



## Association between Comorbidities and COVID-19 Mortality in Two African Countries: A Case- Control Study

Adelard Kakunze<sup>1</sup>, Birungi Patience<sup>2</sup>, Ingabire Kabarega Betty<sup>1</sup>, Gizaw Teka Nibzane<sup>3</sup>, Masresha Tessema<sup>4</sup>, Chioma Dannwafo<sup>5</sup>, Rejoice Luka-Lawal<sup>6</sup>, Charles Ameh<sup>7</sup> and Mohammed Abdulaziz<sup>1\*</sup>

<sup>1</sup>Department of Disease Control and Prevention, Africa Centres for Disease Control and Prevention, Ethiopia.

<sup>2</sup>Department of Epidemiology and Biostatistics School of Public Health, Makerere University, Uganda.

<sup>3</sup>Department of Centre for Public Health Emergency Management, Ethiopian Public Health Institute, Ethiopia.

<sup>4</sup>Department of Nutrition and Environmental Health Research Directorate Director, Ethiopian Public Health Institute, Ethiopia.

<sup>5</sup>Department of Surveillance and Epidemiology, Nigeria Centres for Disease Control and Prevention, Nigeria.

<sup>6</sup>Department of Health Emergency, Preparedness and response, Nigeria Centres for Disease Control and Prevention, Nigeria.

<sup>7</sup>Head of Department International Public Health, Liverpool School of Tropical Medicine, United Kingdom.

### ABSTRACT

**Background:** COVID-19 revealed significant health disparities globally, with comorbidities exacerbating outcomes, Africa faced heightened risks from pre-existing conditions during the pandemic.

**Objective:** The aim of the study was to assess the association between comorbidities and mortality of hospitalised patients with corona virus disease in two African countries after adjusting for confounders such as age.

**Setting:** Study was conducted in treatment centres from 4 states in Nigeria and 6 regions in Ethiopia.

**Methods:** An unmatched case-control study with equal distribution of cases and controls, conducted using secondary data. All files of COVID-19 patients hospitalised between February 2020 and February 2021 were enlisted as participants in the study. A case was an individual who died of COVID-19 whereas a control was one who survived. Both cases and control were of African descent. Multi-variable logistic regression was conducted.

**Results:** A total of 2,576 adult hospitalised participants diagnosed with COVID-19 were enrolled in the study. Their mean age was 51.1±19.4 with the controls being 41±17.3 the cases being 61.3±15.7 years. Fifty-seven percent (57%) had at least one comorbidity. Presence of comorbidities, as opposed to no comorbidity, was associated with mortality (adjusted odds ratio: 1.91; 95% confidence intervals 1.41-2.59;  $p < 0.01$ ) even after adjustment for sex, marital status, age, education level and occupation. Hypertension ( $p < 0.001$ ) and HIV/AIDS ( $p < 0.001$ ) were independently correlated with mortality".

**Conclusion:** This study showed that comorbidities such as hypertension and HIV/AIDS were linked to mortality in patients with COVID-19 in Africa after adjusting for age.

### ARTICLE HISTORY

Received 01 September 2025

Accepted 19 October 2025

Published 28 October 2025

### KEYWORDS

COVID-19, Mortality, Comorbidities, Clinical outcomes.

### Introduction

Africa has been affected by COVID-19 like other continents on the globe, as of 02 January 2023 COVID-19 has accounted for a total of 12,258,502 cases with 256,729 deaths. In Ethiopia the initial confirmed COVID-19 case was reported on March 13<sup>th</sup>, 2020 and has since registered, 500,116 cases and recorded 7,572 deaths. Similarly, Nigeria confirmed its first case on February 27, 2020 and has also recorded 266,628 cases and 3,155 deaths.

Currently available evidence since onset of the COVID-19 pandemic shows that individuals with co-morbidities face an increased risk of severe disease and mortality due to the virus [1,2]. Initial estimates from China's National Health Commission regarding COVID-19 fatalities indicated that 75% of those who died had underlying health conditions including diabetes and cardiovascular disease. Other studies also highlighted a significant prevalence of pre-existing conditions in COVID-19 patients such as chronic kidney disease, hypertension, chronic heart disease, cancer, chronic liver disease, HIV/AIDS, chronic obstructive pulmonary disease and Asthma among others [3-6].

**Contact** Mohammed Abdulaziz, Department of Disease Control and Prevention, Africa Centres for Disease Control and Prevention, Ethiopia, Tel: +251 947373351.

In Africa, infectious diseases like HIV, tuberculosis and malaria are widespread and are known to impact immune function and activation, potentially influencing the body's response to COVID-19 [7]. However, there is limited understanding of the extent to which these infections alter the immune response to SARS-CoV-2 [8]. Global evidence has shown that individuals with pre-existing comorbidities such as hypertension, cardiovascular disease, and diabetes face a significantly higher risk of fatality from COVID-19. Despite this, the exact role that comorbidities play in increasing susceptibility to infection and the severity of COVID-19 remains unclear [9-12].

