# Uneven Impact of COVID-19 on Ethnic or Racial Minorities Explained by Differences in The Prevalence of Pre-existing Health Conditions.

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A thesis submitted to the Mathematics and Natural Sciences in partial fulfillment
of the requirements for the degree of
Bachelor of Science in Microbiology and Biotechnology

Mathematics and Natural Sciences

Brac University

August 2021

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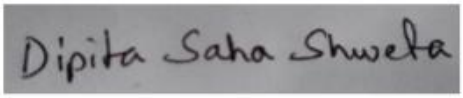

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## Abstract/ Executive Summary

COVID-19 has had an enormous impact on the health and economy with certain individuals being more vulnerable to its effect. Regardless of age, pre-existing health conditions in people, such as cardiovascular disease, hypertension, respiratory conditions, chronic kidney disease, cancer, human immunodeficiency disorder (HIV), tuberculosis and more, have shown to have an effect on COVID-19 infections in terms of hospitalization, disease severity, and mortality, amongst other factors. The impact of these health conditions is further differentiated in their effect on minority individuals based on race and ethnicity. Minority groups are affected to different degrees by COVID-19 infections, compared to the majority population along with having disparities in the epidemiology of pre-existing health conditions linked to COVID-19. The paper aims to look into the effect of these comorbidities on COVID-19 infections and how the incidence of these illnesses differs in minority populations resulting in differences in COVID-19 disease susceptibility, progression, and outlook.

**Keywords:** COVID-19, co-morbidity, pre-existing health condition, minority, race, ethnicity

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# List of Acronyms

| | |
|---|---|
| ACE2 | Angiotensin converting enzyme 2 |
| ARBs | Angiotensin Receptor Blockers |
| ACR | Albumin to Creatinine Ratio |
| AIDS | Acquired Immunodeficiency Syndrome |
| AKI | Acute Kidney Infection |
| APO1 | Apolipoprotein 1 |
| ART | Antiretroviral Therapy |
| BAME | Black, Asian and Minority Ethnic |
| BCG | Bacillus Calmette–Guerin |
| CDC | Center for Disease Control |
| CKD | Chronic Kidney Disease |
| COPD | Chronic Obstructive Pulmonary Disease |
| EHDIC-SWB | Integrated Communities-Southwest Baltimore |
| ESKD | End-Stage Kidney Disease |
| ESRD | End-Stage Renal Disease |
| GFR | Glomerular Filtration Rate |
| HDL | High Density Lipoproteins |
| HIV | Human Immunodeficiency Virus |
| ICU | Intensive Care Unit |
| LDL | Low Density Lipoprotein |
| LOS | Length of Stay |
| MTB | M. tuberculosis |
| NCHS | National Centers for Health Statistics |
| NHB | Non-Hispanic Black |
| NHIS | National Health Interview Survey |
| NHW | Non-Hispanic White |
| PLH | People Living with HIV |
| SNP | Single Nucleotide Polymorphism |
| TB | Tuberculosis |
| TMPRSS2 | Transmembrane Serine Protease 2 |
| UK | United Kingdoms |

| | |
|---|---|
| USA | United States of America |
| USAID | United States Agency for International Development |

# Introduction

The coronavirus disease 2019 (COVID-19) outbreak in China, caused by SARS-CoV-2, was declared a pandemic last March after spreading to 114 countries [1]. *John Hopkins Research Centre* has reported that the worldwide death toll has reached 4.35 million, and 206 million people have been infected till the date of writing [2]. The risk factors of COVID-19 have been listed to be gender, age, race, pre-existing medical conditions such as obesity, diabetes, asthma, chronic lung diseases, hypertension, and cardiovascular diseases; along with socioeconomic factors such as poverty and occupation [3-5]. In order to consider the frequency of disease severity, hospitalization rates, ICU admissions, morbidity\mortality, intubation or susceptibility; a complex of these heterogenous factors must be considered which happens to be also interlinked.

The disproportionate catastrophic impacts of COVID-19 on different ethnic groups living in the same geographic location have been observed and is in fact a point of description. The death rate of Black, Hispanic, and indigenous people of the United States of America (USA) has shown be to significantly higher than White people [6] [7]. Similarly, the United Kingdom's (UK) national reports also suggest that excluding Chinese, all other ethnic minority groups, mainly Black and South Asian people, have higher death rates than Whites [14]. Apart from these two countries where immigration is common, both Sweden and Norway have found out that the citizens born in Somalia are more prone to infection than the nationals [8] [9]. And one of indisputable reasons behind the disparity is prevalence of certain pre-existing medical conditions. Such as Black, Asian, and Minority Ethnic (BAME) communities or African Americans in the USA are more prone to be suffering from cardiovascular diseases, hypertension, diabetes, chronic kidney diseases, respiratory issues, cancer, and acquired immunodeficiency syndrome (AIDS) [10-13].

In this review, we try to explore a correlation between different pre-existing biological conditions present in ethnic minorities and how these factors can be responsible for adverse COVID-19 outcomes among them. We discuss a few indisputable socioeconomic factors that lead to some ethnic minorities having greater odds of these comorbidities than others. We also included several studies that haven't found minorities to be unequally affected to point out in which cases or circumstances the occurrence might be true. Lastly, we've considered ethnic minorities to be

subjective to a particular nation because ethnic groups may be recognized differently by countries. Although both race and ethnicity have entirely different meanings, in terms of inequalities, they were considered the same because most studies have included broader racial groups rather than specifying such as BAME [14].

