Microbial Science Archives (2025) Vol. 6 (3), 60-75

Microbial Science Archives (ISSN: 2583-1666)

An International Research Journal

Journal homepage: www.microbial.sciencearchives.org

https://doi.org/10.47587/MSA.2026.6301

Review Article

Epidemiology of COVID-19 in Vulnerable Populations: A Review of the Risk Factors, Outcomes, and Implications for Public Health

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Received: June 3, 2026/ Revised: July 29, 2026/Aug 2, 2026

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Abstract

The Coronavirus Disease 2019 (COVID-19) pandemic has profoundly impacted global health, revealing stark disparities in disease burden across different population groups. Vulnerable populations including the elderly, individuals with chronic diseases, racial and ethnic minorities, socioeconomically disadvantaged communities, and those in congregate living settings have faced disproportionate risks of infection and adverse outcomes. Factors such as limited healthcare access, crowded living environments, lower health literacy, and pre-existing social inequities have intensified the challenges faced by these groups. Epidemiological data over the past years consistently demonstrate higher rates of COVID-19 morbidity and mortality among such populations, underscoring the urgent need for targeted intervention strategies. Understanding these dynamics is crucial for designing effective public health measures and reducing overall health inequities. The aim of this review was to investigate current evidence on the epidemiology of COVID-19 in vulnerable populations, focusing on risk factors, disease outcomes, and the broader public health implications. Findings from this study revealed that advanced age, underlying comorbidities (such as diabetes, hypertension, and chronic respiratory diseases), poverty, and racial/ethnic minority status are the most prominent risk factors for severe COVID-19 outcomes. Vulnerable populations also experience higher barriers to testing, treatment, and vaccination, which further exacerbate disparities. Outbreaks in institutionalized settings, such as nursing homes and prisons, have resulted in devastating mortality rates. Additionally, intersecting vulnerabilities, such as being both elderly and economically disadvantaged, compound risks. These findings highlight the complex interplay of biological, social, and structural determinants in shaping COVID-19 outcomes. In conclusion, mitigating the impact of COVID-19 among vulnerable populations requires equity-driven policies, improved healthcare access, and tailored public health interventions. Addressing these challenges is essential for reducing disparities and ensuring a more resilient response to current and future public health emergencies.

Keywords: COVID-19, Vulnerable populations, Risk factors, Health disparities, and Public health

1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic, caused by the novel coronavirus SARS-CoV-2, has left an indelible mark on global health since its emergence in late 2019. While COVID-19 has affected populations worldwide, its impact has not been evenly distributed (Bambra et al., 2020). Instead, the pandemic has dramatically exposed and exacerbated pre-existing health disparities, reflecting deeper social, economic, and structural inequities that shape vulnerability to both infection and adverse outcomes (Webb Hooper et al., 2020). COVID-19 rapidly spread from its origins in Wuhan, China, to become a global health crisis, resulting in over 770 million confirmed cases and more than 6.9 million deaths by early

2024 (World Health Organization [WHO], 2024). The speed and scale of transmission challenged even the most advanced healthcare systems and revealed significant weaknesses in public health infrastructure, especially in resource-limited settings (Mude et al., 2021). Although the pandemic initially appeared as a universal threat, it soon became clear that not all individuals or communities faced equal risks. Instead, COVID-19's trajectory mapped closely onto existing lines of disadvantage including age, race, socioeconomic status, occupation, and living conditions magnifying long-standing health inequities on a global scale (Patel et al., 2020).

COVID-19 health disparities have manifested in higher rates of infection, hospitalization, and mortality among marginalized and underserved groups (Centers for Disease Control and Prevention [CDC], 2020; Mathur et al., 2021). In the United States, Black, Hispanic, and Indigenous communities have borne a disproportionate burden of COVID-19 cases and deaths, largely due to social determinants such as crowded housing, limited access to healthcare, greater occupational exposure, and chronic stress linked to systemic racism ((Marmot et al., 2008; CDC, 2020; Yancy, 2020;). Similarly, in the United Kingdom and other high-income countries, ethnic minorities and those living in deprived neighborhoods have experienced worse outcomes (Public Health England, 2020; Mathur et al., 2021).

