Annals of Medical Laboratory Science (2022) **2**(2): 45 - 54
https://www.annalsmls.org
https://doi.org/10.51374/annalsmls.2022.2.2.0064

Clinical significance of body temperature in SARS-COV-2 positivity: A prospective study among travelers

Yussif Adams[1]*, Robert Kofi Bugah[1] and Peter Paul M. Dapare[1]

[1]*Department of Biomedical Laboratory Science, School of Allied Health Science, University for Development Studies, Tamale, Ghana*
**Corresponding Author: E-mail: adamsyussif@uds.edu.gh:* ORCID ID*: https://orcid.org/0000-0003-0840-255X*

How to cite this paper: Adams, Y, Bugah. R. K., and Dapare, P. P. M. (2022). Clinical significance of body temperature in SARS-COV-2 positivity: A prospective study among travelers. *Annals of Medical Laboratory Science* **2**(2): 45 - 54

Received: January 17, 2022
Accepted: May 16, 2022
Published: June 01, 2022

ISSN No: 2805-4024

ABSTRACT

Background: Globally, SARS-CoV-2 infections continue to rise with dire consequences on the social and economic activities in affected countries. This prospective cross-sectional study aimed to evaluate the evidence of body temperature and the presence of COVID-19 diseases among travelers.

Methods: The study recruited 314 travelers who visited the Trust Specialist Hospital in Accra hospital. Body temperature readings, demographic information, and the RT-PCR test results of nasopharyngeal swabs were collected routinely from the travelers between March and August 2021. Descriptive statistics and measures of association were performed for the associations between the body temperature readings as an outcome variable verses age, sex, ORF1AB gene, and NGene CT values. An alpha value ($p<0.05$) was considered statistically significant.

Results: There was an even distribution of body temperature readings among the SARS-CoV-2 infected patients however, 90.4% of them were asymptomatic with low/normal body temperature. The ORF1AB mean CT values indicated high infectivity at low/normal and high body temperatures of the patients (26.9 and 25.9 cycles respectively). About 70.1% recorded ORF1AB CT values less than 30 cycles.

Conclusion: The study demonstrates that asymptomatic SAR-CoV-2 infected individuals are equally infectious as those who present with symptoms, hence, temperature checks alone may be misleading. This study was restricted to the use of a rise in body temperature to define asymptomatic cases therefore does not seek to generalize.

Annals of Medical Laboratory Science (2022) 2(2), 45 - 54

Keywords: SARS-CoV-2 infections, Real Time-PCR test, ORF1AB gene, NGene, asymptomatic, body temperature

INTRODUCTION

In December 2019, a novel disease outbreak discovered in Wuhan, China, fast-traveled across global borders due to its extremely high transmission rate (Guan *et al.*, 2020; WHO, 2020a; WHO, 2021a). The Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2), also known as Covid-19 was declared a global pandemic on March 11, 2020, by the World Health Organization (WHO) and has since posed a great threat to global lives with the risk of life-threatening pulmonary complications (Li *et al.*, 2020). This was necessitated by the increase in cases across the globe.

Global confirmed case count of COVID-19 as of 7:07pm CEST, 9th August 2021 stood at 202,608,306 with 4,293,591 deaths (WHO, 2021a). Over 4,033,274,676 vaccine doses have been administered worldwide as of this day as a measure of preventing symptomatic and severe forms of viral infection to control the pandemic (WHO, 2021a; UNICEF, 2021). The majority of the confirmed cases were recorded in United States of America with 78,718,104 making her the hardest hit by the pandemic more than any other country in the world. This was followed by Europe, Asia with Africa recording slightly above 5 million (5,156,790) confirmed cases as of 9th August, 2021 (WHO, 2021a).

Ghana recorded its first two cases on 12th March 2020 following a close outbreak readiness, surveillance, and response assessment by the Ghana Health Service (Odikro *et al*., 2020). These were imported cases that prompted stringent measures to protect its borders. The subsequent surge in cases demanded a 3-week partial locked down in the 4 hotspot cities of the country namely Accra, Kumasi, Tema, and Kasoa which started on 30th March 2020 (myjoyonline.com). As of 10th August 2021, Ghana had recorded 108,677 confirmed cases, 6,922 active cases, and 880 deaths (GHS, 2021).