Therefore, identifying the risk factors associated with poor outcomes among COVID-19 patients is crucial. This study aimed to assess the degree to which comorbidities contribute to COVID-19 related fatalities.

## Methods

### Study site

We conducted this study using secondary data in both government and private health facilities within randomly selected regions and states in Ethiopia and Nigeria respectively. These, two countries were selected because of their large populations in Africa. Due to political insecurities in Nigeria at the time of data collection, only 22 facilities with highest COVID-19 patients were considered in the 4 states of Edo, Federal Capital Territory (FCT), Kano, and Rivers. In Ethiopia, 6 regions; Addis Ababa, Dire Dawa, South Nation Nationality and People Regional state (SNNPR), Sidama, Hareri and Amhara were selected for the study.

### Study design

An unmatched case control design utilizing incidence density sampling with controls selected from the same facilities as the cases. Individuals were included if they were hospitalised with SARS-CoV-2 infection with evidence of a PCR result on their file from February 27, 2020 to November 2021. Comorbidities associated with COVID-19 among patients that died or recovered were analysed using secondary data.

### Study population

The study considered all files of adult hospitalised patients of African descent in both government and private health facilities in Ethiopia and Nigeria that were diagnosed with COVID-19. A total of 2,576 COVID-19 patients were recruited into this study. Cases (death due to COVID-19) were 1, 288 patients, of which 644 were from Nigeria. While 1,288 were controls of which 644 were from Ethiopia (recovered from COVID-19).

### Case definition and selection

The main outcome was mortality due to COVID-19. It was assessed by reviewing of patient files as recorded or documented by the doctor at the time of the patients' death. A case was defined as an adult who tested positive for COVID-19 and died.

### Selection of controls

Controls were adults hospitalised within the same period as cases, tested positive and recovered from COVID-19. Controls

were not matched with cases for any variable. For every case, one control was picked. Controls were picked from the same facilities as cases.

### Sample size and sampling

Using a formula for two proportions by Schlesselman [13] the calculated sample size was 644 per group. This was arrived at after considering obesity, diabetes and hypertension as the exposures. Hypertension (22.5% vs 14%, [14]), ratio of 1:1, 95% confidence level, 80% power and odds ratio of 2 yielded the highest sample size of 644 after adjusting for missingness. Considering a design effect of 2, the final sample size was 1288 per group. Thus the overall sample size of 2576. The sample was collected from different regions and states in the study countries to allow fair representation, simple random sampling was used to select facilities, proportionate to size sampling was done at each region. A total of 8028 files were retrieved. Of these, 7728 were eligible. Using systematic sampling and a sampling interval of 3, 2576 files selected and included into the study.

### Inclusion and Exclusion

Adults of African Descent aged 18 years and older diagnosed with COVID-19 who later died/ recovered and were in the country of interest at the time of diagnosis were eligible for this study. The study excluded individuals whose patient files were missing all the key information relevant for the study. Two hundred thirty-two (232) participants were excluded from the analysis. These had missing information on some of the variables including age, comorbidities and marital status. Of these 107 were cases and 125 were controls.

### Study Variables

The main outcome analysed was mortality associated with COVID-19. In addition to socio-demographic factors highlighted in the literature such as age, gender, education, marital status, nationality, occupation, ethnicity and country of residence as risk factors for COVID-19. A range of 13 comorbidities were abstracted and analysed, including chronic obstructive pulmonary disease, tuberculosis, asthma, chronic haematological disease, peptic ulcer disease, HIV/AIDS, chronic lung disease, liver disease, diabetes, renal disease, neurological impairment and hypertension.

### Data collection, quality control and Supervision

Manual file review was performed to confirm the main outcome variable and ensure accuracy.

Data was extracted from the patients' file at the facility medical records office using an excel sheet. The data collectors were experienced and skilled health workers who were hired and trained before data collection. The virtual training involved equipping the team with techniques of secondary data collection without revealing patient key identifiers hence no patient names were recorded. Case managers at national level and the study team provided oversight and supervision to ensure that ethical standards and procedures were adhered to and prevent inconsistencies and inaccurate data.

## Data Management and Analysis

Data was analysed using STATA version 14 with categorical variables summarized as frequencies and percentages. The resultant percentages were compared across groups by mortality and survival status using chi-square and Fisher's exact test. To determine whether the underlying co-morbidity was a predictor for the patient outcome (died vs. survived) unconditional logistic regression model was used at both bivariate and multivariate levels. At bivariate, all the socio-demographics and the co-morbidities with a p-value less or equal to 0.2 were considered significant and thus entered into the multi-variate model using the stepwise LR method. This was used to aid the identification of comorbidities that contributed most to COVID-19 related deaths. At this level of analysis, all factors and co-morbidities with a p<0.05 were considered statistically significant.