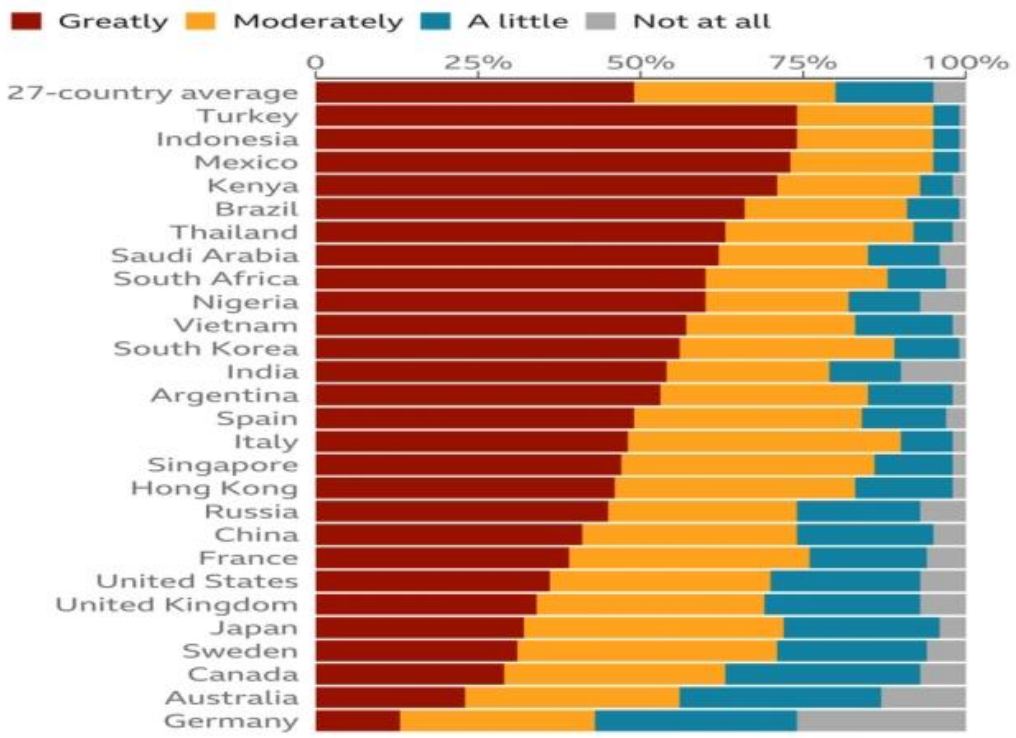

Figure 1. Statistical data showing the most affected countries following Covid-19 pandemic
Source: BBC World Service/GlobeScan

Globally, the impact of COVID-19 on health disparities has been even more pronounced in low- and middle-income countries (LMICs), where fragile health systems, poverty, and resource constraints have limited the ability to test, treat, and vaccinate at scale (Ohuabunwa & Ankomah, 2021; WHO, 2024) (Figure 1). In addition, the economic fallout of the pandemic has widened existing gaps in income and social protection, further increasing vulnerability among already marginalized groups (Blundell et al., 2020). Against this backdrop, the concept of "vulnerable populations" has become central to understanding and addressing the disparate impacts of COVID-19. Vulnerable populations are broadly defined as those individuals or groups who, due to a confluence of biological, social, and structural factors, face a heightened risk of infection, severe illness, or adverse socioeconomic consequences (CDC, 2020; WHO, 2021). This vulnerability is neither fixed nor uniform; rather, it can change over time and may be compounded by multiple intersecting risk factors.

Older adults are among the most widely recognized vulnerable groups in the context of COVID-19. Age is the strongest risk factor for severe illness and death, with those aged 65 and older especially residents of long-term care facilities facing dramatically higher mortality rates (Mueller et al., 2020; CDC, 2023). People with underlying health conditions such as hypertension, diabetes, obesity, chronic respiratory diseases, and immunosuppression also experience greater risks of complications and poor outcomes (Zhou et al., 2020; CDC, 2023).