COVID-19 presents with diverse symptoms in humans which includes; headaches, cough, sore throat, runny nose, fever or chills, shortness of breath or difficulty in breathing, and muscle or body aches. Less commonly, the disease presents with loss of taste or smell, diarrhea, fatigue, nausea, or vomiting (Zhou, 2021). The disease spreads from person to person through the exchange of body fluids in the face openings such as the eyes, nose, and mouth. This occurs commonly through close contact with droplets from the nose or mouth of infected individuals hence the recommended social distancing, frequent hand hygiene, respiratory etiquette, and the use of nose masks (Gostic *et al*., 2020; Klompas *et al*., 2020; WHO, 2021b). The high-risk groups identified were older adults and individuals with comorbidities such as diabetes, respiratory diseases, and heart diseases among others (Del Rio and Malani, 2020; Wu *et al*., 2020).

In an attempt to track, trace, and control the pandemic, several strategies were deployed by the infectious disease surveillance and control institutions of many countries. The World Health Organization recommended safety protocols for individuals, institutions, homes, and offices (WHO, 2020b; WHO, 2021c). These protocols focused on hygiene on surfaces and objects, hand hygiene, display of posters to promote hand hygiene, temperature checks, and social distancing among others. The Ghana Health Service and the COVID-19 rapid response team in Ghana adopted these protocols and affirmed them with an executive instrument to bind all citizens and foreigners.

Again, Ghana among other countries on the globe also implemented a robust surveillance and control program against COVID-19 using the 3T strategies (preemptive Testing, prompt Tracing, and proper Treatment) (MOH, 2020; Park *et al*., 2020). Key among these were body temperature checks at the entrance of every institution in Ghana including its borders with a Non-Contact Infrared Thermometer (NCIT) (CDC, 2020; Bitar *et al*., 2009; Wang *et al*., 2020). This practice resonates in all parts of the country as various entry points including airports, schools, borders, health institutions, worship centers, and hotels among others conduct temperature checks before allowing entry (Bwire and Paulo, 2020; Gostic *et al*., 2020; Klompas *et al*., 2020). In this regard, individuals with low-grade fever (37.3^{o}C or more) were denied access to these areas and were quarantined or subjected to the COVID-19 test (WHO, 2020b; CDC, 2020).

Unfortunately, this screening approach missed several COVID-19 cases, granted entry of asymptomatic patients into institutions based on normal body temperature (WHO, 2020d) while others who were not positive for COVID-19 were wrongfully delayed, denied access to institutions, and traumatized through quarantine due to a spike in temperature (Brooks *et al*., 2020). Although high body temperature (fever) is a cardinal symptom presented by the majority of COVID-19 patients (WHO, 2021c; Zhou, 2021), there has been inadequate evidence to evaluate the significance of body temperature on COVID-19 positivity in suspected cases, especially among travelers. Hence, the need for the study.

MATERIALS AND METHODS

Ethics and human subject issues

Study approval was sought from the Institutional Review Board (IRB) of the University for Development Studies (UDS). Written permission was sought from the Hospital Administrator of the Trust Specialist Hospital before the start of the study. Informed consent was sought from the travelers before their recruitment into the study.

https://doi.org/10.51374/annalsmls.2022.2.2.0064

Only travelers who consented to partake in the study were included.

Study design
The current study employed a prospective cross-sectional study design carried out among travelers who attended the Trust Specialist Hospital in Accra. This spanned through March and August 2021. Trust Specialist Hospital in Accra, Ghana is located at Osu, Kuku Hill.. Its establishment is aimed at providing health care services to SSNIT staff and their dependents. However, this mandate has extended to the entire populace. This facility serves as a COVID-19 testing center and infected patients' management and treatment center.

Population and study sample
The study was conducted among asymptomatic travelers who attended the Trust Specialist Hospital for routine examination. These travelers received routine body temperature checks and SARS-CoV-2 RT-PCR tests at the center for various reasons including traveling requirements.

