0
Missing	19	10.5	34	26.5	15	0.0	1	0.0

	August 2020 (n=1305)		Oct 2020 (n=395)		Dec - 2020 (n=393)		Jan- Feb 2021 (n=636)	
	Number Sampled	Antibody Positivity %	Number Sampled	Antibody Positivity %	Number Sampled	Antibody Positivity %	Number Sampled	Antibody Positivity %
Educational level								
None/Basic	402	26.6	128	22.7	117	12.0	202	17.8
Secondary	245	24.5	54	14.8	148	11.5	139	25.9
Tertiary	616	13.5	133	15.0	106	10.4	279	24.7
Missing	42	4.8	80	8.8	22	4.5	16	25.0
Employment type								
Formal	520	15.0	171	11.7	72	6.9	257	23.7
Informal	655	24.0	175	20.6	190	13.7	261	24.9
Student	59	16.9	21	4.8	114	9.6	48	12.5
Unemployed	44	9.1	19	21.1	11	0	70	18.6
Missing	27	11.1	9	33.3	6	16.7		
Socio-economic status								
Low	524	23.1	170	17.1	158	15.8	249	18.1
Middle	259	19.7	122	15.6	78	10.3	124	25.0
High	522	15.3	103	15.5	157	6.4	263	26.2
	IgG	13.0	IgG	15.2	IgG	9.7	IgG	22.8
	IgM	1.6	IgM	1.3	IgM	2.3	IgM	2.2

Phases II and III: Targeted follow-up seroprevalence surveys

As follow-ups to Phase I, the trend of population seroprevalence was again investigated in Phase II and III. Two months after the initial public places screening (October, 2020), 144 individuals were screened at a lorry station in Accra and 212 participants at two hospitals in Accra and Cape Coast. Overall, seroprevalence at the lorry station was 19.7%, and 13% at the two hospitals. The H4 facility staff had higher (18.5%) seroprevalence level than those at H1, previously sampled in Phase I. A Phase III screening exercise was conducted at M1, which was originally sampled in Phase I, and that showed an estimated seroprevalence of 23.5%. Additionally, 200 individuals were screened in the Upper East Region (C1), an area with low population density and very few reported COVID-19 cases at the time. Here, 4 out of 200 individuals (2%) tested positive for SARS-CoV-2 antibodies (Table 1). Individuals screened at the Afrochella concert (C2) showed an estimated seroprevalence of 16%, which was similar to the Phase I data, with the HC site excluded.

Phase IV: Impact of the second wave

Beginning in late December 2020, large numbers of symptomatic COVID-19 cases started to be detected at hospitals and treatment centres in Accra and other major cities. The patients were mostly of high socio-economic standing [32]. We therefore performed repeat screening at M1 and H2 (both sampled in Phase I) and sampled again at M3 and a small town in the Eastern Region (C3). The average seroprevalence at the two malls (M1 and M3) was at 27%, whilst H1 and C3 recorded 25% and 17% respectively.

Discussion

This study was necessitated by a dearth of epidemiological data on COVID-19 prevalence in Ghana. In the first few months of the pandemic when prevalence was low, Ghana ranked high among African countries, and even globally, for administering high numbers of tests per million people [33]. To meet the high demand for testing, Ghana's main testing centre, Noguchi Memorial Institute for Medical Research, employed "sample pooling" methods [34-

277 37]. However, since then, Ghana has declined significantly to number 22 in tests per million
278 of population in Africa [38]. Data from the Ghana Health Service's COVID-19 archives [3]
279 indicates that testing has significantly reduced after peaking in June, correlating with a drop
280 in daily reported cases. Among other factors, the reduced testing could be due to the fact
281 that at the current positivity rate of 8.3% of tested cases, sample pooling is no longer a
282 viable cost-cutting and test-rate enhancing measure. The seroprevalence rate average of
283 19.3% obtained from our public screening exercises is probably a better reflection of SARS-
284 CoV-2 infections in Ghana, especially in the large and densely populated urban areas.
285 Additionally, currently, most RT-PCR tests in the country are administered to travellers,
286 representing a higher economic tier of society. The relatively low (9.3%) seroprevalence
287 initially observed in malls, assumed to be frequented by the higher tiers of society, may
288 correlate well with the official 10% RT-PCR test positivity rate reported in September 2020
289 [3].

290 Participants across all sites demonstrated good knowledge of COVID-19 risks, symptoms
291 and preventive measures. This did not however translate into observation of protocols in the
292 markets and lorry stations, where, by visual estimation, 10–50% of the study participants
293 arrived mask-less and had to be requested to wear a mask donated by the study. This
294 attitude corresponds with two surveys on mask-wearing, carried out by the Ghana Health
295 Service which showed public mask wearing of ~40% and 10% in July and September,
296 respectively [39, 40]. Our previous genomic study showed evidence of undetected
297 community spread likely caused by asymptomatic individuals [27]. Of note, nearly 80% of
298 people who were seropositive did not report significant COVID-19 symptoms (Figure 3),
299 confirming that SARS-CoV-2 infections in Ghana are predominantly asymptomatic,
300 consistent with reported global trends [8]. With the 19.3% seroprevalence in the Greater
301 Accra Region (GAR), we inferred that nearly 1 million out of the estimated 5 million GAR
302 residents may have already been exposed to SARS-CoV-2. This staggering number
303 suggests that the actual fatality rate of COVID-19 in Ghana may be much lower than the

304 reported CFR of 0.7%, since that would have translated to approximately 7000 deaths in a
305 large metropolis like Accra, which would have been rather very obvious . Additionally, there
306 was no evidence of a stressed or panicked healthcare system nor visible or anecdotal
307 evidence of excess deaths during the Phase I hospital screening.