Racial and ethnic minorities have consistently been identified as vulnerable, not due to inherent biological susceptibility but because of structural racism and social exclusion that result in greater exposure to the virus and reduced access to quality healthcare (Webb Hooper et al., 2020; Yancy, 2020). For example, in the US, Black and Hispanic populations have experienced hospitalization rates two to three times higher than those for White populations (CDC, 2020). Similar trends have been observed in the UK and other countries with diverse populations (Public Health England, 2020; Mathur et al., 2021). Socioeconomically disadvantaged communities are more likely to live in crowded housing, rely on public transportation, and work in essential, public-facing jobs that do not allow for remote work or adequate social distancing (Bambra et al., 2020; Blundell et al., 2020). These factors, combined with lack of health insurance, language barriers, and limited digital access, increase both exposure to SARS-CoV-2 and barriers to timely testing and treatment (Patel et al., 2020; WHO, 2021). People in congregate settings including nursing homes, prisons, migrant worker dormitories, and homeless shelters have faced devastating outbreaks due to the impossibility of physical distancing and often inadequate infection control measures (Barnett & Grabowski, 2020; WHO, 2021). Essential workers, including healthcare professionals, grocery staff, public transport operators, and cleaners, have faced sustained occupational exposure, often with insufficient personal protective equipment in the early stages of the pandemic (Lan et al., 2020). Other groups such as migrants, refugees, people with disabilities, and those with limited language or digital access have also been identified as vulnerable due to unique barriers in accessing healthcare, information, and social support (Kluge et al., 2020; WHO, 2021). For many, these challenges have been compounded by legal, cultural, or policy-related obstacles.

The rationale for this review is rooted in the urgent need to understand and address the inequities that COVID-19 has made visible and, in many cases, worse. Despite remarkable scientific progress in diagnostics, therapeutics, and vaccine development, disparities in outcomes persist both within and between countries (Mathur et al., 2021; Ohuabunwa & Ankomah, 2021). For example, while some high-income countries have achieved widespread vaccine coverage, many LMICs continue to struggle with access to vaccines and medical supplies, resulting in higher case fatality rates and prolonged outbreaks (WHO, 2024). This review therefore aims to investigate current evidence on the epidemiology of COVID-19 in vulnerable populations, with particular attention to risk factors, outcomes, and implications for public health. Specifically, the objectives are:

i. to distill what is known about elevated risks and poor outcomes among vulnerable groups;
ii. to clarify the biological, social, and structural mechanisms underpinning these disparities;
iii. to discuss what these findings mean for the design and implementation of equitable public health policies.

2. Overview of Vulnerable Populations to COVID-19

2.1 Elderly Individuals

Older adults, especially those aged 65 and above, have been disproportionately affected by the COVID-19 pandemic. Age-related changes in the immune system, known as immunosenescence, impair the body's ability to mount effective responses to novel pathogens, including SARS-CoV-2 (Jordan et al., 2020). Furthermore, elderly individuals are more likely to experience atypical disease presentations, such as delirium or falls, which can delay diagnosis and appropriate management. The increased risk of severe outcomes, including hospitalization, intensive care unit (ICU) admission, and mortality, has been repeatedly demonstrated in epidemiological studies. For example, data from multiple countries show that individuals over 60 years old account for the vast majority of COVID-19-related deaths (Williamson et al., 2020).

In addition to biological vulnerability, older adults often face social challenges that exacerbate their risk. Many reside in long-term care facilities or nursing homes, communal settings that have been epicenters of severe outbreaks due to close quarters and difficulties implementing infection control measures (Salcher-Konrad et al., 2022). Social isolation, which has been necessary to prevent transmission, can also lead to negative mental health outcomes such as depression and anxiety. Elderly individuals with limited mobility or cognitive decline may struggle to access information or healthcare services, further increasing their vulnerability during the pandemic (Jordan et al., 2020).