Sample size and selection of sample
As of 20th August 2021, the infection rate of SARS-CoV-2 in Ghana stood at 0.35% (WHO, 2021a). Using the country-specific infection rate for COVID-19, the minimum required sample size for the study was determined by Cochran's sample size formula (Cochran, 1954). The minimum required sample size was sampled by convenience sampling which permits us to conveniently sample from the available pool of respondents. This involved extraction of data of SARS-CoV-2 positive respondents;

$$n = (Z^2\ (1\text{-}\alpha/2)P(1\text{-}P))/e^2$$

where; n = sample size required; Z = Z score for 95% confidence interval = 1.96; P = Ghana's SARS-CoV-2 infection rate = 0.35% = 0.0035 (WHO, 2021a); e =Margin of error (5% =0.05). Using P = 0.5

$n = (1.96)^2\ (0.0035)\ (1\text{-}0.0035)/\ (0.05)^2$. n = 6

However, a sample size of 314 was used in this study.

Data collection
Primary data was collected using a standard case-based questionnaire adopted from the Ghana Health Service. These were completed in an interview with the respondents who consented to participate. These included demographic information, body temperature readings, and RT-PCR laboratory test result from the nasopharyngeal swab.

Temperature check
Routine temperature checks were performed and recorded using Quick Time Engineering Inc. handheld body infra-red thermometer UT305R Portable. Temperature recordings were taken in degrees Celsius (^oC).

Nasopharyngeal swab
Nasopharyngeal swabs were taken following standard procedures (Pondaven-Letourmy *et al.*, 2020). The patient was prepared for sample collection whilst sitting on a chair and the viral transport vial was well-labeled. With the head tilted back and the nasopharyngeal swab stick held like a pen. The swab stick was inserted into the nostril through the nasal cavity until resistance was met. This indicates that the swab stick has made contact with the posterior wall of the nasopharynx. Here the swab was inclined in the same plane as that of the nose and the ear. The swab stick was rotated a few times and left for a few seconds to absorb some secretions. The stick was removed and quickly inserted into the viral transport medium and the tip was broken. The transport vial was covered and stored in a cold box and transported into the RT-PCR laboratory.

RT-PCR test
Nasopharyngeal swab samples were run for SARS-CoV-2 using the Sansure Biotech RT-PCR. The kit operates on fluorescence real-time quantitative PCR. This is an automated system that gives results in approximately 1:35 minutes. It is an in vitro diagnostic test that detects the Open reading Frame gene region (ORF1AB) and viral nucleocapsid (N) region-specific to SARS-CoV-2.

 https://doi.org/10.51374/annalsmls.2022.2.2.0064

The test procedure follows that of the Sansure Biotech RT-PCR manufacturer and the in-house standard operation procedures for the Trust Hospital Laboratory. The collected sample in the vial was vortexed for approximately 10 seconds and incubated at 65°C for 10 minutes. During sample processing, the specimen was centrifuged briefly and 10 µl aliquoted into PCR microtubes, capped, and incubated for 10 minutes. A 2 milliliter PCR master-mix reagent made up of PCR mix and enzyme mix proportions were prepared and transported to the working area. 30 µl of the master mix is pipetted into both test and control wells. A test project was created on the computer. FAM, ROX, and CY5 dyes are selected to detect ORF1AB, N genes, and the RNaseP internal control respectively. Plates are inserted into the system and run to initiate cycling with unique test identifications assigned. After the test run, results are exported into a Microsoft Excel sheet.

Data analysis

All study respondents were given unique identification numbers coded for identification purposes and to promote confidentiality. The data was extracted into Microsoft excel spreadsheets (version 2010) (www.ibm.com), cleaned, and coded for statistical analysis. Stata 16.0 was used for the statistical analysis of the data. Results were presented in tables and graphs. Descriptive statistics were run on data to have an overview of the frequency distribution of data and to help identify study proportions of interest. Univariate measures of association were performed for the associations between the body temperature readings as an outcome variable verses age, sex, ORF1AB gene, and NGene CT values as independent variables using the T and F test. Spearman's correlation analysis was performed to identify the predictive factors of fever in SARS-CoV-2 infections. Statistical significance was estimated at a p-value <0.050

RESULTS

Socio-demographic characteristics of study participants

Table 1 shows the general characteristics of study participants recruited for the study. The majority of them were between the ages of 18 and 44 years. This represents 64% of the study population. Ages 65 and above recorded the lowest number of respondents (2.9%). More males (54.1%) were recruited for the study than females (45.9%).

Body temperature distribution among SARS-CoV-2 infected patients

Figure 1 gives the graphical distribution of the body temperatures recorded on the patients who tested positive for SARS-CoV-2. There was an even distribution of body temperature among the patients with few outliers. The majority of the body temperatures were equal to or less than 37°C; the normal average body temperature.