308 Given the higher-than-expected seroprevalence observed in the Greater Accra Region,
309 follow-up surveys were conducted at some of the Phase I locations as well as other parts of
310 the country to confirm the findings and obtain vital information about infection dynamics over
311 time. Repeated screening of markets and lorry stations in October and December yielded
312 seroprevalence rates of 19.7% and 23.5%, respectively. The seeming plateau in
313 seroprevalence in lower socioeconomic status individuals may be indicative of, either a
314 peaking of infections -coincident with the onset of Phase I seroprevalence [3], or loss of
315 antibody expression in some section of the population over time. Phase II surveys at the
316 health and research facilities which were not directly handling patients or testing samples, in
317 October, also showed a similar overall seroprevalence (13%), as observed in August.
318 Participants in Navrongo and Bolgatanga in the Upper East region (C1), with some of the
319 lowest reported cases, showed very low (2%) seroprevalence, confirming the reliability of
320 this study. Consistent with global reports, participants in the 40-60 and 60+ year age groups
321 exhibited the highest seroprevalence levels across all 3 phases (Figure 4, S4, S5). The
322 results of Phase IV reflected the high levels of new COVID-19 cases and hospitalisations in
323 Ghana, mainly in the middle socioeconomic class [32]. As such, it was not surprising that the
324 socioeconomic divide in prevalence observed in Phase I had mostly disappeared and even
325 appeared reversed by Phase IV.

326 Our observed seropositivity rates are in line with previous reports from other African
327 countries[41, 42]. A study in Kenya estimated 20% SARS-CoV-2 seropositivity in adults
328 (~1.6 million people) at a time when the total reported infections were 2093 (with
329 approximately 90% asymptomatic cases) and 71 deaths of all ages [43]. The initial trend
330 relating income disparity and COVID-19 seropositivity is not surprising. Even in countries

where lower seroprevalence was reported, such as China (1.63%), lower income status correlated with the highest seroprevalence (5.62%) [44], and this trend was initially reflected in this current study. The shift to high prevalence even in high socioeconomic brackets is likely due to poor adherence to COVID-19 protocols during the period of this study, likely due to election activities [45] and the 2020 Christmas/2021 New Year holiday festivities.

Strengths and Limitations of this study

By surveying participants at different sites and times, representing categories of different perceived risk factors, this study obtained credible estimates for population-level prevalence across these sites and how that changed over the sampling period. This will allow future screening at these sites to determine the seroprevalence trends. However, most seroprevalence studies only reflect past disease burden. Using Markets and Lorry Stations enabled sampling of a broad cross-section of the Ghanaian populace.

Phase I of the study was conducted in the region with the greatest burden of reported infections and it was expected that a country-wide survey would yield less seroprevalence. Site H3, situated in the town of Cape Coast, a tourist hub and Central regional capital, exhibited a very high prevalence at 18.5% during Phase II, but this was not surprising given that M4, located in Kasoa, also in the Central Region, exhibited an exposure rate of 28% during Phase I. The low seroprevalence observed at C1 (2%) during Phase III hinted that community size/density may play a role in COVID-19 transmission. Given the geographical remoteness of C1 to the major hotspots of Accra and Kumasi, another small community (C3) in the country's Southern belt with higher population density was screened, yielding an observed prevalence rate of 17%, and showing that SARS-CoV-2 exposure is not just a metropolitan burden, but one that needs to be tracked across the country. This, however, does not rule out that towns with lower population densities and who are far from metropolitan areas may exhibit lower seroprevalence levels.

356 During validation, this kit showed a sensitivity of 66%, when compared to PCR positivity.
357 This is despite the manufacturer reporting sensitivity and specificity values above 98%. The
358 apparent lower than expected sensitivity observed in local validation could at least partly be
359 due to weak or delayed antibody responses in some of the infected persons. The import of
360 this is that the seroprevalence levels reported in this study are likely underestimates of true
361 disease prevalence.

362 One oft-repeated concern with SARS-CoV-2 seroprevalence studies in Africa is cross-
363 reactivity due to pre-existing antibodies to other viruses and vaccines [46]. Some studies
364 have reported extensive cross-reactivity against SARS-CoV-2 in Africa [47]). However, most
365 of these studies had limitations, and as such their conclusions are unreliable. These flaws
366 include extremely small study sizes (below 500 and even sometimes below 100) [48], tend
367 to be based at single institutions and/or cities [47] and use samples collected at widely
368 divergent time periods for their 'Western' and 'African' pre-COVID-19 samples [48]. The
369 UNSCIENCE COVID-19 IgG/IgM antibody Rapid Test Kit used in our study exhibited 94%
370 specificity during validation (with plasma from 100 COVID-19 PCR-negative individuals).
371 Antibody RDTs are contraindicated in cases of active fever, based on manufacturer's
372 information leaflets, unpublished analyses and other studies [47]. We confirmed that none of
373 the study respondents had temperature above 38, thereby reducing the likelihood of fever
374 affecting the results.

375 Antibody cross-reactivity with other pathogens is often manifested in IgM detection [49, 50].
376 During validation, and in the field, detection of IgM was uncommon, and when detected, IgM
377 was often accompanied by IgG. This reduced the likelihood that those IgM detections were
378 as a result of cross-reactivity. That said, a cross-reactivity rate of 6% with IgM was detected
379 during validation. However, the test kit performed even better in the field; Navrongo and
380 Bolgatanga in the Upper-East region of Ghana are towns with populations highly vaccinated
381 against other pathogens, yet only 2% of 200 individuals (4 individuals) showed seropositivity
382 in this study. This low seropositivity corelated well with the low level of reported COVID-19 in

those towns at the time and hinted that the rates observed in Accra and environs were due to the SARS-CoV-2 exposure rate, but not from cross-reactivity. Taken together, there is a low likelihood that cross-reactive antibodies played a significant role in this study.

Conclusions and Recommendations

This study highlights a relatively high level of SARS-CoV-2 infections in the Greater Accra, Central and Eastern Regions, but not in the Upper East region. Most of these infections were unreported and likely asymptomatic.

As one of the first studies with such depth and nuance, we provide some of the first evidence of low levels of symptomatic COVID-19 infection, previously only anecdotally reported. These findings imply that there is a need for increased enforcement of COVID-19 mitigation protocols and more effective public education.

Large scale cross-sectional studies of seroprevalence across Ghana and West Africa may be a practical approach for disease tracking even as vaccines are being deployed[55,56]. The dynamism observed in demographic exposure risk over time highlights the need for continuous risk and prevalence assessments to track highly transmissible disease agents like SARS-CoV-2.

Finally, resources should be mobilised to research the molecular and immunological mechanisms underlying the apparent high tolerance to COVID-19 observed in Ghana, the West African sub-region, and Africa as a whole.