2.2 Individuals with Chronic or Pre-existing Medical Conditions

A robust body of evidence indicates that individuals with comorbidities such as diabetes, hypertension, obesity, cardiovascular disease, chronic respiratory disease, and cancer are at significantly higher risk for severe COVID-19 outcomes. These conditions can compromise immune system function or place chronic stress on the body, making it more difficult to recover from viral infections (Zhou et al., 2020). For instance, diabetes impairs the innate immune response, while chronic lung disease makes patients more susceptible to respiratory complications. Patients with multiple comorbidities experience additive risks, leading to higher rates of hospitalization, ICU admission, and death (Sanyaolu et al., 2020).

The prevalence of comorbidities tends to increase with age and is often higher in socioeconomically disadvantaged groups, further compounding risk. Many individuals with chronic illnesses require regular medical appointments,

medication, and monitoring, which may be disrupted during periods of lockdown or health system strain. Additionally, the fear of contracting COVID-19 has led some patients to avoid healthcare settings, resulting in delayed management of their underlying conditions and worse overall outcomes (CDC, 2021).

2.3 Immunocompromised Individuals

Immunocompromised individuals, such as those undergoing chemotherapy, recipients of organ transplants, and people living with HIV/AIDS or autoimmune diseases, face unique challenges during the COVID-19 pandemic. Their weakened immune systems may not only increase susceptibility to infection but also contribute to prolonged viral replication and shedding, which can complicate infection control efforts (Sanyaolu et al., 2020). Evidence suggests that immunocompromised patients are at greater risk for severe disease, with higher rates of hospitalization, longer duration of illness, and, in some cases, increased mortality (Williamson et al., 2020).

These individuals often require frequent contact with healthcare facilities for treatments or monitoring, increasing their potential exposure to COVID-19. Moreover, immunosuppressive therapies may need to be adjusted or temporarily discontinued if infection occurs, which can destabilize underlying conditions. The interplay between COVID-19 and immunosuppression remains an active area of research, with emerging evidence suggesting that vaccination strategies and preventive measures may need to be tailored specifically for this group (CDC, 2021).

2.4 Socioeconomically Disadvantaged Groups

Socioeconomic status is a powerful determinant of health, and the COVID-19 pandemic has starkly highlighted its role in shaping disease risk and outcomes. People living in poverty often face overcrowded housing, limited access to clean water and sanitation, and a greater likelihood of employment in high-exposure, essential roles such as food service, transportation, or healthcare support (Patel et al., 2020). These factors contribute to higher rates of infection and reduced capacity to implement preventive measures such as social distancing or quarantine.

In addition to increased exposure, socioeconomically disadvantaged populations frequently encounter barriers to healthcare access, including lack of insurance, transportation challenges, and limited availability of culturally appropriate services. Such barriers can delay diagnosis and treatment, resulting in more severe disease progression. The economic fallout from the pandemic such job loss, food insecurity, eviction, among others have also disproportionately affected these groups, compounding both health risks and psychosocial stressors (Patel et al., 2020).

2.5 Ethnic and Racial Minorities

COVID-19 has exposed and intensified existing health inequities among ethnic and racial minority groups. Data from the United States, United Kingdom, and other countries demonstrate that Black, Hispanic, Indigenous, and other minority populations experience higher infection rates, more severe disease, and increased mortality compared to majority populations (Mackey et al., 2021). These disparities are driven by a complex interplay of structural factors, including systemic racism, discrimination in healthcare, and socioeconomic disadvantage. Minority populations are also more likely to reside in multigenerational households or densely populated neighborhoods, further increasing transmission risk (Tai et al., 2021).

Language barriers, limited access to culturally sensitive health information, and mistrust of healthcare systems can further hinder effective prevention and treatment. Additionally, minority workers are disproportionately represented in frontline and essential service roles, where the risk of exposure is elevated. Addressing these disparities requires not only medical interventions but also broader efforts to dismantle systemic inequities and promote social justice in public health (Mackey et al., 2021).

2.6 Residents in Congregate Settings

Individuals residing in congregate settings such as nursing homes, prisons, homeless shelters, migrant worker dormitories, and refugee camps face unique vulnerabilities in the context of COVID-19. These environments are often characterized by high population density, shared facilities, and limited opportunities for effective infection control (Salcher-Konrad et al., 2022). Outbreaks in such settings have been associated with rapid spread and high case-fatality rates, particularly among residents with underlying health conditions.