Table 1. General characteristics of respondents

Variable	Frequency, n=314	Percent (%)
Age (years)		
≤17	35	11.2
18-44	201	64.0
45-64	69	21.9
≥65	9	2.9
Sex		
Male	170	54.1
Female	144	45.9

The proportion of asymptomatic study participants according to body temperature

Figure 2 illustrates the proportion of study participants who presented with normal to low body temperatures. The majority of them were asymptomatic (90.4%).

Mean distribution of measured parameters in

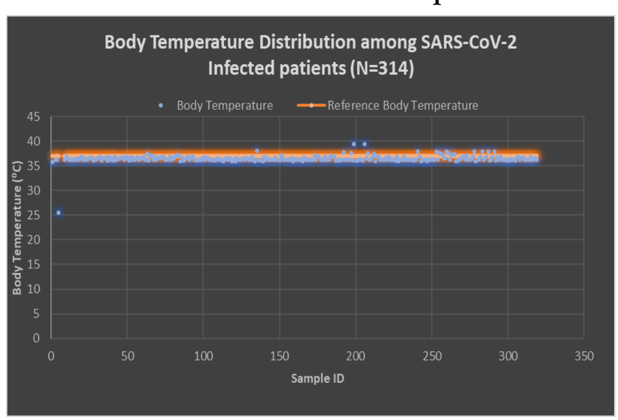

Figure 1 Body Temperature Distribution among SARS-CoV-2 infected patients

the study
Table 2 shows the mean distribution of measured parameters in the study. The mean age of the study participants was 36 years. Averagely, the study participants presented with a body temperature of 36.5°C. The average cycle threshold (CT) established

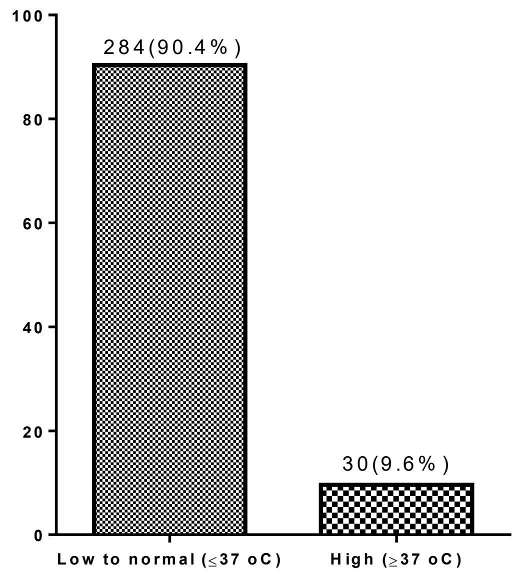

Figure 2: Proportion of asymptomatic study participants using their body temperature readings

by the ORF1AB and NGene were 26.9 and 32.4 cycles respectively.

Association between body temperature and RT-PCR gene-specific CT
Table 3 gives the association between the body temperature recordings of the patients and the cycle thresholds of the ORF1AB and N genes of the SARS-CoV-2. The ORF1ab mean CT values indicate high

Table 2. Description of continuous variables

Variable	Mean ± SD
Age (years)	36.1±13.94
Body Temperature	36.5±0.78
CT value (ORF1AB)	26.9±5.00
CT value (NGene)	32.4±6.14
Internal Control	27.5±2.28

infectivity at low/normal and high body temperatures of the patients (26.9 and 25.9 cycles respectively). This was consistent with the internal control. However, the N Gene established low infectivity with high CT values at either body temperature phase (32.2 and 33.9 cycles respectively). There was no statistical difference between the CT values recorded by the two gene regions with the body temperature of the infected patients at a p-value <0.050.

Association between gene-specific cycle threshold and body temperature
Table 4 shows the association between the gene-specific CT values and the body temperature of the study participants. Out of the 284 SARS-CoV-2 infected individuals with low to normal body temperatures, 199 recorded ORF1AB CT values less than 30 indicating highly infectious. This represented 70.1% of the asymptomatic persons. Again, with NGene, 79 (27.8%) out of the 284 asymptomatic persons were infectious. However, these findings were not statistically significant.

Association between patients' demographic information and body temperature
Table 5 gives the association between patients' demographic information and their body temperatures. There was no statistical difference between the body temperature recordings of the age groups likewise by sex at a p-value< 0.050.