## Ethical Approval

The study was approved in Ethiopia by the Ethiopian Public Health Institute (EPHI- IRB-356-2021) and in Nigeria by National Health Research Ethics Committee (NHREC/01/01/2007-29/03/2021) In addition, permission to conduct the study at health facility level was obtained from the Ministry of Health and the respective facility managers. During data collection and analysis, Confidentiality was observed by the research team in an effort to protect patient data. All patient data was codified before entering it into the general database, thereby ensuring patient anonymity to the investigator analysing the data.

## Waiver of Consent Statement

This study utilized secondary data abstracted from patient files, and direct contact with patients was not feasible. To ensure compliance with ethical standards, a waiver of informed consent was obtained from two ethical review bodies: the Ethiopian Public Health Institute (EPHI) and the National Health Research Ethics Committee (NHREC). These bodies reviewed and approved the use of the data for research purposes, recognizing that obtaining consent directly from patients was impractical. The waiver was granted on the condition that all data used in the study would remain anonymized, ensuring the confidentiality and privacy of the patients.

## Public and patient Involvement

Neither patients nor the public participated in the design or implementation of this research

## Results

### Study profile

The study recruited a total of 2,576 patients diagnosed with COVID-19, including an equal number of cases and controls. Of these 23.4% (604/2576) lacked information on at least one co-morbidity and were excluded from analysis. Of those that had missing information on co-morbidities, majority 76.3% (461/604) were controls.

### Socio-demographic

The overall mean age for the study participants was 51.1±19.4 with the controls being 41±17.3 while that among the cases

being 61.3±15.7 years., The majority 71% (915/1288) and 68.0% (876/1288) were male, 62.5% (715/1144) and 85.0%(646/760) were married, 66.2% (830/1253) and 56.5%(403/713) had attained tertiary education and more than half were working among the cases and controls respectively. All the socio-demographic characteristics studied varied significantly (p>0.005) between the cases and controls apart from sex (p=0, .095).

**Table 1:** Demographic and social attributes of the study participants.

Variable	Overall (n/%)	Controls	Cases	p-value
<b>Sex</b>				
Male	1,791(69.5)	915(71.0)	876(68.0)	0.095
Female	785(30.5)	373(29.0)	412(32.0)	
<b>Marital status</b>				
Single	397(20.8)	362(31.6)	35(4.6)	<0.001
Married	1,361(71.5)	715(62.5)	646(85.0)	
Separated	146 (7.7)	67(5.89)	79(10.4)	
<b>Age</b>				
<25	267 (10.4)	239(18.6)	28(2.2)	<0.001
25-34	353 (13.7)	307(23.8)	46(3.6)	
35-44	332(12.9)	224(17.4)	108(8.4)	
45-54	406 (15.8)	205(15.9)	201(15.6)	
55-64	452 (17.5)	163(12.7)	289(22.4)	
65+	766 (29.7)	150(11.6)	616(47.8)	
<b>Education level</b>				
No formal education	113(5.8)	43(3.4)	70(9.8)	<0.001
Primary	227 (11.5)	161(12.8)	66(9.3)	
Secondary	393(20.0)	219(17.5)	174(24.4)	
Tertiary	1,233 (62.7)	830(66.2)	403(56.5)	
<b>Occupation</b>				
Not working	574 (29.6)	321(28.3)	253(31.3)	0.161
Working	1,368 (70.4)	812(71.7)	556(68.7)	

### Distribution of co-morbidities in relation to cases and controls among the COVID-19 patients

Overall, 67% (767/1145) and 43.1% (356/827) had at least one co-morbidity among the cases and controls respectively. Hypertension was the commonest at 41% (490/1195) and 20.2% (258/1275), and this varied significantly at p=0.0071. This was followed by diabetes at 34.0% (402/1182) and 11.1%(138/1242), with p<0.001 significance level and prostate cancer at 1%(9/1044) and 0.1%(1/1151) at P<0.001 among the cases and controls. Table 2 summarises the co-morbidities in relation to cases and controls.

### Association between co-morbidities and COVID-19 Mortality

At bi-variate analysis, it was revealed that all the socio-demographic characteristics studied and the co-morbidities except lung cancer, liver cancer, oesophageal cancer, malaria, CPD and peptic ulcers showed independent association with mortality in patients diagnosed with COVID-19 (p<0.2).

At multivariate analysis, having HIV/AIDs (OR=4.78, 95%CI 2.07-11.05, P<0.001), hypertension (OR=1.82, 95% CI 1.39-2.39, P<0.01 and age (OR= 4.88, 11.10, 17.14, 42.82, P<0.001) for those aged above 35 were strongly linked to mortality in patients with COVID-19.