Management of COVID-19 in congregate settings is complicated by logistical and resource constraints, including shortages of personal protective equipment, difficulties in isolating infected individuals, and limited access to medical care. Staff working in these facilities may also act as vectors for transmission between the community and the resident population. The concentration of vulnerable individuals in these environments highlights the need for targeted surveillance, outbreak control measures, and policy reforms to protect high-risk groups (Salcher-Konrad et al., 2022).

2.7 Individuals with Limited Healthcare Access

Access to healthcare is a fundamental determinant of health outcomes, and its absence poses significant risks during a pandemic. Rural residents, undocumented migrants, and uninsured individuals may face significant obstacles in obtaining timely testing, diagnosis, and treatment for COVID-19 (Kirby, 2020). Geographic isolation, transportation

challenges, and shortages of healthcare providers are common barriers in rural areas, while fear of deportation or financial hardship may deter undocumented or uninsured persons from seeking care.

Moreover, limited access to healthcare can delay the identification and containment of outbreaks, contributing to broader community transmission. Disparities in healthcare access are often intertwined with other social determinants of health, such as language proficiency, health literacy, and socioeconomic status. Ensuring equitable access to COVID-19 prevention and treatment resources is essential for reducing morbidity and mortality across all segments of the population (Kirby, 2020).

3. Risk Factors for COVID-19 in Vulnerable Populations

3.1 Biological Factors

Biological factors are foundational in shaping the risk landscape for COVID-19 among vulnerable populations. Advanced age remains one of the most influential risk determinants, as older adults experience immunosenescence, a decline in immune system function that undermines the body's ability to recognize and respond efficiently to novel pathogens such as SARS-CoV-2 (Jordan et al., 2020). This immunological decline is often compounded by chronic, age-associated inflammatory states ("inflammaging") and the cumulative burden of comorbidities, both of which have been shown to exacerbate the severity of COVID-19 outcomes (Williamson et al., 2020). For example, the OpenSAFELY study found that individuals over 80 years of age had more than a 20-fold increased risk of COVID-19-related death compared to those in their fifties (Williamson et al., 2020).
Pre-existing medical conditions also represent significant biological risk factors. Conditions such as diabetes mellitus, hypertension, obesity, chronic respiratory diseases (e.g., COPD and asthma), cardiovascular disease, and chronic kidney disease are consistently linked to poor COVID-19 outcomes (Zhou et al., 2020). These ailments can impair the body's immune response or place chronic stress on vital organs, making individuals more susceptible to acute complications like ARDS, sepsis, and multi-organ failure (Sanyaolu et al., 2020). The presence of multiple comorbidities, common especially in older adults and certain disadvantaged groups appears to have a multiplicative, not merely additive, effect on risk, further increasing the likelihood of hospitalization, ICU admission, and death (Sanyaolu et al., 2020).

Immunocompromised states, whether due to primary immunodeficiencies, cancer therapies, organ transplantation, HIV/AIDS, or immunosuppressive drugs for autoimmune conditions, also heighten susceptibility to infection and severe disease (Williamson et al., 2020). These individuals often exhibit atypical or prolonged courses of illness, with evidence suggesting longer viral shedding periods and higher viral loads (Sanyaolu et al., 2020). This not only endangers their health but may also pose ongoing risks for transmission and complications related to viral evolution. Notably, certain demographic patterns, such as male sex, have been associated with higher risk of severe disease and mortality, possibly due to differences in immune response, hormonal influences, and comorbidity profiles, though further research remains ongoing (Williamson et al., 2020).

3.2 Social Determinants of Health

Social determinants of health are critical, non-biological factors that significantly influence exposure risk, access to care, and outcomes related to COVID-19. Socioeconomic status profoundly affects an individual's ability to practice preventive measures and seek timely care. People living in poverty or low-income households often contend with overcrowded and substandard housing conditions, which make social distancing and self-isolation nearly impossible (Patel et al., 2020). These living environments facilitate rapid household and community transmission, particularly in urban areas with high population density.