## Cardiovascular Disease (CVD) and Hypertension

Hypertension has been calculated to be the most prevalent comorbidity in a meta-analysis, almost 21.1% of thousands COVID-19 patients, followed by 8.4% having cardiovascular diseases [15]. Although hypertension is not a definite risk factor for COVID-19, it has been suggested that controlled blood pressure may be vital for reducing the disease burden [16]. Most meta-analytical studies have found both hypertension and cardiovascular diseases to be significantly prevalent among COVID-19 patients [17-19]. Older patients had greater prevalence because age is a factor in having heart-related complications [17,20]. Hypertension treated with angiotensin-converting enzyme (ACE) inhibitors results in the upregulation of ACE2, which SARS-CoV-2 uses to bind to their target cells, thus possibly increasing the risk of developing severe COVID-19, although it has not been confirmed [21]. ACE2 inhibitors have been frequently used as therapy for hypertension, in fact, it is a first-choice among other treatments such as Angiotensin Receptor Blockers (ARBs) [22]. Nevertheless, studies have found both ACE2 and ARBs to be responsible for greater expression of the ACE2 receptor and thus put people with cardiovascular diseases at risk for COVID-19 [23].

One very important spotlight of recent events has been the mass coronavirus mortality of South Asians, mostly Bangladeshis, in the UK [24]. In the UK, Indian Asian subgroups such as Pakistanis, Bangladeshis, and Indians have a higher risk for cardiovascular diseases (CVD) than the host population [25]. The Caribbean and African immigrants also have increased mortality from hypertensive diseases, indicating how severe their conditions are [25]. This is also demonstrated in a recent study that shows that in the UK, age-adjusted mortality for COVID-19 among individuals with hypertension and CVD is higher for Black and Asian groups [26]. Not just UK, descendants from the Indian subcontinent living in other countries such as South Africa, the Caribbean,

Singapore, the United States, and Canada also have greater chances of having cardiovascular diseases [27].

There have been many proposed explanations over the years on why certain ethnicities may be at more risk for cardiovascular conditions; it could be genetic differences or changes in the metabolism while growing up to be middle-aged [27]. South Asian children have greater fat deposition tendencies, so this particular group of people has a higher chance of developing coronary heart diseases at a younger age [27] [28]. South Asians include various populations with different food cultures and lifestyles, but a sharp change in these factors greatly impacts developing CVD [29]. After migration, they tend to have more meat, dairy products, and fatty food; they switch from whole grains to refined carbohydrates while reducing fiber and vegetables [30]. A change in the diet leads to populations with low levels of high-density lipoproteins (HDL), high levels of smaller less-effective HDL particles, or small low-density lipoproteins (LDL) particles, which results in atherosclerosis, a vital cause for CVD [29].

Hypertension is the foremost risk factor for coronary heart disease; it is responsible for 54% of strokes and 47% CVD [6]. Hispanic individuals and non-Hispanic Black (NHB) in the USA have been reported to have a far more uncontrolled blood pressure than non-Hispanic whites (NHW). NHB individuals in the USA have the highest prevalence (44%) for hypertension, and in the case of Native Hawaiians/Pacific Islanders and American Indians/Alaska Natives, the values are 37% and 25%, respectively [31]. There is a very complex combination of both socioeconomic and pathophysiological factors behind particular ethnicities being more affected. According to National Centers for Health Statistics (NCHS), only 70% of Hispanic adults routinely took their hypertension medications, most likely due to lack of awareness [32]. Hypertensive patients must take medications regularly to maintain good blood pressure and follow an active lifestyle [33]. Unfortunately, immigrants have less access to healthcare due to poor insurance coverage; Hispanics have the lowest records of antihypertensive therapies [34]. NHB individuals have shown a high rate of hypokalemia and nocturnal blood pressure [35] [36]. Long-term hypokalemia has been associated with hypertension and arrhythmias, and the blood pressure changes due to salt intake are different in NHB than the whites [37]. Exceptionally, during the adolescence of NHB, the nocturnal blood

pressure dipping is reduced, indicating rapid vascular contractions, which may result in CVD later in life [37].

Hypertension and Cardiovascular heart diseases are co-related, as mentioned earlier, and are both associated with the severity of COVID-19 disease. Most studies have identified ethnic minorities as drastically affected by these conditions because of various reasons such as diet, lack of insurance or awareness, limited access to healthcare, physiological conditions, occupations, or socioeconomic factors. Although some researchers claimed socioeconomic or demographic differences to be the greater cause for COVID-19 severity among minorities, heart conditions are also an important factor to consider.

## Diabetes

The prevalence of diabetes in the world was estimated to be 9.3% (463 million people) back in 2019 and could escalate to 10.9% (700 million) by 2045 [38]. Over the two decades, obesity, BMI, hypertension, increasing age, sex, family history, smoking, physical activities, and insomnia have been listed as the risk factors for diabetes [39-41]. Like cardiovascular diseases, diabetes mellitus is also a common underlying condition associated with the severity of COVID-19. A retrospective study in Wuhan has found that 17.6% of 1561 COVID-19 patients who required incentive care had diabetes, whereas only 7.8% were non-diabetic. [42]. Patients who died during hospitalization also had other comorbidities such as hypertension, cardiovascular disease, and chronic pulmonary disease, but each was independently associated with mortality [42]. Referring to a study in the USA, among 570 dead or discharged COVID-19 patients, 184 patients with diabetes and\or uncontrolled hyperglycemia had a 28.8% mortality rate, and those without the conditions only had a rate of 6.2% [43]. The median length of stay (LOS) was also longer for the diabetic patients than non-diabetic patients- 5.7 vs 4.3 days [43]. Another group of researchers has found diabetic COVID-19 patients with no other comorbidities to have more risks of uncontrolled inflammatory responses and hypercoagulability, dysregulated glucose metabolism, excessive release of tissue injury-related enzymes, and severe pneumonia [44].