Table 6 shows the correlation between the measured parameters and body temperature stratified by sex. There was no significant correlation between age, CT values (ORF1AB and NGene), and body temperature stratified by sex (p-value <0.050).

DISCUSSION
SARS-CoV-2 infections continue to surge globally with an increasing mortality rate despite the discovery and introduction of several brands of approved vaccines (WHO, 2020a; WHO, 2020h). In 2020, the surge in asymptomatic cases commonly characterized by normal body temperatures prompted the revision of the case definitions for SARS-CoV-2 infection by the World Health Organization (WHO, 2020f). This led to the over-reliance on tem-

https://doi.org/10.51374/annalsmls.2022.2.2.0064

Table 3. Association between Body Temperature and RT-PCR Gene-specific CT values

Variable	Body Temperature		
	≤37°C (low to normal)	>37 °C (High)	P-value
CT value (ORF1AB)	26.9±0.29	25.9±0.91	0.271
CT value (NGene)	32.2±0.36	33.9±1.12	0.163
Internal Control	27.5±0.14	27.2±0.42	0.490

Table 4. Association between gene-specific cycle threshold and body temperature

Variable	Body temperature			
	Total n=314	≤37°C (low to normal) n=284	>37 °C (High) n=30	P-value
CT (ORF1AB)				0.055
CT<30 (High infectivity)	225	199(70.1))	26(86.7)	
CT≥30 (Low infectivity)	89	85(29.9)	4(13.3)	
CT (N Gene)				0.524
CT<30 (High infectivity)	89	79(27.8)	10(33.3)	
CT≥30 (Low infectivity)	225	205(72.2)	20(66.7)	

Table 5 Association between patients' demographic information and body temperature

Variable	Body Temperature (°C)	p-value
Age (years)		
≤17	36.6±0.59	0.294
18-44	36.5±0.47	
45-64	36.3±1.38	
≥65	36.6±0.66	
Sex		
Male	36.4±0.06	0.209
Female	36.5±0.07	

Table 6: Correlation between the measured parameters and body temperature stratified by sex

Variable	Total (n=314)		Male (n=170)		Female (n=144)	
	r	p-value	r	p-value	r	p-value
Age	-0.06	0.298	-0.12	0.130	0.08	0.381
CT value (ORF1AB)	-0.05	0.396	-0.03	0.706	-0.13	0.132
CT value (NGene)	0.01	0.920	-0.04	0.649	0.08	0.341

perature checks being questionable. The current study evaluated the evidence of body temperature and the presence of COVID-19 diseases among travelers who attended The Trust Specialist Hospital in Accra. Specifically, the study associated the low or normal body temperatures in asymptomatic persons with high infectivity among these travelers using the cycle threshold values of the ORF1AB gene region and NGene.

The current study demonstrated an even distribution of body temperature among the SARS-CoV-2 infected patients, however, 90.4% of them reported low or normal body temperature representing the asymptomatic group. The majority were mainly males with an average temperature of 36.5°C. The average cycle threshold (CT) established by the ORF1AB and NGene were 26.9 and 32.4 cycles respectively indicating infectivity and non-infectivity phase of the viral transmission (Singanayagam *et al.*, 2020; Hiroi *et al.*, 2021). The ORF1ab mean CT values indicated high infectivity at low/normal and high body temperatures of the patients (26.9 and 25.9 cycles respectively). Again, out of the 284 SARS-CoV-2 infected individuals with low to normal body temperatures indicating the asymptomatic group, 70.1% recorded ORF1AB CT values less than 30 indicating highly infectious while 27.8% out of the 284 asymptomatic persons were infectious according to the N gene CT values.

Although the entire study population involved travelers infected with SAR-CoV-2, the majority of them presented with low to normal body temperatures. This finding is consistent with similar studies (Buitrago-Garcia *et al*., 2020; Byambasuren *et al*., 2020; He *et al*., 2020; Oran and Topol, 2020). Buitrago-Garcia *et al*. (2020) in a systematic review and meta-analysis, estimated that about 20% (95% CI: 17-25) of the individuals infected with SARS-CoV-2 present asymptomatic and remain asymptomatic throughout infection phases. Similarly, Byambasuren *et al*. (2020) indicated a range of 4% to 41% of asymptomatic cases in 2,454 research articles, however, another meta-analysis produced a 17% proportion of asymptomatic cases. Oran and Topol (2020) and He *et al*. (2020) recorded 40% and 27.7% asymptomatic cases respectively. These studies associated the surge in asymptomatic cases with the subclinical lung abnormalities which are common in young adults especially children compared with the older population.