Table 3 summarizes the co-morbidities that demonstrated a significant relationship with mortality among COVID-19 patients.

**Table 2:** Distribution of co-morbidities by cases and controls among the COVID-19 patients.

Co-morbidity	Cases (n/%)	Controls (n/%)	p-value
<b>Obesity</b>			
Yes	53 (5.5)	17 (2.3)	0.0014
No	915 (94.5)	708 (97.7)	
<b>Breast cancer</b>			
Yes	7 (0.7)	2 (0.2)	0.0691
No	1026 (99.3)	1136 (99.8)	
<b>Lung cancer</b>			
Yes	6 (0.6)	3 (0.3)	0.2531
No	1041 (99.4)	1146 (99.7)	
<b>Prostate cancer</b>			
Yes	9 (0.9)	1 (0.1)	0.0071
No	1035 (99.1)	1150 (99.9)	
<b>Liver cancer</b>			
Yes	3 (0.3)	1 (0.1)	0.2722
No	1040 (99.7)	1147 (99.9)	
<b>Oesophageal cancer</b>			
Yes	1 (0.1)	2 (0.3)	0.3671
No	1044 (99.9)	1152 (99.7)	
<b>Diabetes**</b>			
Yes	402 (34.0)	138 (11.1)	<0.001
No	780 (66.0)	1104 (88.9)	
<b>HIV/AIDS**</b>			
Yes	39 (3.7)	15 (1.2)	<0.001
No	1023 (96.3)	1195 (98.8)	
<b>TB</b>			
Yes	18 (1.7)	9 (0.8)	0.068
No	1041(98.3)	1085 (99.2)	
<b>Hypertension**</b>			
Yes	490 (41.0)	258 (20.2)	<0.001
No	705 (59.0)	1017 (79.8)	
<b>Malaria</b>			
Yes	60 (5.4)	81 (6.6)	0.207
No	1060 (94.6)	1147 (93.4)	
<b>Renal disease**</b>			
Yes	147 (13.1)	34 (2.8)	<0.001
No	977 (86.9)	1195 (97.2)	
<b>CPD</b>			
Yes	54 (5.0)	72 (6.0)	0.302
No	1030 (95.0)	1135 (94.0)	
<b>Asthma</b>			
Yes	47 (4.2)	28 (2.3)	0.010
No	1063 (95.8)	1176 (97.7)	
<b>Chronic lung disease</b>			
Yes	26 (2.4)	12 (1.0)	0.010
No	1073 (97.6)	1194 (99.0)	
<b>Peptic ulcers</b>			
Yes	36 (3.4)	29 (2.7)	0.414
No	1039 (96.6)	1029 (97.3)	

**Table 3:** Association between co-morbidities and mortality among COVID-19 patients.

Variable	unadjusted OR	95%CI	p-value	Adjusted OR	95%CI	P-value
<b>Sex</b>						
Male						
Female	1.15	0.97-1.36	0.095			
<b>Marital status</b>						
Single						
Married	9.34	6.50-13.4	<0.001			
Seperated/widowed	12.19	7.57-19.6	<0.001			
<b>Age</b>						
<25						
25-34	1.3	0.77-2.10	0.334	1.36	0.61- 3.05	0.443
35-44	4.1	2.61-6.48	<0.001	4.88	2.27-10.52	<0.001
45-54	8.4	5.40-12.9	<0.001	11.10	5.22-23.61	<0.001
55-64	15.1	9.78-23.40	<0.001	17.74	8.29-38.0	<0.001
65+	35.0	22.80-53.90	<0.001	42.82	20.0-91.76	<0.001

<b>Education level</b>						
No formal education						
Primary	0.25	0.15-0.40	<0.001			
Secondary	0.48	0.32-0.75	0.001			
Tertiary	0.30	0.20-0.44	<0.001			
<b>Occupation</b>						
Not working						
Working	0.87	0.71-1.06	0.162			
<b>Co-morbidity</b>						
<b>Presence of comorbidity</b>						
<b>Yes</b>						
No	1.79	1.46-2.19	<0.001	1.91	1.41-2.58	<0.001
<b>Obesity (n=1,693)</b>						
Yes	2.4	1.36- 4.48	0.0014			
No						
<b>Breast cancer(n=9)</b>						
Yes	3.9	0.73- 38.3	0.0691			
No						
<b>Lung cancer(n=9)</b>						
Yes	2.2	0.47- 13.6	0.2531			
No						
<b>Prostate cancer</b>						
Yes	10	1.38- 438.61	0.0071			
No						
<b>Liver cancer</b>						
Yes	3.31	0.26-173.82	0.2722			
No						
<b>Oesophageal cancer</b>						
Yes	0.37	0.01-4.59	0.3671			
No						
<b>Diabetes**</b>						
Yes	4.1	3.31-5.1	<0.001			
No						
<b>HIV/AIDS**</b>						
Yes	3.04	1.62- 5.96	<0.001	4.78	2.07-11.05	<0001
No						
<b>TB</b>						
Yes	2.08	0.88- 5.29	0.068			
No						
<b>Hypertension**</b>						
Yes	2.74	2.28- 3.29	<0.001	1.82	1.39-2.39	<0.001
No						
<b>Malaria</b>						
Yes	0.80	0.56- 1.14	0.207			
No						
<b>Renal disease**</b>						
Yes	5.29	3.58-7.99	<0.001			
No						
<b>CPD</b>						
Yes	0.83	0.56- 1.20	0.302			
No						
<b>Asthma</b>						
Yes	1.86	1.13- 3.10	0.010			
No						
<b>Chronic lung disease</b>						
Yes	2.41	1.17-5.27	0.010			
No						
<b>Peptic ulcers</b>						
Yes	1.23	0.73-2.09	0.414			
No						