Considering the intensity of inflammatory storms, the progression of COVID-19 is also rapid in the case of patients with diabetes. The same study results also include higher CT imaging scores, establishing that diabetes is also responsible for pneumonia [44]. The biochemical tests revealed that the number of LDH, HBDH, ALT, and GGT proteins that indicate organ injury were higher in COVID-19 patients with diabetes [44]. The susceptibility has been explained by the lack of IFN-α production in Type 2 diabetes patients and increased viral replication due to high blood sugar [45][46]. The entry of SARS-CoV-2 into the cells is efficient due to an increased expression of ACE-2 receptors present in alveolar epithelial cells. So, the virus has a higher affinity for binding to ACE-2 receptors in diabetic patients, and thus the viral load is higher [47]. The cytokine storm syndrome initiated by lymphocytopenia that results in high cytokine or chemokine levels has been suspected to be responsible for the many organ failure cases [47]. So, all this evidence suggests that diabetic patients infected by COVID-19 are more prone to have higher mortality rates, risks for pneumonia and organ failure, and are more likely to receive intensive care and have more extended periods of hospitalization.

As for ethnic minorities in the USA, diabetes wasn't a significant factor for intensive care or in-hospital death for black COVID-19 patients despite being more in number [48]. The study's findings suggested that age (50-64) is far more notable than ethnicity in associating diabetes with COVID-19 [48]. The South Asians in the UK had higher COVID-19 mortality and were more likely to require critical care because of pre-existing diabetes [25]. Ethnic minorities such as Black, South, and East Asian people were younger but had a higher prevalence of type 1 or type 2 diabetes than White people [25]. Among the South Asian sample, 18% of the excess mortality was due to diabetes [25]. The phenomenon is actually not very new; diabetes indeed has always been common among South Asians in the UK [49]. Indian Asian subgroups in the UK were observed to have more cases of hyperinsulinemia, insulin resistance, higher fasting and post-glucose serum insulin concentrations in comparison with European groups [49]. As the study included a correlation of waist-hip ratio with insulin levels and glucose intolerance, obesity and lack of physical activity were listed as primary reasons for diabetes in the subgroup [49]. South Asians have a higher waist-to-hip ratio comparatively, which means they have central body obesity [48]. This phenotype is associated with high insulin levels, insulin resistance, and ultimately greater prevalence of diabetes

[50]. Another disparity observed was that South Asian adolescents were more likely to be diabetic than Caucasian young individuals, and hyperinsulinemia was also more common among them at birth [50]. South Asians have higher odds of having Type 2 diabetes or prediabetes despite having lower body weight, but there weren't any significant differences compared to other minority groups such as the Chinese and African Americans [51]. Some of the physiological factors that are likely to cause diabetes or prediabetes in Indians are hypertension, visceral adiposity, microalbuminuria, and fatty liver [51]. However, socioeconomic status such as income or education isn't listed to be associated with a greater prevalence of diabetes in the ethnic group [51]. Type 2 diabetes is also most prevalent among South Asians because they have a lower β-cell function and find it difficult to break down excess glucose due to insulin resistance [52].

Diabetes ketoacidosis was observed frequently among COVID-19 patients, including individuals aged less than 19 years [53]. The majority of the hospitalized cases consisted of NHB, and Hispanic races of people reported to have severe hyperglycemia and lower insulin pump use [58]. This particular study didn't find age and gender to be potential risks for hospitalization but found higher blood sugar to be significantly responsible [53]. Among 355 adult COVID-19 patients in a study, 70% were found to be African Americans, and those with diabetes have faced severe consequences [54]. Nevertheless, compared to non-African Americans, this ethnic group had no notable difference in mortality, vasopressors requirement, or need for intubation [53]. Generally, African Americans have a higher prevalence of type 2 diabetes due to obesity, insulin resistance, poor glycemic control, or discriminative healthcare systems [55][56]. Age-adjusted mortality for diabetes was statistically generated to be significantly higher in NHB compared to white ethnicities in the USA [57]. The disparity in this study mainly was correlated to economic inequality across different cities [57]. The socioeconomic limitations do play an essential role while analyzing the prevalence of diabetes among different races. An investigation compared data from National Health Interview Survey (NHIS) and Integrated Communities-Southwest Baltimore (EHDIC-SWB) to evaluate the prevalence of diabetes among races [58]. African Americans had higher chances of having diabetes than white people in NHIS, but the odds were similar in EHDIC-SWB; because the risk environments for both races were similar [58]. Whatever the factors are, minorities such as American Indians, African Americans, Hispanics, Native Hawaiians, and other Pacific Islanders have a more significant burden for diabetes and mortality than white people [59]. Given that

COVID-19 outcomes could be worse with hyperglycemia, which is quite common, a more specific approach towards eliminating racial disparities could be a great way to reduce death rates.

## Chronic Kidney Disease (CKD)

Chronic Kidney Disease (CKD) involves abnormalities in kidney function for prolonged periods that have implications on health, with the global estimated prevalence of the disease being 13.4%. It stands as a major health concern with CKD leading to end-stage kidney disease (ESKD), cardiovascular disease, along with other complications [60]. SARS-CoV-2 cells that utilize ACE2 receptors to gain entry into cells also manage to bind and infect kidneys due to their abundance of ACE2 receptors [61]. The ACE2 receptors are more expressed in the kidneys than the lungs, making the kidneys a vulnerable target for the virus [62] [63]. The virus also depends on cellular protease Transmembrane Serine Protease 2 (TMPRSS2) for priming, thus both ACE2 and TMPRSS2 having an impact on cellular entry of SARS-CoV-2, especially into tubular cells and podocytes of the kidney where the co-expression of the two molecules is relatively high [64] [65]. This was also shown with COVID-19 patients' autopsies reporting virus particles within the tubular epithelium and podocytes [66].