Ethical Approval

Procedures in this study conform with the Ghanaian Public Health Act, 2012 (Act 851) and the Data Protection Act, 2012 (Act 843). Ethical approval was received from the Ethics Board of the College of Basic and Applied Sciences, University of Ghana (ECBAS 063/19-20), and the Ethical Review Committee of the Ghana Health Service (GHS-ERC 011/03/20).

Consent

In line with the ethical protocol above, written informed consent was obtained for all study participants. Upon consent, each participant was assigned a unique identification number (ID). This ID was used for testing and data recording, thereby delinking participant identification with the test results and questionnaire answers. All consent forms are kept in a locked cabinet accessible to only the study PI and the WACCBIP Data Manager.

Other WACCBIP COVID-19 Team members

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Author contributions

GAA and FM conceived the study. GAA and PKQ designed the study, wrote the SOP for the fieldwork and supervised all aspects. YB, JKM, PCO, PKQ, WKA, AJU and some members of WCT performed validation of the kit. PKQ, JKM, PCO, DO-M, AJU, WCT, FK, EA, IA, LP, RA, CK, NAB, YB, JA, PA and GAA participated in seroprevalence screening activities. KB planned the site visits and partook in screening activities. PKQ, FD and PCO analysed the data. PKQ, JKM and GAA wrote the manuscript with additional editing by DO-M,YB, OQ and NN. All authors read and approved the final version of the manuscript before submission.

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Conflicts of Interest

None to declare

Figures

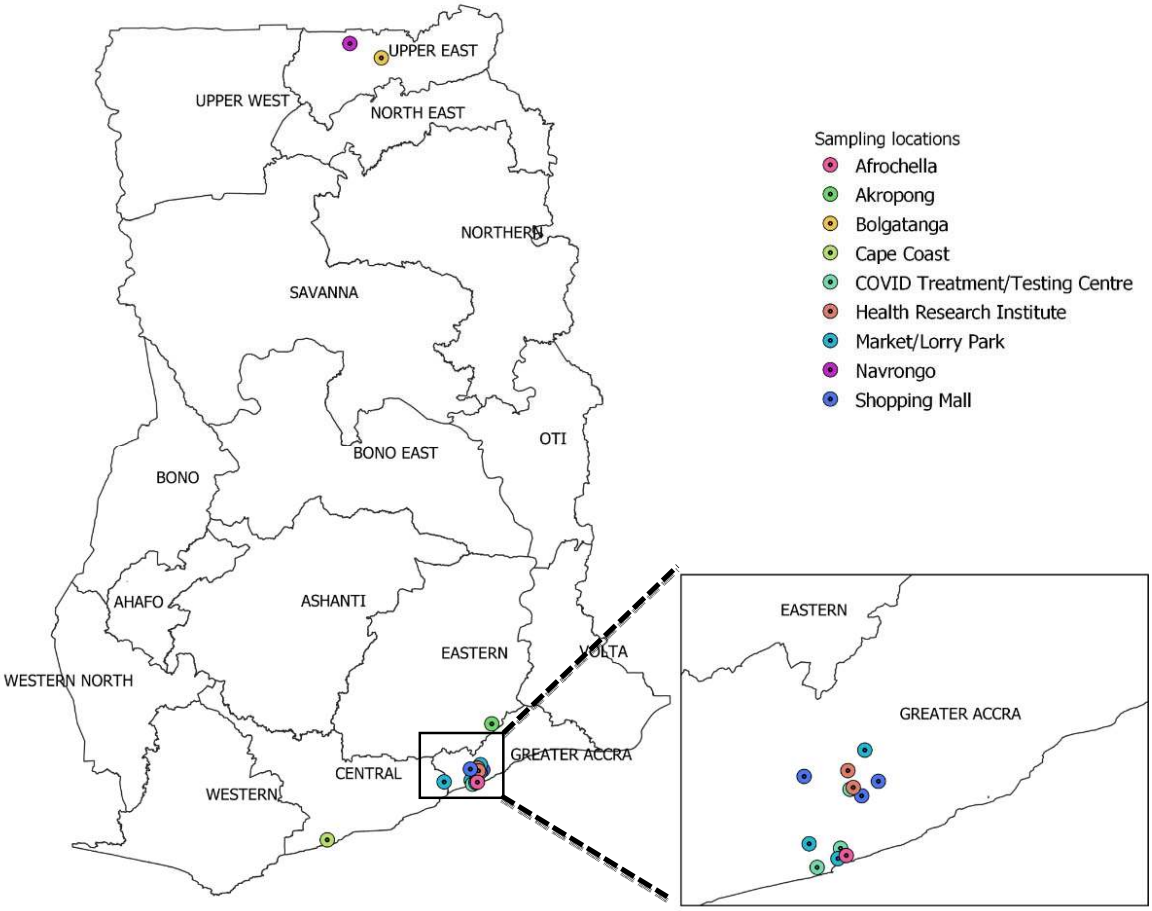


Figure 1: Map of Ghana showing study sites. Figure was generated using QGIS (QGIS Development Team, 2009. QGIS Geographic Information System. Open Source Geospatial Foundation. URL http://qgis.org)