## Discussion

This study contributes to existing literature on the factors associated with mortality in COVID-19 patients treated in selected facilities in Nigeria and Ethiopia. The findings of this study show that more male than females died of COVID-19 71% a trend observed in other studies, this is in line with other similar studies that revealed higher proportions of fatalities in males than females in nearly all countries [15-21]. A study by Jian, et al., found that the death rate in men was nearly twice that of women [22]. Similarly, higher mortality rate was observed among patients that had attained tertiary level of education 66.2%.

In this study 56.9% of all participants had at least one comorbidity, and higher proportions are observed among the cases 67%. This finding confirms the existing literature that COVID-19 patients with pre-existing conditions have a higher risk of COVID-19 related death [2,14,23-29]. Pre-dominant underlying conditions seen in the study population is Hypertension, Diabetes, prostate cancer and renal diseases. This paper just like others also puts hypertension as the commonest pre-existing condition that has contributed to poor outcomes among the COVID-19 patients [30-32].

At bi-variate level all socio-demographic factors were linked to mortality among COVID-19 patients as well as comorbidities such as Asthma, renal disease, hypertension, HIV/AIDS diabetes, prostate cancer, breast cancer and obesity. This is revealed in other studies that reviewed each of these factors independently in relation to COVID-19 related mortality. A study by Choi, et al. revealed that Asthma was associated with poor outcomes. Mortality rate for COVID-19 patients with underlying asthma was significantly higher than that of other patients, however it was not an independent risk factor for the clinical outcomes of COVID-19 after adjustment [33].

After adjusting for all other factors, hypertension, HIV/AIDS and Age were strongly linked to COVID-19 Mortality. These results concur with studies of [34] that indicated that Hypertension can affect severity of COVID-19. The study found hypertension to be significantly linked to COVID-19 mortality. High blood pressure, is a common co-morbidity in the population and can contribute to increased COVID-19 mortality. Hypertension is often linked to other health conditions, such as diabetes and heart disease, which can exacerbate the severity of COVID-19. Additionally, some COVID-19 cases with hypertension may be on medications that affect their immune response [35].

Similarly, a population cohort study conducted in Western Cape Province, South Africa revealed that that HIV was associated with a doubling of COVID-19 mortality risk [36]. Individuals with HIV/AIDS were identified as having a significantly higher odds ratio for COVID-19 related deaths. This is consistent with previous research indicating that people with compromised immune systems, such as those with HIV/AIDS, may face greater risk of severe illness and death when infected with COVID-19 [37,38].

Lastly, studies have reported older age especially 65 years and above as a contributing factor to poor outcomes among those

diagnosed with COVID-19 [39-41], this is in line with the findings of this paper because results suggest a marked link between age and COVID-19 deaths. Older age groups were found to have substantially higher odds of mortality. This finding is consistent with global trends in COVID-19 mortality, where older individuals are more susceptible to severe illness and death. Age-related factors, such as a weakened immune system, higher prevalence of co-morbidities, and reduced physiological reserve, make older individuals more vulnerable to the virus [42-44].

Therefore, patients with comorbidities should take every possible precaution to prevent infection during disease outbreaks.

## Strength and Limitations

The study had a big sample size and in addition used data from more than one population (Nigeria and Ethiopia which increased generalizability. The major limitation of this study was the use of secondary data as a source of information. This data was gathered for other purposes thus it was difficult to generate all necessary variables. The files also had some missing variables. Secondly, the effect of unobserved variables could not be accounted for. In addition, residual confounding could still be present due to the retrospective design that was used. Furthermore, the case control design used relies on data that was collected thus limiting in the amount and type of data to be collected.