Those with CKD are already predisposed to have other comorbidities such as hypertension and diabetes, although CKD itself is associated with greater chances of infection [67]. A meta-analysis has shown that 20% of COVID-19 patients with CKD had a severe illness, with the risk being 3 times higher than patients without CKD [68]. Although COVID-19 infection is often identified with lung damage and respiratory distress, acute kidney infection (AKI) is also characterized in many cases, as well as kidney abnormalities, and AKI is associated with worse prognosis and greater mortality [67][69]. CKD alone showed an association for the greater risk of inpatient and outpatient pneumonia in COVID-19 patients; pneumonia-related mortality in CKD patients was 14-16 times higher than the general population [68] [70]. A study conducted on COVID-19 patients admitted to a hospital in Spain showed that 9.1% of the sample were diagnosed with CKD, and 41.1% faced mortality. The in-hospital death risk for patients with CKD was almost twice that for patients without previous CKD [71].

The prevalence of CKD as a comorbidity for COVID-19 may be more pronounced in minorities, such as Blacks and Hispanics in the USA due to its already more pronounced effects in their populations. Nearly 40% more Hispanics received dialysis for end-stage renal disease (ESRD), developed from CKD, compared to non-Hispanics in the USA. Although the prevalence of CKD between Hispanics and non-Hispanics was similar, the disparity in ESRD may show greater disease progression for the Hispanic population, as shown by several studies [72-74]. Disease progression is also worse for black individuals with CKD, with the incidence of ESRD being 3.4 times higher than the white population, even though the initial prevalence of CKD was less for African Americans [75] [76]. A study has shown that African Americans in stage 3 or 4 of CKD, adjusted independent of income, had a higher risk for mortality than White individuals [77]. Although general studies have shown that incidence of CKD is not related to race, when considering association to low socioeconomic status, there was twice the higher risk for CKD in African Americans but no elevated risks for White-Americans [78][79]. Another study focusing on the markers of early stages of CKD in Asian Americans showed a higher risk of elevated albumin-to-creatinine ratio (ACR), indication of early kidney damage, but a reduced risk of having a low glomerular filtration rate (GFR), low levels of which would have also indicated kidney damage [80]. A cross-sectional study focusing on ACR levels also found all minorities (African-Americans, Hispanics, Asians, American-Indians/Alaskan Natives) to have a higher odd of albuminuria (Urine ACR $\geq$ 30mg/g) after multivariate adjustment, with the highest odds for American-Indians/Alaskan Natives [81].

The etiology for poor disease progression in these minorities is multifactorial, including structural racism and poor access to healthcare, unregulated metabolic conditions, cardiovascular disease, and socioeconomic conditions [82]. The disparities in Hispanics may be attributed to not achieving CKD management goals, compared to non-Hispanic whites, including control of blood pressure, prevention of cardiovascular disease, and proper use of ACE inhibitor/angiotensin receptor blockers to manage cardiometabolic effects [83]. Blacks with CKD also suffered from racial disparity in treatment, as they were less likely to have delayed or no referral to nephrology than Whites [83] [84]. CKD and ESRD may develop from other comorbidities such as hypertension and diabetes, with these factors being 12 times more attributable for CKD in African Americans than White

Americans [85]. Furthermore, the risk of non-diabetic kidney disease may be caused by the *apolipoprotein 1* (*APO1*) gene variant found more commonly in African descent than those of European descent [86]. This gene variant is associated with higher levels of albuminuria, low levels of GFR (both albuminuria and GFR being important biomarkers for CKD), and CKD with quicker progression [86][87]. Early stages of CKD in Asians, determined by higher levels of specific biomarkers, may be attributed to diet or genetic factors [88][89].

## Respiratory Conditions

Respiratory conditions such as chronic obstructive respiratory disorders arise early on in life, presenting as illnesses such as asthma and chronic obstructive pulmonary disease (COPD). These are attributed to not only genetic factors but also linked to early life environmental exposures such as smoking and pollution [90]. With respiratory diseases such as COPD, the lungs become damaged over time, making patients more susceptible to COVID-19 and increasing their chances of developing acute respiratory distress syndrome [91]. SARS-CoV2 has been shown to invade host cells using the ACE2, which is upregulated in smokers and patients with COPD, making them more vulnerable to the infection [92].

Over 250 million people around the world are diagnosed with COPD. A study published in the European Respiratory Journal evaluated 1590 cases of COVID-19 patients where COPD was reported as having less prevalence as a comorbidity but with poorer outcomes after hospitalization [93]. A systematic review and meta-analysis of the prevalence of COPD and smoking in patients with COVID-19 also reported a much higher risk of severity associated with a 60% high mortality [94]. Another study in New York found COPD patients to have the highest mortality risk compared to other pre-existing metabolic conditions, with a high mortality rate also independently associated with ethnic groups and minorities [95]. Na Xi and Bai ethnic minority groups had higher chances of having COPD compared to the majority population, with a lower probability of diagnosis and treatment [96]. COPD, however, had a lower prevalence in minorities of the UK with 2.3% prevalence in South Asians and 0.6% in the black population, compared to 4.4% prevalence in Caucasians [97]. This was also reflected in minority populations of another study in America, where African, Hispanic, and Asian populations had a lower incidence of COPD than Caucasians [98].

Although studies have found a lower prevalence of COPD in African-American communities, other studies show that African Americans develop COPD at a significantly earlier age even those that have spent fewer years smoking [99] [10]. Compared to Caucasians, African-Americans were more likely to be admitted to the hospital due to exacerbation of COPD conditions. This is attributed to many factors, including racial inequalities in treatment and a more inferior socioeconomic status [1061]. Genetic factors resulting in COPD include the gene cluster for a cholinergic nicotinic receptor subunit found on the genetic locus on chromosome 15q24–q25.1, associated with lung cancer, nicotine dependence, and cigarettes smoked per day [10] [103]. The single nucleotide polymorphism (SNP) for rs16969968 and rs2036527, found in the gene cluster, achieved significance for the association to nicotine dependence and cigarettes smoker per day respectively, with the SNPs having a stronger concordance in African-Americans [104] However, another study could not determine the differences in COPD risk between ethnicities in the UK even after adjusting for the intensity of smoking. It cited possible differences in susceptibility to the effects of tobacco and other exposure and environmental risk factors as a possible cause for such differences [105].