Since the outbreak of COVID-19, RT-PCR has played a vital role in the early detection of the SARS-CoV-2 and the diagnosis of the disease (WHO, 2020g; Sethuraman *et al*., 2020). In the influx of community transmissions, it was necessary to detect the infectious virus in an infected person and to analyze the possibility of the individual infecting others. The cycle threshold values of the target gene help to quantitatively analyze the infectivity as it gives the number of cycles required for the fluorescent signal to cross the threshold. Though this assertion is argued (Platten *et al*., 2021), others imply that cycle threshold (CT) values of more than 30 in the test results of persons infected with SARS-CoV-2 make them non-infectious (La Scola *et al*., 2020; Hiroi *et al*., 2021). According to Singanayagam *et al*. (2020), CT has a negative correlation with cultivable virus i.e., the higher the CT values, the lower the probability of culturing the virus due to inadequate quantifiable load of the virus or viral titer. The current study agrees with the assertions by La Scola *et al*. (2020) and Hiroi *et al*. (2021). Asymptomatic patients who presented with low to normal body temperatures recorded CT values less than 30 on the ORF1ab gene target. This represented 70.1% of the study population. Again, this disputes the over-reliance on body temperature checks which may be misleading. This reflects the negative correlation between the ORF1AB CT and body temperature in both males and females.

COVID-19 still lingers hence there is a need for a more convenient approach to track and break community transmission. Temperature checks alone could be misleading since there is evidence of possible transmission by asymptomatic persons. The study recommends that as much as strict adherence to the COVID-19 prevention protocols are important, cheaper, efficient, and portable self-check tests are made accessible for routine examinations. This study was restricted to the use of a rise in body temperature to define asymptomatic cases hence it does not seek to generalize. However, future studies may account for other symptoms.

CONCLUSION

The study reveals the inconsistency and inefficiency in the reliance on routine temperature as the pass for accessing institutions in Ghana. The current study in consonance with similar studies demonstrates that asymptomatic SARS-CoV-2 infected individuals are equally infectious as those who present with symptoms hence temperature checks alone may be misleading.

COMPETING INTEREST

Authors declare that they have no competing interests.

ACKNOWLEDGMENT

We acknowledge the administration, management and Covid-19 Testing Unit of the Trust Hospital Company Limited for access to the facility to conduct this study.

REFERENCE

Bitar D., Goubar A. and Desenclos J.-C. (2009) International travels and fever screening during epidemics: a literature review on the effectiveness and potential use of non-contact infrared thermometers. *Eurosurveillance* 14(6), 19115.

Brooks S.K., Webster R.K., Smith L.E., Woodland L., Wessely S., Greenberg N. and Rubin G.J. (2020) The psychological impact of quarantine and how to reduce it: rapid review of the evidence. *The lancet* 395

(10227), 912-920. DOI: https://doi.org/10.1016/S0140-6736(20)30460-8

Buitrago-Garcia D., Egli-Gany D., Counotte M.J., Hossmann S., Imeri H., Ipekci A.M., Salanti G. and Low N. (2020) Occurrence and transmission potential of asymptomatic and presymptomatic SARS-CoV-2 infections: A living systematic review and meta-analysis. *PLoS medicine* 17(9), e1003346. doi: 10.1371/journal.pmed.1003346

Bwire G.M. and Paulo L.S. (2020) Coronavirus disease-2019: is fever an adequate screening for the returning travelers? *Tropical medicine and health* 48(1), 1-3.

Byambasuren O., Cardona M., Bell K., Clark J., McLaws M.-L. and Glasziou P. (2020) Estimating the extent of asymptomatic COVID-19 and its potential for community transmission: systematic review and meta-analysis. *Official Journal of the Association of Medical Microbiology and Infectious Disease Canada* 5(4), 223-234.

CDC (2020). Centers for Disease Control and Prevention. Migration and border health. considerations for health screening for COVID-19 at points of entry. Available at: https://www.cdc. gov/coronavirus/2019-ncov/global-covid-19/ migration-border-health.html

Cochran W.G. (1954) The combination of estimates from different experiments. *Biometrics* 10(1), 101-129.