Occupational exposure further amplifies risk among socioeconomically disadvantaged groups. Essential workers, disproportionately from marginalized communities, are employed in public-facing jobs including healthcare support, food service, public transportation, and sanitation that cannot be performed remotely and often lack adequate protective measures (Tai et al., 2021). This increased exposure risk, compounded by insufficient access to paid sick leave and health insurance, means that infected individuals may continue working due to financial necessity, inadvertently contributing to further spread (Patel et al., 2020).
Educational attainment and health literacy are additional social determinants that shape vulnerability. Individuals with lower education levels may struggle to access, interpret, and implement public health guidance, leading to suboptimal adherence to preventive strategies (Mackey et al., 2021). Language barriers, cultural differences, and systemic mistrust of healthcare institutions sometimes rooted in historical discrimination can further disincentivize seeking care or participating in vaccination programs (Tai et al., 2021). These intersecting social forces result in delayed care, missed opportunities for early intervention, and ultimately, poorer health outcomes in vulnerable populations.

3.3 Behavioral and Cultural Factors

Behavioral and cultural factors have a profound influence on the transmission dynamics and severity of COVID-19 within vulnerable communities. Health-seeking behaviors such as willingness to obtain testing, adhere to isolation protocols, or seek medical care when symptomatic are shaped by both individual beliefs and community norms. Misinformation, stigma, and fear of discrimination can discourage timely testing and disclosure of symptoms, leading to undetected transmission chains and exacerbating outbreaks (Mackey et al., 2021).

Cultural norms play a significant role in shaping risk. In many cultures, multigenerational households are common, and social or religious gatherings are central to community life. While these arrangements provide social support, they also facilitate viral spread, particularly when public health measures are not strictly followed (Tai et al., 2021). In some communities, skepticism toward government or health authorities can fuel resistance to mask-wearing, vaccination, and social distancing mandates. This resistance may be intensified by language barriers or a lack of culturally tailored health communications, further impeding the implementation of effective prevention strategies (Patel et al., 2020).

Table 1. Overview of populations vulnerable to COVID-19 and associated challenges

Vulnerable Population	Why at Higher Risk	Examples of Challenges	References
Older Adults	Weaker immune systems, more comorbidities	Severe illness, higher mortality	(CDC, 2023)
People with Chronic Diseases	Underlying health conditions (e.g., diabetes, heart disease)	Complications, hospitalization	(WHO, 2022)
Immunocompromised Individuals	Reduced ability to fight infections (e.g., cancer, HIV, organ transplant)	Severe symptoms, prolonged illness	(CDC, 2023)
Pregnant Women	Immune & physiological changes	Higher risk of complications	(CDC, 2023)
People in Congregate Settings	Close quarters increase transmission (e.g., nursing homes, prisons)	Rapid spread, outbreaks	(CDC, 2023)
Ethnic & Racial Minorities	Disparities in healthcare access, socioeconomic factors	Higher infection and death rates	(CDC, 2023; WHO, 2022)
Low-Income Populations	Limited resources, crowded living, less healthcare access	Difficulty accessing care, higher exposure	(WHO, 2022)
People with Disabilities	May have underlying conditions or barriers to care	Increased risk, challenges in prevention	(CDC, 2023)

Furthermore, the psychological toll of the pandemic including anxiety, depression, and social isolation can influence behaviors relevant to risk. Individuals experiencing pandemic-related stress may be less likely to adhere to preventive measures, maintain routines such as medication adherence, or seek care for new or worsening symptoms. As such, public health interventions must be culturally sensitive and designed with community input, ensuring that health messaging is both accessible and trustworthy (Tai et al., 2021).

3.4 Healthcare Access and Systemic Barriers

Access to healthcare is a decisive factor in determining COVID-19 risk and outcome severity. Vulnerable populations including rural residents, undocumented migrants, uninsured individuals, and those living in medically underserved communities often encounter substantial barriers in accessing timely testing, diagnosis, and treatment (Kirby, 2020). These barriers may include lack of insurance coverage, transportation difficulties, insufficient healthcare infrastructure, and fear of immigration enforcement. As a result, many individuals may delay or avoid seeking care,

leading to more advanced disease at presentation and worse outcomes (Mackey et al., 2021).