## Tuberculosis

Tuberculosis (TB), caused by infection of *Mycobacterium tuberculosis* (MTB), transmits itself through aerosol droplets resulting in lung disease as well as affecting other organ systems and is a latent infection in up to 2 billion people in the world population [106]. A study analyzing the biological interaction between TB and SARS-CoV-2 found that co-infected TB-COVID-19 patients had significantly reduced response to SARS-CoV-2. Co-infected patients had a low lymphocyte count that may have resulted from massive compartmentalization of specific T-cells in infectious foci or the high dose of antigens resulting in the removal of effector T-cells [107]. This can be further seen by a study in China where TB was found to be a risk factor for patients infected with SARS-CoV-2, presenting as more common than other comorbidities (36% vs diabetes at 25% and hypertension at 22%). In cases of pneumonia caused by COVID-19, comorbidity of MTB infection made up 78% of cases of severe to critical severity, much larger than for cases of slight to moderate severity. It was thus concluded that TB was an important comorbidity associated with severe

clinical conditions and hospitalization due to SARS-CoV-2 infection [108]. A systematic review and meta-analysis also showed a 2.10-fold increase of severe COVID-19 disease for patients that had TB [109]

Racial and ethnic minorities in the USA, along with foreign-born individuals, are disproportionately affected by TB. The rate of the incidence of TB in foreign-born individuals was 13.8 times higher, while in Asian minorities it was 28.5 times higher. This was followed by NHB and Hispanic races at 8 times higher than NHW [110]. The same has been seen in the UK, with a high population of migrants having moved from sub-Saharan Africa and the Indian Subcontinent (India, Pakistan, Bangladesh), accounting for the majority cases (73.6%) of TB compared to the UK-born population. Even within UK-born individuals, TB rates were 3-14 times more in non-White ethnic minorities than the White ethnic group [111].

One of the major causes of migrants having a higher incidence than local-born populations is the difference in exposure to TB in their country of origin. Many migrants travel from high-incidence countries such as Africa and South-East Asia with incidence rates >250 per 100,000 [112] [113]. This is also confounded by the lower rates of vaccination for *Mycobacterium Bovis*, the Bacillus Calmette-Guerin (BCG) in such countries, which offers protection against certain forms of TB [114]. The MTB complex itself has shown genomic diversity that may affect how TB presents itself in individuals; however, ethnicity was shown to be a powerful determinant of the clinical phenotype for TB, regardless of the MTB lineage [115] [116]. The molecular basis in the immune response resulting in TB susceptibility in different racial groups has also been studied. A study with African and Eurasian patients in the UK showed a lower count of neutrophil, a lower level of serum concentrations such as CCL2, CCL11, and DBP, and higher serum concentrations of CCL5 in the African patients; a difference that became more pronounced after antimicrobial therapy, independent of the strain of MTB. This showed that immunological biomarkers specific to different ancestries resulted in a difference in susceptibility and treatment response [117]. Another study in a mixed South African population found a positive correlation between African ancestry and TB susceptibility, although European and Asian populations showed a negative correlation on the matter. It also identified different polymorphisms that were statistically significant for TB

susceptibility before or after adjusting for ancestry, but the study did not adjust for socioeconomic confounders [111] [118].

## Acquired Immunodeficiency Disease (AIDS)

Human Immunodeficiency Virus (HIV) follows a mechanism of infecting and destroying CD4+ T cells; the depletion of CD4+ cells result in a weakened immune system that makes the individual susceptible to many other secondary infections [119]. Concerns were raised if people who have AIDS have a greater risk of dying from COVID-19. A retrospective cohort study conducted in the UK shows HIV-positive people having a higher hazard ratio than those without HIV [120]. Moreover, the study also revealed that these people with HIV mainly belong to the Black ethnicity and live-in poor conditions [120]. This concept is not new; several studies have already related certain races to be more vulnerable to HIV. Hispanic and African Americans of the United States have a higher incidence for HIV compared to the Whites (25%) with Hispanic and Black incidences at 28% and 42% respectively, according to CDC report [121]. Being only 1.8% of the UK population, Black Africans are responsible for 34% of the total HIV cases diagnosed in 2012. HIV transmission among this ethnicity is alarmingly high due to the lack of knowledge about prevention techniques, funding for campaigns, and access to services such as testing, treatment, care facilities, and stigmatization regarding the disease. Other socioeconomic factors include unemployment due to racism or xenophobia, poor housing conditions or poverty in general, and ignorance by the immigration system [122].

However, HIV patients with CD4+ cell count less than 50 and not following antiretroviral therapy or ART; are most likely to face severe consequences of COVID-19 [123] [124]. A case study containing only 33 COVID-19 patients with HIV found no unusual morbidity or mortality among them. But all these patients were on ART which helped in viral suppression, and all but four patients had a sufficient amount of CD4+ T cells [125]. Another research, including thousands of patients, concluded that people living with HIV (PLH) have higher COVID-19 mortality. The study has found PLH were more likely to be African American men and\or have conditions such as obesity,

hypertension, diabetes, chronic kidney diseases; compared to non-PWH. It has also been mentioned that not taking comorbidities or risk factors into account; there is no difference in COVID-19 outcome for both PLH and non-PLH groups [126].

Similarly, the prevalence of hypertension, chronic kidney diseases, heart failure, and diabetes mellitus was greater in COVID-19 patients with HIV after investigating Mount Sinai Health System records in New York City. Sex, age, and comorbidities were taken into account in the analysis, which concluded that patients with HIV who were below 50 held more risks of intubation and death than other age groups [127]. A study based on hospitalized COVID-19 patients in the UK found 0.24% of 47,539 patients to be HIV positive, among which 42% belong to Black ethnicity. After adjusting factors like age, sex, and race, HIV positive group had a 63% increased risk of day-28 mortality compared to HIV negative group. Also, many patients with HIV had to receive non-invasive or invasive ventilation, but after adjusting for sex, age, ethnicity, and other factors, the chances were the same for both groups [128].