Del Rio C. and Malani P.N. (2020) 2019 novel coronavirus—important information for clinicians. *Jama* 323(11), 1039-1040.

GHS (2021). Ghana's COVID-19 situation dashboard. Accessed on 10th August, 2021 from. http://ghs.gov.gh/covid19/dashboardm.php

Gostic K., Gomez A.C., Mummah R.O., Kucharski A.J. and Lloyd-Smith J.O. (2020) Estimated effectiveness of symptom and risk screening to prevent the spread of COVID-19. *Elife* 9e55570.

Guan W.-j., Ni Z.-y., Hu Y., Liang W.-h., Ou C.-q., He J.-x., Liu L., Shan H., Lei C.-l. and Hui D.S. (2020) Clinical characteristics of coronavirus disease 2019 in China. *New England Journal of Medicine* 382(18), 1708-1720.

He F., Deng Y. and Li W. (2020) Coronavirus disease 2019: What we know?[published online ahead of print, 2020 Mar 14]. *J Med Virol* 10. doi:10.1002/jmv.26326 pmid:32691881

Hiroi S., Kubota-Koketsu R., Sasaki T., Morikawa S., Motomura K., Nakayama E.E., Okuno Y. and Shioda T. (2021) Infectivity assay for detection of SARS-CoV-2 in samples from patients with COVID-19. *Journal of Medical Virology* 93(10), 5917-5923. https://doi.org/10.1002/jmv.27145

Klompas M., Morris C.A., Sinclair J., Pearson M. and Shenoy E.S. (2020) Universal masking in hospitals in the Covid-19 era. *New England Journal of Medicine* 382(21), e63. https://doi.org/10.1056/NEJMp2006372

La Scola B., Le Bideau M., Andreani J., Hoang V.T., Grimaldier C., Colson P., Gautret P. and Raoult D. (2020) Viral RNA load as determined by cell culture as a management tool for discharge of SARS-CoV-2 patients from infectious disease wards. *European Journal of Clinical Microbiology & Infectious Diseases* 39(6), 1059-1061.

Li Q., Guan X., Wu P., Wang X., Zhou L., Tong Y., Ren R., Leung K.S., Lau E.H. and Wong J.Y. (2020) Early transmission dynamics in Wuhan, China, of novel coronavirus–infected pneumonia. *New England Journal of Medicine*.

MOH (2020a). President Akufo-Addo Addresses Nation on Measures Taken By Gov't To Combat The Coronavirus Pandemic. Assessed on 11th August, 2021. https://www.moh.gov.gh/president-akufo-addo-addresses-nation-on-measures-taken-by-govt-to-combat-the-coronavirus-pandemic/

myjoyonline (2020). Parts of Ghana to be on lockdown from Monday. Assessed on 10th August, 2021 from https://www.myjoyonline.com/parts-of-ghana-to-be-on-lockdown-from-monday/

Odikro M.A., Kenu E., Malm K.L., Asiedu-Bekoe F., Noora C.L., Frimpong J., Calys-Tagoe B. and Koram K.A. (2020) Epidemiology of COVID-19 outbreak in Ghana, 2020. *Ghana Medical Journal* 54(4s), 5-15.

Oran D.P. and Topol E.J. (2020) Prevalence of asymptomatic SARS-CoV-2 infection: a narrative review. *Annals of internal medicine* 173(5), 362-367. https://www.acpjournals.org/doi/abs/10.7326/M20-3012

Park Y., Huh I.S., Lee J., Kang C.R., Cho S.-i., Ham H.J., Kim H.S., Kim J.-i., Na B.J. and Lee J.Y. (2020) Application of testing-tracing-treatment strategy in response to the COVID-19 outbreak in Seoul, Korea. *Journal of Korean Medical Science* 35(45).doi: 10.3346/jkms.2020.35.e396. PMID: 33230987; PMCID: PMC7683243

Platten M., Hoffmann D., Grosser R., Wisplinghoff F., Wisplinghoff H., Wiesmüller G., Schildgen O. and Schildgen V. (2021) SARS-CoV-2, CT-values, and infectivity conclusions to be drawn from side observations, pp. 1459: Multidisciplinary Digital Publishing Institute. https://doi.org/10.3390/v13081459

Pondaven-Letourmy S., Alvin F., Boumghit Y. and Simon F. (2020) How to perform a nasopharyngeal swab in adults and children in the COVID-19 era. *European annals of otorhinolaryngology, head and neck diseases* 137(4), 325-327. https://doi.org/10.1016/j.anorl.2020.06.001

Sethuraman N., Jeremiah S.S. and Ryo A. (2020) Interpreting diagnostic tests for SARS-CoV-2. *Jama* 323(22), 2249-2251.