Systemic barriers within healthcare systems also contribute to disparities in COVID-19 burden. Implicit bias and discrimination can result in minority and marginalized patients receiving lower quality care, longer wait times, or inadequate communication from providers (Mackey et al., 2021). Additionally, the rapid shift to telemedicine during the pandemic, while beneficial for many, has left behind those without reliable internet access, technological literacy, or private spaces for virtual care exacerbating existing digital divides and healthcare disparities (Patel et al., 2020).

Resource allocation during surges, such as triage protocols for ICU beds and ventilators, may inadvertently disadvantage those with underlying conditions or disabilities if not guided by principles of equity and justice. Effective pandemic response requires not only expanding healthcare access but also implementing structural reforms to address systemic inequities, ensure culturally competent care, and prioritize the needs of the most vulnerable (Kirby, 2020).

4. Transmission Dynamics in Vulnerable Populations

4.1 Modes of Transmission Relevant to Vulnerable Groups

COVID-19 is primarily transmitted via respiratory droplets and aerosols exhaled by infected individuals, with the risk particularly heightened in enclosed, poorly ventilated, or crowded environments (Morawska & Cao, 2020; Prather et al., 2020). Aerosol transmission is of particular concern in congregate settings where vulnerable individuals reside, such as long-term care facilities, homeless shelters, and prisons. These settings often lack adequate ventilation and space for physical distancing, making it difficult to minimize the risk of airborne spread (Lu et al., 2020; van Doremalen et al., 2020).
Beyond direct person-to-person transmission, shared surfaces and fomites can play a secondary role, especially in situations where hand hygiene is inadequate or sanitation resources are limited. Studies have shown that SARS-CoV-2 can persist on surfaces like plastic and stainless steel for up to 72 hours, although the likelihood of transmission via fomites is lower than via respiratory routes (Goldman, 2020; van Doremalen et al., 2020). Nevertheless, in high-density environments with frequent contact with communal surfaces such as doorknobs, light switches, and shared bathrooms; these risks are amplified among populations with limited access to hygiene supplies (Kampf et al., 2020; CDC, 2021).

Asymptomatic and pre-symptomatic individuals further complicate transmission dynamics. Several studies have demonstrated that individuals can spread the virus before the onset of symptoms, making it difficult to identify and isolate cases quickly (He et al., 2020; Oran & Topol, 2020). This is especially problematic in vulnerable populations who may not have access to regular screening or rapid testing, allowing outbreaks to propagate unchecked in group settings.

4.2 Role of Household, Community, and Institutional Settings

Household transmission is a major driver of COVID-19 spread, especially in settings where physical distancing and isolation are not feasible. Studies have reported secondary attack rates in households ranging from 10% to 30%, with higher rates observed in crowded and multigenerational homes (Grijalva et al., 2020; Madewell et al., 2020). Vulnerable populations are disproportionately affected, as they are more likely to live in such environments due to economic constraints or cultural practices. Children and young adults, who may be less symptomatic, can inadvertently transmit the virus to older family members or those with underlying health conditions (Li et al., 2020).

Community transmission is also a significant concern, particularly in urban areas with high population density and frequent social interactions. Public transportation, markets, places of worship, and other communal spaces can become sites of super-spreader events if preventive measures are not consistently implemented (Fisher et al., 2020; Furuse et al., 2020). The effectiveness of public health interventions in community settings often depends on clear communication, cultural competence, and the ability to reach linguistically and socially diverse groups (Patel et al., 2020).

Institutional settings including nursing homes, prisons, and migrant worker dormitories are especially vulnerable to rapid outbreaks and high mortality rates. Research has shown that a single introduction of SARS-CoV-2 can lead to large clusters of cases in these settings due to close quarters, shared amenities, and frequent staff movement (Chen et al., 2021; Salcher-Konrad et al., 2022). The lack of adequate infection prevention protocols, limited resources for isolation, and the presence of high-risk individuals make outbreak control in institutions particularly challenging (Comas-Herrera et al., 2020).