It is difficult to generalize the association of HIV with COVID-19 among ethnic minorities based on studies from a few countries. But there is no doubt that most HIV patients belong to minorities due to various socioeconomic factors. However, HIV can be faintly related to being one reason why COVID-19 is more impactful towards ethnic minorities, but many other factors must be considered as well. In most studies, patients with HIV were less than 50 years old, so several comorbidities for COVID-19 such as chronic pulmonary disease, diabetes, and hypertension were absent in them. HIV patients who died were older and had more of these comorbidities. Antiretroviral therapy is one main reason why HIV patients are prevented from suffering critical consequences. One of the popularly used medications for HIV, Tenofovir blocks RNA-dependent RNA polymerase required in viral replication [129]. Remdesivir has been used in treatment for COVID-19, and Tenofovir has structural similarities to it [129]. However, only 81% of total HIV cases (38 million) in the world are aware of their condition, and 67% have had access to ART as reported by the United States Agency for International Development (USAID) [130]. Besides African Americans having 40% lesser chances of accessing competent specialists who provide appropriate treatment, other minority groups such as American Indians, Alaskan Native, Asian, and Pacific Islanders also have 56% fewer odds of getting such opportunities [131]. This is where the disadvantage still lies. In conclusion we

can say that although AIDS is more prevalent in ethnic minorities, a young individual who is well aware of being infected with HIV, taking proper treatment, and has fewer or no comorbidities share the same risk as non-HIV people.

## Cancer

There has been an excess of deaths reported for both cancer patients infected by COVID-19 and those that aren't, as cancer increases the risk for COVID illness and those uninfected face changes in health provisions during the pandemic [132]. Cancer is an abnormal growth of cells that can spread to other parts of the body and is thus treated by killing or stopping these fast-dividing cells. However, cancer treatment may unintentionally suppress the immune system cells from diving, such as B and T lymphocytes, or cancer may itself spread to the bone marrow and affect the body's immune response [132] [134]. This results in a weakened immune system that has caused cancer patients to be 3 times more vulnerable to death than the general population due to COVID-19, especially those with hematologic cancer, lung cancer, and cancer in metastatic stages showing a more severe prognosis. Moreover, patients that underwent surgery due to cancer were also shown to have higher death rates and chances of critical symptoms due to COVID-19 [135]. Several other studies have also concluded the higher risk of COVID in patients with cancer, with greater risk factors, greater severity of illness, and higher mortality [136-138]. Lung cancer was shown to be the most frequent comorbidity in a study conducted with 28 cancer patients in China [139]. In a study conducted with lung cancer patients infected by COVID, a very high mortality rate was observed at 52.3% compared to the death of 192 amongst 1878 total COVID patients analyzed. This was largely attributed to the predisposition of lung cancer patients to respiratory infections, immunosuppression from cancer treatment, and a history of COPD and metastatic disease [137].

Different cancer types have shown different levels of incidence in the minority populations when compared to the majority group. In the case of lung cancer, NHB men in America had the highest incidence at 87.9 per 100,000, followed by the majority population of NHW men at 75.9 and all other minorities having lower incidences. Although smoking is highly correlated with lung cancer rates, lung cancer in nonsmokers has become a leading cause of cancer deaths, with nonsmoker African-Americans in the US more likely to develop the condition than nonsmoker Caucasians

[140]. This difference is also observed with Colorectal cancer incidences, with a 28% difference in incidence reported in distant-stage colorectal cancer between African-Americans and NHW [141]. Different hematological malignancies affect ethnic groups in different proportions. For Acute Myeloid Leukemia, the minority population in the USA sees a lower incidence but a lower survival rate with Black and Hispanic patients who have an increased risk of death by 12% and 6%, respectively [142][143]. Acute Lymphocytic Leukemia is one of the most commonly diagnosed cancers for children has the highest prevalence in Hispanic children [144]. Multiple myeloma was the most common for African Americans at 11 per 100,000 compared to 4.9 per 100,000 for Whites [145]. This disparity is also present for Hodgkin's Lymphoma with Black and Hispanics having a 62% and 35% higher risk of death as well as a higher chance of being diagnosed at a later stage, compared to NHW, although the incidence of certain types of Non-Hodgkin's Lymphoma was more common in NHW then the minority populations [151]. Although there are varying incidences of cervical cancer and breast cancer between populations, minorities have the worst outcomes [147][148]. Prostate cancer, however, had a much higher incidence in African-Americans as well as higher rates of mortality [149].

With lung cancer being an important comorbidity for COVID patients and African American minority populations being more affected by the malignancy, it is essential to look at the cause behind the disparity. Self-reported exposure to asphalt, tar, automobile exhaust, and asbestos has shown to be a significant risk factor due to the polycyclic aromatic hydrocarbons for lung cancer in the overall population [150]. Historically, African-Americans have come in excess contact with such substances and other carcinogens due to occupational exposure, and studies have shown that it may have resulted in disparities in the incidence of lung carcinoma in this population [151]. Possible links to the incidence of lung cancer deaths to genetic polymorphisms in the racial population and familial clustering have also been studied [152]. There also exist several barriers for all minority populations for cancer screening, such as limited knowledge of family history and access to care, which results in higher mortality rates, with survival dropping drastically when cancer is detected at an advanced stage [141, 153-154]. Many kinds of cancer are also known to have genetic determinants. Some are inherited through generations, and some are familial with mutations on susceptibility genes that increase the risk of an individual developing a malignancy, while others develop cancer sporadically. Thus, testing for genetic indicators of cancer risk can help

individuals prevent the development of the condition or better prepare through regular screening [155]. Genetic screening for cancer is also low among minority groups due to similar reasons of limited knowledge of familial cancer risk but also due to sociocultural beliefs around the stigma of inherited cancer. Referral to professionals is also limited due to challenges in cross-cultural communication from third-party interpreters or communication within families about the complex context of genetic screening [156].