## Conclusion

This study showed that comorbidities such as hypertension and HIV/AIDs were associated with COVID-19 mortality in Africa after adjusting for age. These findings highlight the significance of targeting prevention, vaccination, and care efforts toward vulnerable populations, including older individuals and those with specific co-morbidities, to reduce COVID-19 mortality.

## Recommendation

This study recommends more prospective studies examining the impact of comorbidities on COVID-19 outcomes in Africa and also patients with underlying conditions need to be given priority when responding to disease outbreaks.

## What is known?

Similar studies have revealed that the most common comorbidities reported till now are hypertension, cardiovascular diseases, and diabetes [45]. Hypertension has been repeated as the highest pre-existing comorbidity in COVID-19 patients [2,46-49]. Survival data globally has reported that men had a considerably higher mortality rate and experienced more severe symptoms than women. A study by Scully, et al. reported that the case fatality rate for males is 1.7 times higher than for females ( $P < 0.0001$ ) [48,50]. In addition, older COVID-19 infected individuals aged 65 years and above who have comorbidities have an increased admission and mortality rate [51-53].

## What this study adds

The current study has revealed that COVID-19 patients

having HIV/AIDS as an underlying condition have a fivefold increased risk of death compared to those without HIV. This finding conforms to the notion that people infected with HIV maybe affected disproportionately by COVID-19. This finding is however, contrary to some studies that have reported no major link to HIV/AIDS and COVID-19 patient outcomes [54-57].

## Funding

This study was funded by CDC foundation.

## Acknowledgement

The writers acknowledge Ethiopian Public Health Institute and Nigeria Centres for Disease Control and Prevention Who offered technical guidance, oversight, and assistance throughout the study process. We thank staff at the various health facilities both in Ethiopia and Nigeria where data collection took place. We acknowledge our research assistants.

## References

- Ye C, Zhang S, Zhang X, Cai H, Gu J, et al. Impact of comorbidities on patients with COVID-19: a large retrospective study in Zhejiang, China. *J Med Virol.* 2020; 92(11): 2821-2829.
- Sanyaolu A, Okorie C, Marinkovic A, Patidar R, Younis K, et al. Comorbidity and its impact on patients with COVID-19. *SN Compr Clin Med.* 2020; 2(8): 1069-1076.
- Lippi G, Wong J, Henry BM. Hypertension and its severity or mortality in Coronavirus Disease 2019 (COVID-19): a pooled analysis. *Pol Arch Intern Med.* 2020; 130(4): 304-309.
- Ssentongo P, Ssentongo AE, Heilbrunn ES, Ba DM, Chinchilli VM. Association of cardiovascular disease and 10 other pre-existing comorbidities with COVID-19 mortality: A systematic review and meta-analysis. *PloS one.* 2020; 15(8).
- Ejaz H, Alsrhani A, Zafar A, Javed H, Junaid K, et al. COVID-19 and comorbidities: Deleterious impact on infected patients. *J Infect Public Health.* 2020; 13(12): 1833-1839.
- Gu T, Chu Q, Yu Z, Fa B, Li A, et al. History of coronary heart disease increases the mortality rate of coronavirus disease 2019 (COVID-19) patients: A nested case-control study based on publicly reported confirmed cases in Mainland China. *MedRxiv.* 2020.