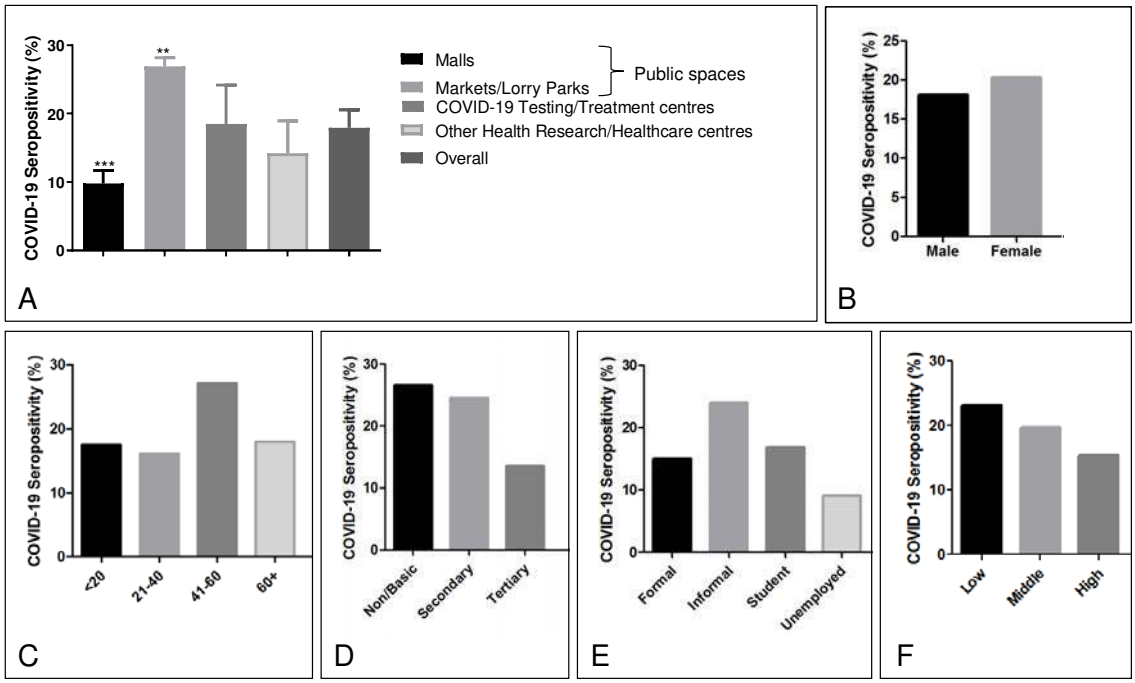


Figure 2: SARS-CoV-2 seropositivity reported by (A) Sampling sites, (B) gender, (C) Age, (D) Highest education level, (E) Employment status and (F) Socioeconomic status. Error bars reflect the standard error of measurement. Where relevant, p-values are indicated as follows p<0.05; *,p<0.01;**, p<0.001; ***. Error bars, where relevant, represent standard deviation across sites.

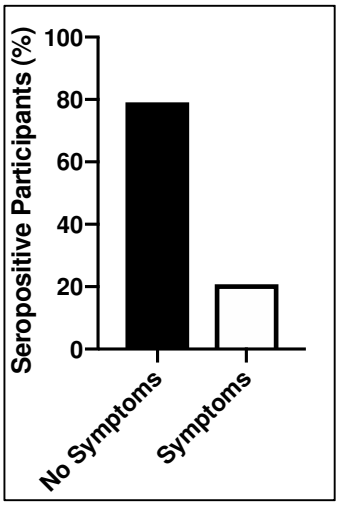
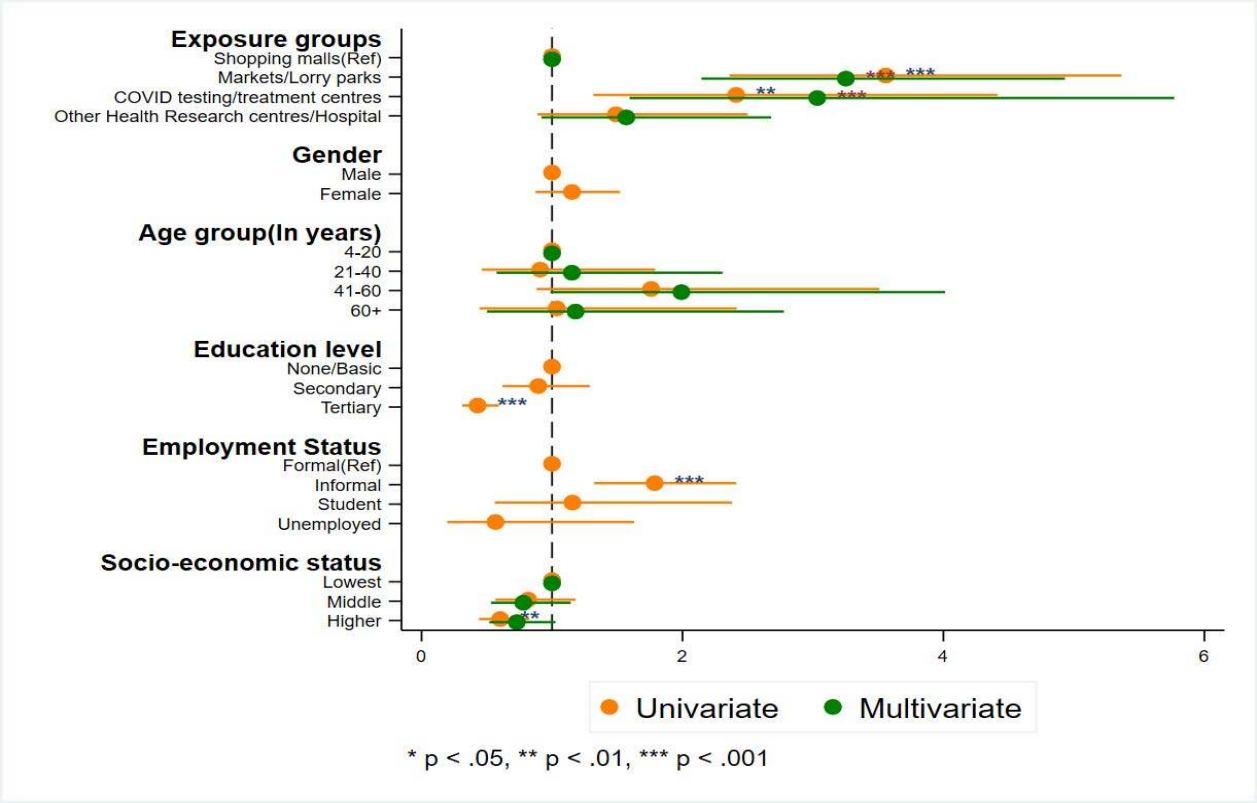


Figure 3 Presence of two or more self-reported COVID-19 symptoms in seropositive individuals in the month preceding the study.