## Studies including minorities affected by COVID-19 and the impact of comorbidities

To gain a better understanding of the direct relationship between pre-existing health conditions to COVID-19 infections in minority groups, studies were selected from the papers that included “minority”, “covid-19” and “co-morbidity” in their text fields. These multivariate studies were then parsed through to collect only those that mentioned co-morbidity statistics in a sample that included minority racial groups infected by COVID-19. Studies not mentioning any rates of pre-existing health conditions or not differentiating their sample into minority groups were discarded. The research papers selected have been compiled to show the different comorbidity finding and remarks based on racial disparities as shown in Table 1. This provides a general outlook into many of the health conditions discussed thus far and how it affects different COVID infected populations in the USA and the UK. However, the number of large-scale investigations on racial disparities during the pandemic associated with pre-existing conditions is still insufficient with slightly varying data and conclusions.

| Sl | Location | Published (Month, Year) | Sample | Minority Group | Incidence of COVID-19 | Mortality | Comorbidity Findings | Remarks | Ref |
|---|---|---|---|---|---|---|---|---|---|
| 1 | London, United Kingdom | May 2020 | 1157 | Black or Black British | 32.6% | - | Comorbidities were not separately stated for the minority groups.<br><br>Comorbidities in the whole sample were Hypertension (52.9%), Diabetes (35.3%), ischemic heart disease (13.2%), CKD (16.3%), Chronic Lung Disease (10.2%), Active Malignancy (10.2%) | The BAME population in the sample had a hazard ratio for death of 1.19 (CI 95%, 0.89-1.58). They had a higher hazard ratio for critical illness of 1.53(CI 95%, 1.12-2.09) | 157 |
| | | | | Asian or Asian British | 5.5% | | | | |
| | | | | Other or mixed | 10.1% | | | | |
| 2 | United Kingdom (rural and urban settings) | June 2020 | 1326 | BAME | 13.1% | - | Comorbidities that showed a higher prevalence in the BAME population were Hypertension (51%), Diabetes (21%), high cholesterol (33%) | The percentage of the BAME population in the group that tested positive (13.1%) was higher than the BAME population in the group that tested negative (7.6%). This was the opposite for the Whites where the percentage of the population in the group that tested positive (86%) was less than the percentage in the group that tested negative (91.9%). | 158 |
| 3 | London, United Kingdom | July 2020 | 60 | BAME | 55% | - | Comorbidities that showed a higher prevalence in the minority groups were Hypertension (31.7%), Chronic Pulmonary Disease (13.3%), Diabetes (25%), Renal failure (16.7%), Obesity (11.7%) | Among Black and Asian ethnic minorities, Hypertension and Diabetes were the most common comorbidities during the COVID period. During pre-COVID this was metastatic cancer and hypertension. | 159 |

| Sl | Location | Published (Month, Year) | Sample | Minority Group | Incidence of COVID-19 | Mortality | Comorbidity Findings | Remarks | Ref |
|---|---|---|---|---|---|---|---|---|---|
| 4 | England, UK | August 2020 | 428,494 | Black | 70% of Black Participants | - | Only Black participants had a higher prevalence of Hypertension (62.4%). Only Asians had a higher prevalence of CVD (7.8%). All Minorities had a higher prevalence of Diabetes, Black (11.1%), Asian (16.8%), Other (7.9%). All minorities had a lower prevalence of chronic bronchitis compared to Whites. | Adjusted for age and sex, Black participants had a 4 times higher risk for hospitalization due to COVID-19 (OR 4.32; 95% CI, 3.00–6.23), compared to White participants.<br><br>Asians and Others showed a two-fold greater risk for hospitalization, (OR 2.1; CI 95% 1.37-3.28) and (OR 1.84; CI 95%, 1.13-2.99) respectively. | 160 |
| | | | | Asian | 50% of Asian Participants | | | | |
| | | | | Other | 34% of Other Participants | | | | |
| 5 | New York City (NYC), USA | May 2020 | 257 | Hispanic or Latino | 62% | 38% | 82% of all patients had at least 1 chronic illness. These were not separately stated for the minority groups.<br><br>Comorbidities in the whole sample were Hypertension (63%), Diabetes (36%), Chronic cardiac disease (19%), CKD (14%), Chronic Pulmonary Disease (9%), Asthma (8%), HIV (3%). | The White population had a lower incidence (12%) in the population but a higher mortality rate (47%).<br><br>White patients had a shorter duration of illness before presenting to the hospital compared to Black or Hispanic patients (3 vs 5 and 7 days respectively) | 161 |
| | | | | Black or African | 19% | 41% | | | |
| | | | | Asian | 3% | - | | | |
| | | | | Other | 2% | - | | | |