- Tessema SK, Nkengasong JN. Understanding COVID-19 in Africa. *Nat Rev Immunol.* 2021; 21(8): 469-470.
- Anjorin AA, Abioye AI, Asoyata OE, Soipe A, Kazeem MI, et al. Comorbidities and the COVID-19 pandemic dynamics in Africa. *Trop Med Int Health.* 2021; 26(1): 2-13.
- Otuonye NM, Olumade TJ, Ojetunde MM, Holdbrooke SA, Ayoola JB, et al. Clinical and demographic characteristics of COVID-19 patients in Lagos, Nigeria: A descriptive study. *J Natl Med Assoc.* 2021; 113(3): 301-306.
- Levin AT, Hanage WP, Owusu-Boaitey N, Cochran KB, Walsh SP, et al. Assessing the age specificity of infection fatality rates for COVID-19: systematic review, meta-analysis, and public policy implications. *Eur J Epidemiol.* 2020; 35(12): 1123-1138.
- Ghisolfi S, Almås I, Sandefur JC, von Carnap T, Heitner J, et al. Predicted COVID-19 fatality rates based on age, sex, comorbidities and health system capacity. *BMJ global health.* 2020; 5(9).
- Singh AK, Misra A. Impact of COVID-19 and comorbidities on health and economics: Focus on developing countries and India. *Diabetes Metab Syndr.* 2020; 14(6): 1625-1630.
- Schlesselman JJ. *Case-control studies: design, conduct, analysis:* Oxford university press. 1982.
- Osibogun A, Balogun M, Abayomi A, Idris J, Kuyinu Y, et al. Outcomes of COVID-19 patients with comorbidities in southwest Nigeria. *PloS One.* 2021; 16(3).
- Chang W-H. Understanding the COVID-19 pandemic from a gender perspective. *Taiwan J Obstet Gynecol.* 2020; 59(6): 801-807.
- Peckham H, de Gruijter NM, Raine C, Radziszewska A, Ciurtin C, et al. Male sex identified by global COVID-19 meta-analysis as a risk factor for death and ICU admission. *Nat Commun.* 2020; 11(1): 6317.
- Papadopoulos V, Li L, Samplaski M. Why does COVID-19 kill more elderly men than women? Is there a role for testosterone? *Andrology.* 2021; 9(1): 65-72.
- Krieger N, Chen JT, Waterman PD. Excess mortality in men and women in Massachusetts during the COVID-19 pandemic. *Lancet.* 2020; 395(10240): 1829.
- Biswas R. Are men more vulnerable to covid-19 as compared to women. *Biomed J Sci Tech Res.* 2020; 27(2): 20645-20646.
- Gebhard C, Regitz-Zagrosek V, Neuhauser HK, Morgan R, Klein SL. Impact of sex and gender on COVID-19 outcomes in Europe. *Biol Sex Differ.* 2020; 11(1): 29.
- Sharma G, Volgman AS, Michos ED. Sex differences in mortality from COVID-19 pandemic: are men vulnerable and women protected? *JACC Case Rep.* 2020; 2(9): 1407-1410.
- Jin J-M, Bai P, He W, Wu F, Liu X-F, et al. Gender differences in patients with COVID-19: focus on severity and mortality. *Frontiers in public health.* 2020; 8: 152.
- Bucholc M, Bradley D, Bennett D, Patterson L, Spiers R, et al. Identifying pre-existing conditions and multimorbidity patterns associated with in-hospital mortality in patients with COVID-19. *Sci Rep.* 2022; 12(1): 17313.
- Liu W, Yang C, Liao Y-G, Wan F, Lin L, et al. Risk factors for COVID-19 progression and mortality in hospitalized patients without pre-existing comorbidities. *J Infect Public Health.* 2022; 15(1): 13-20.
- Hernández-Galdamez DR, González-Block MÁ, Romo-Dueñas DK, Lima-Morales R, Hernández-Vicente IA, et al. Increased risk of hospitalization and death in patients with COVID-19 and pre-existing noncommunicable diseases and modifiable risk factors in Mexico. *Arch Med Res.* 2020; 51(7): 683-689.