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473 **Figure 4: Modelling of COVID-19 exposure risk across Phase I study participant**

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Refrences

1. World Health Organization. *Pneumonia of unknown cause – China*. January 5, 2020; Available from: https://www.who.int/csr/don/05-january-2020-pneumonia-of-unkown-cause-china/en/.
2. *Africa CDC-Outbreak Brief 66: Coronavirus Disease 2019 (COVID-19) Pandemic*. April 20 2021; Available from: https://africacdc.org/download/outbreak-brief-66-coronavirus-disease-2019-covid-19-pandemic/.
3. Ghana Health Service, G.H. *COVID-19 Updates*. 2020; Available from: https://ghanahealthservice.org/covid19/archive.php.
4. Chu, D.K.W., et al., *Molecular Diagnosis of a Novel Coronavirus (2019-nCoV) Causing an Outbreak of Pneumonia.* Clin Chem, 2020. **66**(4): p. 549-555.
5. Emery, S.L., et al., *Real-time reverse transcription-polymerase chain reaction assay for SARS-associated coronavirus.* Emerg Infect Dis, 2004. **10**(2): p. 311-6.
6. Loeffelholz, M.J. and Y.W. Tang, *Laboratory diagnosis of emerging human coronavirus infections - the state of the art.* Emerg Microbes Infect, 2020. **9**(1): p. 747-756.
7. Organisation, W.H. *COVID-19 symptoms*. 2020 [cited 2021 January 16]; Available from: https://www.who.int/health-topics/coronavirus#tab=tab_3.
8. World Health Organization, W.H. *Coronavirus disease 2019 (COVID-19): situation report, 46.* 2020; Available from: https://apps.who.int/iris/handle/10665/331443.
9. Hongjun Zhao , X.L., Yibin Deng, Yujin Tang, Jiachun Lu, *COVID-19: asymptomatic carrier transmission is an underestimated problem.* Epidemiology and Infection, 2020. **148**(June 11, 2020).

499 10. Wolfel, R., et al., *Virological assessment of hospitalized patients with COVID-2019.*
500 Nature, 2020. **581**(7809): p. 465-469.
501 11. Lauren M. Kucirka, S.A.L., Oliver Laeyendecker, Denali Boon, Justin Lessler,
502 *Variation in False-Negative Rate of Reverse Transcriptase Polymerase Chain*
503 *Reaction-Based SARS-CoV-2 Tests by Time Since Exposure*. Annals of Internal
504 Medicine, May 13, 2020. **173**: p. 262-267.
505 12. World Health Organization, W.H. *Antigen-detection in the diagnosis of SARS-CoV-2*
506 *infection using rapid immunoassays*. September 11, 2020; Available from:
507 https://www.who.int/publications/i/item/antigen-detection-in-the-diagnosis-of-sars-
508 cov-2infection-using-rapid-immunoassays.
509 13. FIND. *SARS-CoV-2 diagnostic pipeline*. 2020 [cited 2021 January 16]; Available
510 from: https://www.finddx.org/covid-
511 19/pipeline/?avance=all&type=all&test_target=Antibody&status=CE-
512 IVD&section=immunoassays&action=default%23diag_tab.
513 14. Montesinos, I., et al., *Evaluation of two automated and three rapid lateral flow*
514 *immunoassays for the detection of anti-SARS-CoV-2 antibodies.* J Clin Virol, 2020.
515 **128**: p. 104413.
516 15. Van Elslande, J., et al., *Diagnostic performance of seven rapid IgG/IgM antibody*
517 *tests and the Euroimmun IgA/IgG ELISA in COVID-19 patients.* Clin Microbiol
518 Infect, 2020. **26**(8): p. 1082-1087.
519 16. Shah, V.K., et al., *Overview of Immune Response During SARS-CoV-2 Infection:*
520 *Lessons From the Past.* Front Immunol, 2020. **11**: p. 1949.
521 17. Liu Ying, L.Y.-p., Diao Bo, Ren Feifei, Wang Yue, Ding Jinya, Huang Qianchuan,
522 *Diagnostic Indexes of a Rapid IgG/IgM Combined Antibody Test for SARS-CoV-2.*
523 medRxiv, March 26, 2020.

18. Pingping Zhang, Q.G., Tang Wang, Yuehua Ke, Fei Mo, Ruizhong Jia, Wanbing Liu, Lei Liu, Shangen Zheng, Yuzhen Liu, Luping Li, Yao Wang, Lei Xu, Kun Hao, Ruifu Yang, Shiyue Li, Changqing Lin, Yong Zhao, *Evaluation of recombinant nucleocapsid and spike proteins for serological diagnosis of novel coronavirus disease 2019 (COVID-19).* medRxiv, 2020. **20036954**.

19. Gunther, N. and G.W. Hoffmann, *Qualitative dynamics of a network model of regulation of the immune system: a rationale for the IgM to IgG switch.* J Theor Biol, 1982. **94**(4): p. 815-22.

20. Long, Q.X., et al., *Antibody responses to SARS-CoV-2 in patients with COVID-19.* Nat Med, 2020. **26**(6): p. 845-848.

21. Lou, B., et al., *Serology characteristics of SARS-CoV-2 infection after exposure and post-symptom onset.* Eur Respir J, 2020. **56**(2).

22. Okba, N.M.A., et al., *Severe Acute Respiratory Syndrome Coronavirus 2-Specific Antibody Responses in Coronavirus Disease Patients*. Emerg Infect Dis, 2020. **26**(7): p. 1478-1488.

23. Pan, Y., et al., *Serological immunochromatographic approach in diagnosis with SARS-CoV-2 infected COVID-19 patients*. J Infect, 2020. **81**(1): p. e28-e32.

24. Zhao, J., et al., *Antibody Responses to SARS-CoV-2 in Patients With Novel Coronavirus Disease 2019.* Clin Infect Dis, 2020. **71**(16): p. 2027-2034.

25. Duan, K., et al., *Effectiveness of convalescent plasma therapy in severe COVID-19 patients.* Proc Natl Acad Sci U S A, 2020. **117**(17): p. 9490-9496.

26. Kirsten E. Wiens , P.N.M., John Rumunu , Damien Slater , Forrest K. Jones , Serina Moheed , Andrea Caflish , Bior K. Bior , Iboyi Amanya Jacob , Richard Lino Loro Lako , Argata Guracha Guyo , Olushayo Oluseun Olu , Sylvester Maleghemi , Andrew Baguma, Juma John Hassen , Sheila K. Baya , Lul Deng , Justin Lessler ,