| Sl | Location | Published (Month, Year) | Sample | Minority Group | Incidence of COVID-19 | Mortality | Comorbidity Findings | Remarks | Ref |
|---|---|---|---|---|---|---|---|---|---|
| 6 | NYC and Long Island, USA | May 2020 | 5279 | Non-Hispanic African American | 15.8% | - | For the proportion of the sample that resulted in critical illness, 84.1% had at least 1 chronic condition. These were not separately stated for the minority groups. Comorbidities in the sample with critical illness were Cardiovascular condition (76.9%), Hypertension (68.7%), Diabetes (39.3%), Asthma or COPD (17.1%), CKD (26.2%), Cancer (13.9%) | Hispanic patients were at a greater risk of hospital admission with adjusted odds ratios (OR 1.63; CI, 1.35-1.97). This was similar to Other/Multiracial patients (OR 1.6; CI, 1.21-2.11). Black patients were at a similar risk of hospital admission as white patients with a lower risk of critical illness. | 162 |
| | | | | Asian | 7.3% | | | | |
| | | | | Hispanic | 25.2% | | | | |
| | | | | Other | 7.5% | | | | |
| 7 | Detroit, USA | June 2020 | 463 | African-American | 72.1% | - | 94% had at least 1 comorbidity, including hypertension (63.7%), CKD (39.3%), and diabetes (38.4%). These were not separately stated for the African American patients | Population and demographic data of the Michigan area, mentioned in the paper, showed that African Americans only make up 14% of the population but 32% of cases and 41% of deaths | 163 |
| 8 | Louisiana, USA | May, 2020 | 3481 | African-American | 70.4% | 21.6% | Comorbidities that showed a higher prevalence compared to Whites were Hypertension (33.8%%), Diabetes (18.5%), Obesity (53.9%), Asthma (4.2%), COPD (2.4%), high cholesterol (33%), Congestive Heart failure (4.2%), CKD (9.4%), Cancer (4.6%), HIV (0.2%) | Black patients were almost twice as likely to live in low-income areas as white patients<br><br>Black patients had almost twice the odds for hospitalization due to COVID-19 when adjusted for covariates (OR 1.96; 95% CI, 1.62 to 2.37)<br><br>Although incidence in African Americans was higher, mortality percentage was less than White patients (30.1%) | 164 |

| Sl | Location | Published (Month, Year) | Sample | Minority Group | Incidence of COVID-19 | Mortality | Comorbidity Findings | Remarks | Ref |
|---|---|---|---|---|---|---|---|---|---|
| 9 | Georgia, USA | May 2020 | 305 | Black (Non-Hispanic) | 83.2% | 16.2% | Diabetes was not significantly more for black patients than nonblack patients (41.7% versus 32.0%; p = 0.21). CVD was also similar in black and non-black patients (25.1% versus 30%, p=0.48). Hypertension and Severe Obesity was more common in blacks (69.6% versus 54.0%; p=0.047) and (13.9% vs 4.2%, p=0.088) Chronic lung disease, asthma and COPD were also reported more in blacks but not significantly (25.1% vs 12%, p=0.17), (12.1% vs 4%, p=0.13) and (5.7% vs 2%, p=0.48) | Black patients did not have a higher risk than nonblack patients to receive invasive mechanical ventilation (IMV), to die, or to experience the composite outcome of IMV or death. In an adjusted analysis for IMV or death as a composite outcome, black and non-black patients had no significant differences between them (HR = 0.63; 95% CI, 0.35–1.13).<br><br>At 4 affiliated hospitals accounting for 67% of the cohort for the study, 80% of patients were black. This was higher than expected. It was 47% black patients at these hospitals during March 2020. | 48 |
| | | | | non-Hispanic Asian or Pacific Islander | 2.7% | - | | | |
| | | | | Hispanic | 3.4% | - | | | |
| 10 | California, USA | May, 2020 | 1052 confirmed cases | Black or African American | 5.8% | 4.9% | Comorbidities were not separately stated for the minority groups.<br><br>Comorbidities in the whole sample were CVD (9.7%), Congestive heart failure (5.1%), Hypertension 31.8%, Type-II diabetes (14.3%), Cancer (5.2%), COPD (3.5%), Asthma (11.3%). | Among African American patients, 52.5% were hospitalized, compared to 25.7% of white patients. 24.6% of African American patients were transferred to the ICU compared to 10.7% of white patients. | 165 |
| | | | | Asian | 11.8% | 5.6% | | | |
| | | | | Hispanic | 25.8% | 3.7% | | | |
| | | | | Other/Mixed | 15.8% | 3.0% | | | |

**Table 01: This table consists of multivariate studies on COVID-19 patients with comorbidities or pre-existing conditions who have been categorized according to their ethnicities. Their incidence for COVID-19, mortality and prevalence for the conditions are also mentioned; along with possible explanations.**

## Conclusion

Several of the pre-existing conditions mentioned can be concluded to be risk factors for COVID-19 in terms of hospitalization, disease severity, morbidity, or mortality. Such pre-existing health conditions also affect ethnic minorities disproportionately. Some diseases are present in ethnic minority populations in greater proportions, while other conditions show no difference or are more significantly present in the majority population. Nevertheless, conditions that are less prevalent for the minority groups have a more pronounced effect on them, as seen by faster progression, greater severity of the disease, and poor health outcomes. This may be a result of socioeconomic barriers but also due to biological and genetic differences. Prevalence and the impact of these diseases in such groups has also led to disproportionate outcomes in the pandemic, with many minorities facing a greater degree of severe health outcomes due to COVID-19 infections.

Further studies based on large sample sizes, with adjusted models for co-founding factors, are required for a more concrete outlook on how minorities are being affected by the pandemic due to pre-existing conditions. A limitation posed by the lack of studies available is that most papers were based on population groups in the USA and the UK. Studies that identified racial and ethnic groups and linked the outcomes of COVID-19 infection to comorbidities were not available for diverse populations in other countries. As there is also an impact of biological and genetic factors on the prevalence and outcome of pre-existing conditions, it limits the investigation results of the papers to mainly the Asian, African-American, and Hispanic groups that reside as minorities in the USA and UK. More studies need to be conducted by identifying individuals, specifically considering the diverse social and ethnic groups. In conclusion, although it is shown that comorbidities in minority groups disproportionately impacted them due to COVID-19 infections, the current data only provides a narrow look into the subject matter which are mostly based in US and UK. Thus, our idea on the whole degree of COVID-19 disparities among ethnic minorities is not universal. It cannot be applied to other nations with racially different minority groups and their different living conditions.

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