26. Treskova-Schwarzbach M, Haas L, Reda S, Pilic A, Borodova A, et al. Pre-existing health conditions and severe COVID-19 outcomes: an umbrella review approach and meta-analysis of global evidence. *BMC Med.* 2021; 19(1): 1-26.
27. Moula AI, Micali LR, Matteucci F, Lucà F, Rao CM, et al. Quantification of death risk in relation to sex, pre-existing cardiovascular diseases and risk factors in COVID-19 patients: let's take stock and see where we are. *J Clin Med.* 2020; 9(9): 2685.
28. Tehrani S, Killander A, Åstrand P, Jakobsson J, Gille-Johnson P. Risk factors for death in adult COVID-19 patients: frailty predicts fatal outcome in older patients. *Int J Infect Dis.* 2021; 102: 415-421.
29. Gupta R, Agrawal R, Bukhari Z, Jabbar A, Wang D, et al. Higher comorbidities and early death in hospitalized African-American patients with Covid-19. *BMC Infect Dis.* 2021; 21(1): 1-11.
30. Wei Z-Y, Qiao R, Chen J, Huang J, Wu H, et al. The influence of pre-existing hypertension on coronavirus disease 2019 patients. *Epidemiol Infect.* 2021; 149.
31. Venkatakrishnan A, Pawlowski C, Zemmour D, Hughes T, Anand A, et al. Mapping each pre-existing condition's association to short-term and long-term COVID-19 complications. *NPJ Digit Med.* 2021; 4(1): 117.
32. Chakinala RC, Shah CD, Rakholiya JH, Martin M, Kaur N, et al. COVID-19 outcomes amongst patients with pre-existing cardiovascular disease and hypertension. *Cureus.* 2021; 13(2).
33. Choi YJ, Park J-Y, Lee HS, Suh J, Song JY, et al. Effect of asthma and asthma medication on the prognosis of patients with COVID-19. *Eur Respir J.* 2021; 57(3).
34. Chen Y, Gong X, Wang L, Guo J. Effects of hypertension, diabetes and coronary heart disease on COVID-19 diseases severity: a systematic review and meta-analysis. *MedRxiv.* 2020.
35. Bomfim GF, Cau SBA, Bruno AS, Fedoce AG, Carneiro FS. Hypertension: a new treatment for an old disease? Targeting the immune system. *Br J Pharmacol.* 2019; 176(12): 2028-2048.
36. Davies M-A. HIV and risk of COVID-19 death: a population cohort study from the Western Cape Province, South Africa. *MedRxiv.* 2020.
37. Yang Y, Iwasaki A. Impact of chronic HIV infection on SARS-CoV-2 infection, COVID-19 disease and vaccines. *Curr HIV/AIDS Rep.* 2022; 19(1): 5-16.
38. Cordero DA. Fight of the unfit: protecting the immunocompromised and those with certain medical conditions during the COVID-19 pandemic. *JPH.* 2022; 44(2): e274.
39. Chen Y, Klein SL, Garibaldi BT, Li H, Wu C, et al. Aging in COVID-19: Vulnerability, immunity and intervention. *Ageing Res Rev.* 2021; 65: 101205.
40. Grasselli G, Greco M, Zanella A, Albano G, Antonelli M, et al. Risk Factors Associated With Mortality Among Patients With COVID-19 in Intensive Care Units in Lombardy, Italy. *JAMA Intern Med.* 2020; 180(10): 1345-1355.
41. Niu S, Tian S, Lou J, Kang X, Zhang L, et al. Clinical characteristics of older patients infected with COVID-19: A descriptive study. *Arch Gerontol Geriatr.* 2020; 89: 104058.
42. Fulop T, Larbi A, Witkowski JM, McElhane J, Loeb M, et al. Aging, frailty and age-related diseases. *Biogerontology.* 2010; 11(5): 547-563.
43. Ali AM, Kunugi H. Physical frailty/sarcopenia as a key predisposing factor to coronavirus disease 2019 (COVID-19) and its complications in older adults. *BioMed.* 2021; 1(1): 11-40.
44. Mallick U. The Older Age Adults and COVID19. *Cardiovascular Complications of COVID-19: Risk, Pathogenesis and Outcomes: Springer.* 2022; 349-370.
45. Zhou F, Yu T, Du R, Fan G, Liu Y, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *The lancet.* 2020; 395(10229): 1054-1062.
46. Emami A, Javanmardi F, Pirbonyeh N, Akbari A. Prevalence of underlying diseases in hospitalized patients with COVID-19: a systematic review and meta-analysis. *Arch Acad Emerg Med.* 2020; 8(1).
47. Yang J, Zheng Y, Gou X, Pu K, Chen Z, et al. Prevalence of comorbidities and its effects in coronavirus disease 2019 patient: A systematic review and meta-analysis. *Int J Infect Dis.* 2020; 94: 91-95.
48. Yang X, Yu Y, Xu J, Shu H, Liu H, et al. Clinical course and outcomes of critically ill patients with SARS-CoV-2 pneumonia in Wuhan, China: a single-centered, retrospective, observational study. *Lancet Respir Med.* 2020; 8(5): 475-481.
49. Singh AK, Gupta R, Misra A. Comorbidities in COVID-19: Outcomes in hypertensive cohort and controversies with renin angiotensin system blockers. *Diabetes Metab Syndr.* 2020; 14(4): 283-237.
50. Guan W-j, Ni Z-y, Hu Y, Liang W-h, Ou C-q, et al. Clinical characteristics of coronavirus disease 2019 in China. *J Emerg Med.* 2020; 382(18): 1708-1720.
51. Berek MA, Aziz MA, Islam MS. Impact of age, sex, comorbidities and clinical symptoms on the severity of COVID-19 cases: a meta-analysis with 55 studies and 10014 cases. *Heliyon.* 2020; 6(12): e05684.
52. Banerjee D. The impact of Covid-19 pandemic on elderly mental health. *Int J Geriatr Psychiatry.* 2020; 35(12): 1466-1467.
53. Mueller AL, McNamara MS, Sinclair DA. Why does COVID-19 disproportionately affect older people? *Aging (Albany NY).* 2020; 12(10): 9959-9981.
54. Cooper TJ, Woodward B, Alom S, Harky A. Coronavirus disease 2019 (COVID-19) outcomes in HIV/AIDS patients: a systematic review. *HIV Med.* 2020; 21(9): 567-577.
55. Lesko CR, Bengtson AM. HIV and COVID-19: intersecting

- epidemics with many unknowns. *Am J Epidemiol.* 2021; 190(1): 10-16.
56. Brown LB, Spinelli MA, Gandhi M. The interplay between HIV and COVID-19: summary of the data and responses to date. *Curr Opin HIV AIDS.* 2021; 16(1): 63-73.
57. Barbera LK, Kamis KF, Rowan SE, Davis AJ, Shehata S, et al. HIV and COVID-19: review of clinical course and outcomes. *HIV Res Clin Pract.* 2021; 22(4): 102-118.