549 Maya N. Demby , Vanessa Sanchez , Rachel Mills , Clare Fraser , Richelle C.
550 Charles, Jason B. Harris , Andrew S. Azman1, Joseph F. Wamala, *Seroprevalence of*
551 *anti-SARS-CoV-2 IgG antibodies in Juba, South Sudan: a population-based study.*
552 medRxiv[Preprint], 2021.
553 27. Ngoi, J.M., et al., *Genomic analysis of SARS-CoV-2 reveals local viral evolution in*
554 *Ghana.* Exp Biol Med (Maywood), 2021. **246**(8): p. 960-970.
555 28. Oremus, M., et al., *A Computer-Assisted Personal Interview App in Research*
556 *Electronic Data Capture for Administering Time Trade-off Surveys (REDCap):*
557 *Development and Pretest.* JMIR Form Res, 2018. **2**(1): p. e3.
558 29. Team, R.C. *The R Project for Statistical Computing*. 2020; Available from:
559 https://www.r-project.org/index.html.
560 30. Team, R., *RStudio.* 2020.
561 31. GraphPad. *GraphPad Software*. 2020; Available from: https://www.graphpad.com/.
562 32. 3news.com. *Many of Covid-19 cases still among the middle, upper middle class –*
563 *GHS*. 2021; Available from: https://3news.com/many-of-covid-19-cases-still-among-
564 the-middle-upper-middle-class-ghs/.
565 33. Afriyie, D.K., et al., *COVID-19 pandemic in resource-poor countries: challenges,*
566 *experiences and opportunities in Ghana.* J Infect Dev Ctries, 2020. **14**(8): p. 838-843.
567 34. Arnold, M.E., et al., *Evaluation of the sensitivity of faecal sampling for detection of*
568 *monophasic Salmonella Typhimurium and other Salmonella in cattle and pigs.*
569 Epidemiol Infect, 2015. **143**(8): p. 1681-91.
570 35. Deckert, A., T. Barnighausen, and N.N. Kyei, *Simulation of pooled-sample analysis*
571 *strategies for COVID-19 mass testing.* Bull World Health Organ, 2020. **98**(9): p. 590-
572 598.

573 36. PILLA, V. *Coronavirus pandemic: 'Pool testing' for COVID-19 may benefit India as*
574 *US study proves test feasibility, efficacy*. April 6, 2020; Available from:
575 https://www.moneycontrol.com/news/coronavirus/coronavirus-pandemic-pool-
576 testing-for-covid-19-may-benefit-india-as-us-study-highlights-test-feasibility-
577 efficacy-5111811.html.
578 37. Van, T.T., et al., *Pooling nasopharyngeal/throat swab specimens to increase testing*
579 *capacity for influenza viruses by PCR.* J Clin Microbiol, 2012. **50**(3): p. 891-6.
580 38. Worldometer. *Coronavirus Update (Live)*. 2020 [cited 2021 February 2]; Available
581 from: https://www.worldometers.info/coronavirus/#countries.
582 39. Emmanuel Komla Junior Dzisi, O.A.D., *Adherence to social distancing and wearing*
583 *of masks within public transportation during the COVID 19 pandemic.* Transportation
584 Research Interdisciplinary Perspectives, 2020. **7**(September).
585 40. Graphic.com.gh. *COVID-19 prevention in Ghana: 82% not wearing face masks -*
586 *Survey - Graphic Online*. 2020; Available from:
587 https://www.graphic.com.gh/news/general-news/covid-19-accra-not-wearing-face-
588 masks-survey.html.
589 41. NICD, *COVID-19 SPECIAL PUBLIC HEALTH SURVEILLANCE BULLETIN* B.
590 Brooke, Editor. 2020.
591 42. Chibwana, M.G., et al., *High SARS-CoV-2 seroprevalence in Health Care Workers*
592 *but relatively low numbers of deaths in urban Malawi.* medRxiv, 2020.
593 43. Uyoga, S., et al., *Seroprevalence of anti-SARS-CoV-2 IgG antibodies in Kenyan blood*
594 *donors.* Science, 2021. **371**(6524): p. 79-82.
595 44. Chen, X., et al., *Serological evidence of human infection with SARS-CoV-2: a*
596 *systematic review and meta-analysis.* Lancet Glob Health, 2021. **9**(5): p. e598-e609.

45. voanews.com. *Fears Grow of Further COVID-19 Spikes Ahead of Ghana's Election*. 2020; Available from: https://www.voanews.com/africa/fears-grow-further-covid-19-spikes-ahead-ghanas-election.

46. Nkuba Ndaye, A., et al., *Challenges in interpreting SARS-CoV-2 serological results in African countries.* Lancet Glob Health, 2021. **9**(5): p. e588-e589.

47. Yadouleton, A., et al., *Limited Specificity of Serologic Tests for SARS-CoV-2 Antibody Detection, Benin.* Emerg Infect Dis, 2021. **27**(1).

48. Tso, F.Y., et al., *High prevalence of pre-existing serological cross-reactivity against severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2) in sub-Saharan Africa.* Int J Infect Dis, 2021. **102**: p. 577-583.

49. Al-Jighefee, H.T., H.M. Yassine, and G.K. Nasrallah, *Evaluation of Antibody Response in Symptomatic and Asymptomatic COVID-19 Patients and Diagnostic Assessment of New IgM/IgG ELISA Kits*. Pathogens, 2021. **10**(2).

50. *Corrigendum to SARS-CoV-2 Serology: Much Hype, Little Data.* Clin Chem, 2020. **66**(12): p. 1574.