Singanayagam A., Patel M., Charlett A., Bernal J.L., Saliba V., Ellis J., Ladhani S., Zambon M. and Gopal R. (2020) Duration of infectiousness and correlation with RT-PCR cycle threshold values in cases of COVID-19, England, January to May 2020. *Eurosurveillance* 25(32), 2001483. https://doi.org/10.2807/1560-7917.ES.2020.25.32.2001483

UNICEF (2021). Information on the COVID-19 Vaccine, frequently asked questions, Ghana. Assessed on 10th August, 2021 from https://www.unicef.org/ghana/information-covid-19-vaccine

Wang Z., Yang B., Li Q., Wen L. and Zhang R. (2020) Clinical features of 69 cases with coronavirus disease 2019 in Wuhan, China. *Clinical infectious diseases* 71(15), 769-777.

WHO (2003). Cumulative number of reported probable cases of SARS . (2003). Accessed: March 15, 2020: https://www.who.int/csr/sars/country/2003_07_11/en/

WHO (2020a). World Health Organization. Report on the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19). Available online at: https://www.who.int/docs/default-source/coronaviruse/who-china-joint-mission-on-COVID-19-final-report.pdf (accessed March 23, 2020).

WHO (2020b). Getting your workplace ready for COVID-19. 3 March2020. World Health Organization. Assessed on 11th August, 2021 from https://www.who.int/docs/default-source/coronaviruse/getting-workplace-ready-for-covid-19.pdf

WHO (2020c). Coronavirus disease (COVID-19) pandemic. Accessed: 11th August, 2021: https://www.who.int/emergencies/diseases/novel-coronavirus-2019

WHO (2020d). How is COVID-19 transmitted? 14 July, 2020. Accessed on 11th August, 2021 from https://www.who.int/vietnam/news/detail/14-07-2020-q-a-how-is-covid-19-transmitted

WHO (2020e). COVID-19 Public Health Emergency of International Concern (PHEIC) Global research and innovation forum. Assessed on 11th August, 2021 from https://www.who.int/publications/m/item/covid-19-public-health-emergency-of-international-concern-(pheic)-global-research-and-innovation-forum

WHO (2020f). WHO COVID-19: Case Definitions. Updated in Public health surveillance for COVID-19, published 16 December 2020. World Health Organization. WHO reference number: WHO/2019nCoV/Surveillance_Case_Definition/2020.2. Assessed on 16th August, 2021 from https://apps.who.int/iris/rest/bitstreams/1322790/retrieve

WHO (2020g). Episode #14 - COVID-19 – Tests. World Health Organization, Science Conversation. 27th November, 2020. Assessed on 16th August, 2020 from https://www.who.int/emergencies/diseases/novel-coronavirus-2019/media-resources/science-in-5/episode-14---covid-19---tests?gclid=CjwKCAjwmeiIBhA6EiwA-uaeFcShWyzLZDvX_7mDm3n3HNrBW1XitnRh1fe4S6f7zUn5rZ0KR_j22RoCpmUQAvD_BwE

WHO (2020h). Coronavirus disease (COVID-19): Vaccines. https://www.who.int/news-room/q-a-detail/coronavirus-disease-(covid-19)-vaccines?topicsurvey=v8kj13)&gclid=Cj0KCQjwvO2IBhCzARIsALw3ASpj4reBKSuAlTnhI2xVyDwsMqzzPw1KRaRT1Eq9XByQzUSyVQ4HDQaAmKaEALw_wcB

Wu D., Koganti R., Lambe U.P., Yadavalli T., Nandi S.S. and Shukla D. (2020) Vaccines and therapies in development for SARS-CoV-2 infections. *Journal of clinical medicine* 9 (6), 1885.

Zhou X.-N. (2021) Infectious Diseases of Poverty: 10 years' commitment to One Health, pp. 1-4: Springer