Supplemental Files

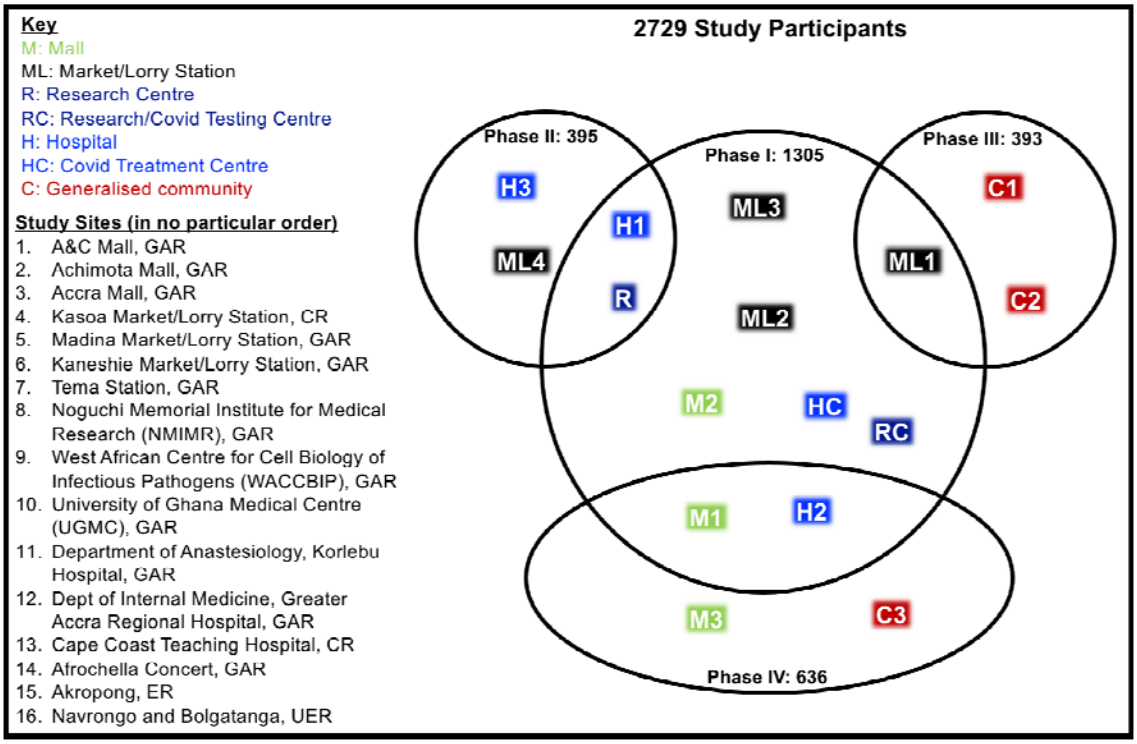

Figure S1. Venn Diagram showing distribution of participants and sites across the different Phases of the study. GAR refers to the Greater Accra Region, CR refers to the Central Region and UER refers to the Upper East Region.

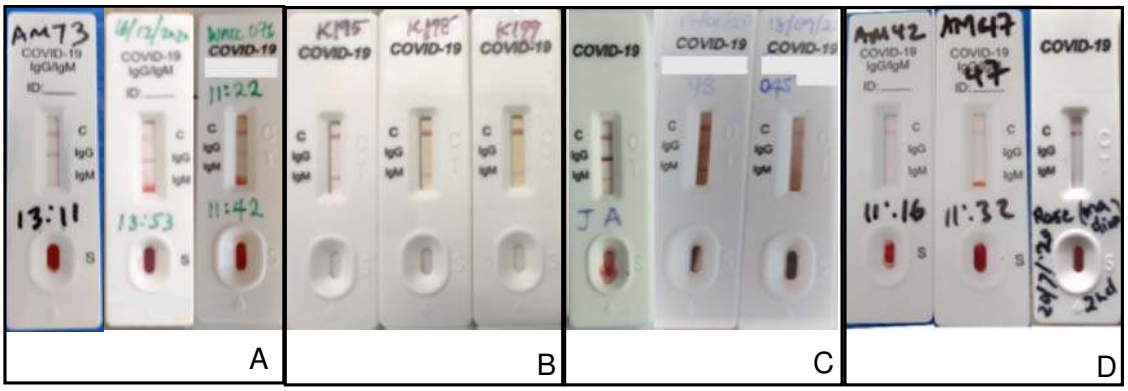

Figure S2: Representative pictures of study cassettes showing (A) Positive IgG, (B) Positive IgM*, (C) Combined positive IgM/IgG and (D) antibody negative test results. *Pictures of IgM are from patients, not from field due to low incidence of IgM only observed in the field and faintness of igM bands in the field

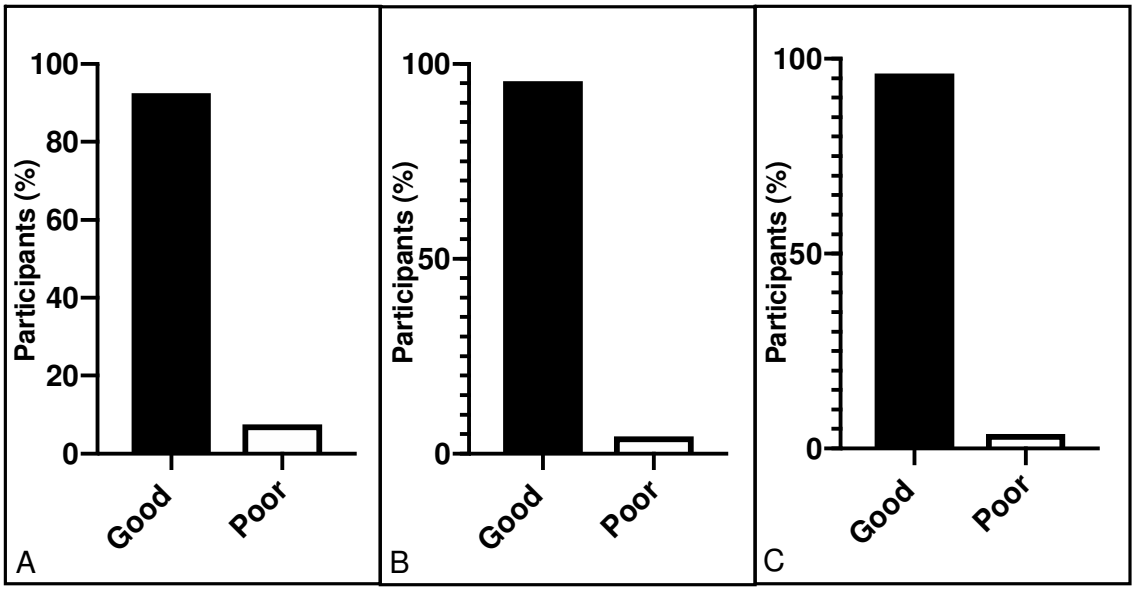

Figure S3: Summary of Phase I participants' knowledge of (A) COVID-19 symptoms, (B) mode of transmission and (C) prevention

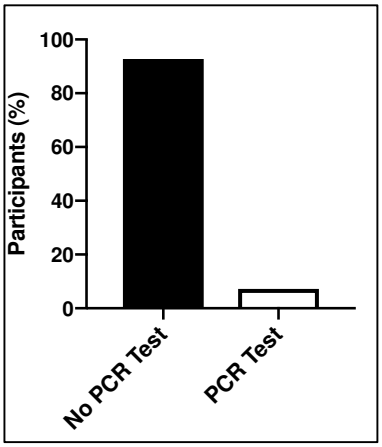

Figure S4: Participants who had previously taken a PCR test that detects SARS-CoV-2

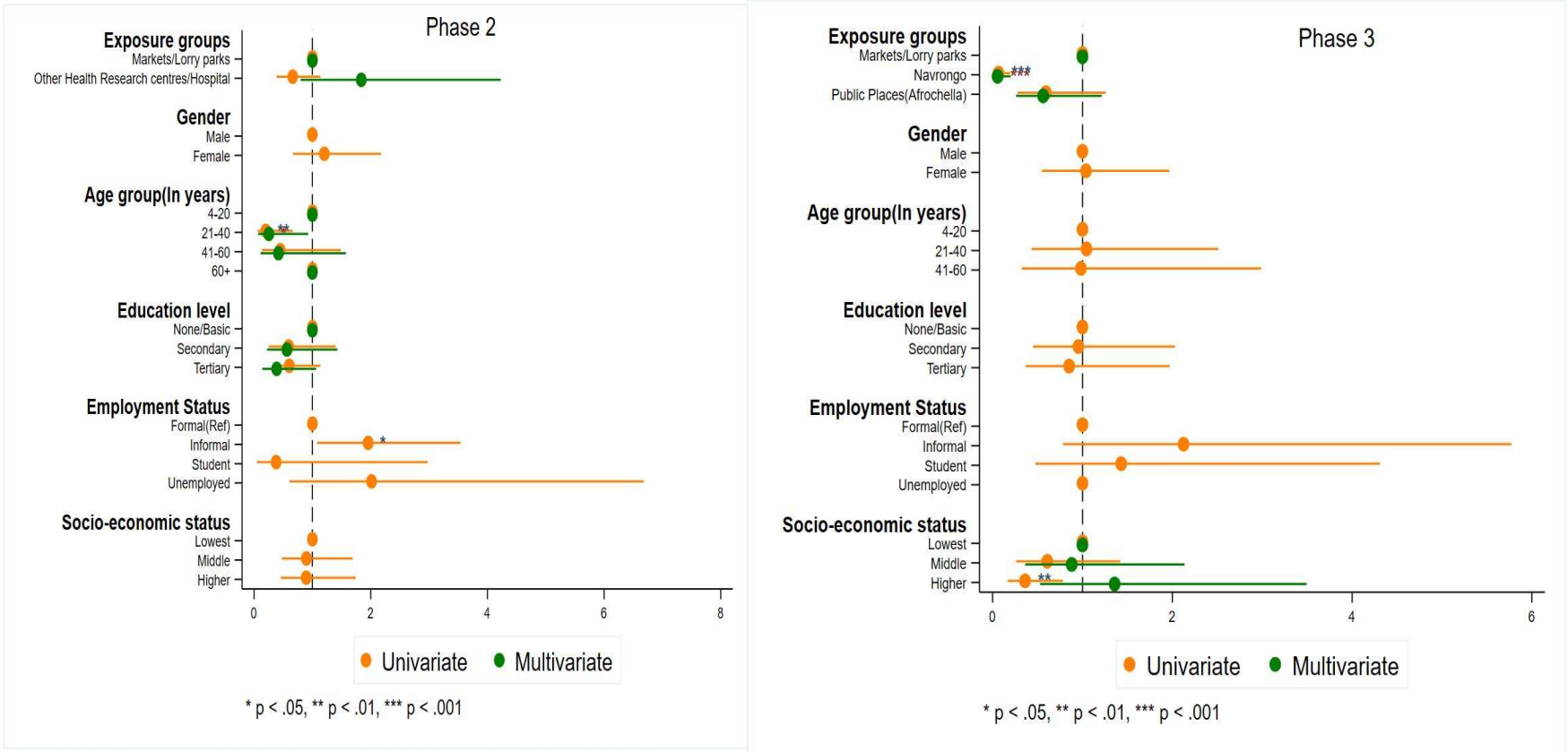

Figure S4: Regressional analysis of Phase II and III exposure rates

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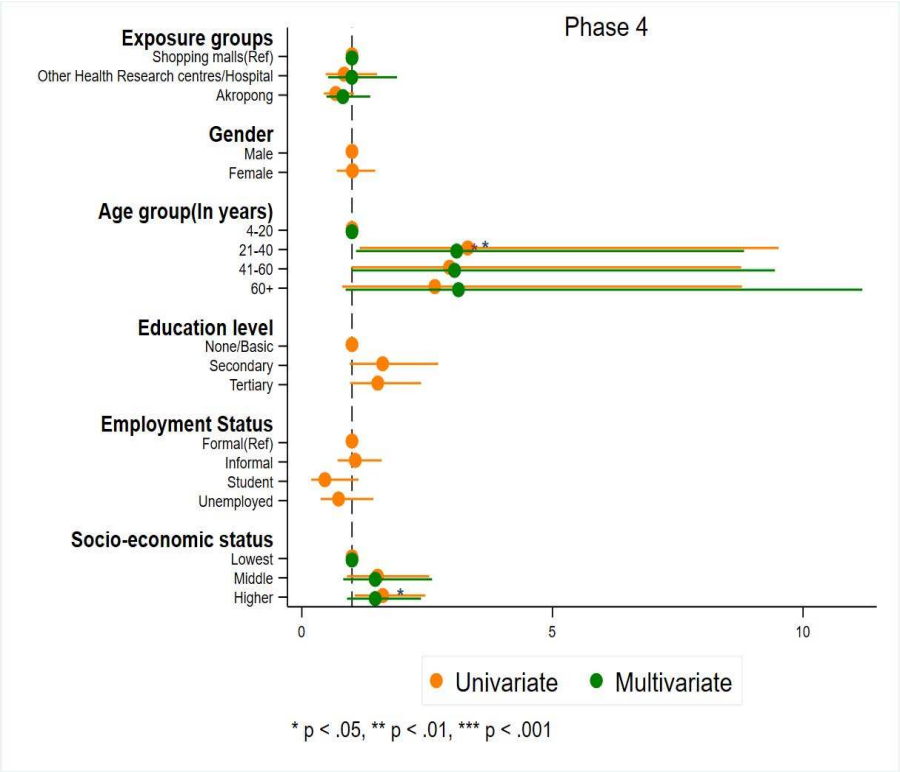

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640 **Figure S5: Regressional analysis of results of Phase IV exposure rates**

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