4.3 Impact of Occupational and Environmental Exposures

A significant proportion of vulnerable individuals work in essential sectors such as healthcare, food processing, agriculture, transportation, and retail. Studies have consistently shown that frontline workers, particularly those from racial and ethnic minority backgrounds, are at increased risk of acquiring COVID-19 due to frequent contact with the public and inability to work remotely (Hawkins, 2020; Nguyen et al., 2020). Workplace outbreaks have been documented in meatpacking plants, warehouses, and hospitals, highlighting the need for stringent occupational health measures (Dyal et al., 2020; Waltenburg et al., 2020).

Workplaces with inadequate ventilation, crowded conditions, and insufficient access to personal protective equipment (PPE) further amplify the risk. Research indicates that improving ventilation, enforcing mask mandates, and providing paid sick leave can substantially reduce workplace transmission (Allen

& Marr, 2020; CDC, 2021). However, many low-wage and migrant workers have limited bargaining power to demand safer conditions, and may fear job loss or deportation if they report illness or unsafe practices (Baker et al., 2020).

Environmental factors, such as poor housing conditions, lack of access to clean water, and seasonal weather that drives people indoors, compound risks for vulnerable groups. Crowded neighborhoods, inadequate public health infrastructure, and limited community resources reduce the effectiveness of COVID-19 prevention efforts (Ahmad et al., 2020; Patel et al., 2020). Addressing the occupational and environmental determinants of transmission is thus critical for protecting high-risk populations and curbing the spread of COVID-19.

Table 2. Transmission dynamics of COVID-19 in vulnerable populations

Transmission Factor	Description	Implications for Vulnerable Populations	References
Airborne & Droplet Transmission	COVID-19 spreads mainly via respiratory droplets and aerosols, especially in enclosed, poorly ventilated, or crowded environments.	Congregate settings (nursing homes, shelters, prisons) are particularly susceptible due to poor ventilation and crowding.	Morawska & Cao (2020); Prather et al. (2020); Lu et al. (2020); van Doremalen et al. (2020)
Fomite (Surface) Transmission	SARS-CoV-2 can persist on surfaces (plastic, steel) for up to 72 hours; less common than airborne, but risk increases with poor hygiene and sanitation.	Settings with frequent communal surface contact and low hygiene (e.g., shelters, prisons) face greater risk.	Goldman (2020); van Doremalen et al. (2020); Kampf et al., (2020); CDC (2021)
Asymptomatic/Pre-symptomatic Spread	Individuals can transmit the virus before symptom onset, complicating outbreak control without regular screening.	Outbreaks in group settings can go undetected without regular/rapid testing, especially in resource-limited environments.	He et al. (2020); Oran & Topol (2020)
Household Transmission	Close contact in crowded, multigenerational households leads to high secondary attack rates (10–30%). Children/young adults may transmit to older relatives.	Vulnerable groups often live in crowded homes, increasing intra-family spread to the elderly or chronically ill.	Grijalva et al. (2020); Madewell et al. (2020); Li et al. (2020)
Community Transmission	Urban density and frequent public interactions (public transport, markets, worship) are major community transmission drivers.	Vulnerable groups relying on public amenities are at higher risk; prevention depends on accessible, culturally competent communication.	Fisher et al. (2020); Furuse et al. (2020); Patel et al. (2020)
Institutional/Group Outbreaks	Outbreaks in nursing homes, prisons, dormitories are rapid/severe due to close quarters, shared facilities, staff movement, and high-risk occupants.	Outbreak management is difficult due to limited isolation, infection control, and high-risk residents.	Chen et al. (2021); Salcher-Konrad et al. (2022); Comas-Herrera et al. (2020)
Occupational & Environmental Exposure	Frontline, low-wage, and migrant workers face higher risk due to public-facing roles, inability to work remotely, and poor workplace PPE/ventilation.	Fear of job loss/deportation discourages reporting illness; poor housing, lack of clean water, and crowding heighten vulnerability.	Hawkins, 2020; Nguyen et al. (2020); Dyal et al. (2020); Waltenburg et al. (2020); Allen & Marr (2020); Baker et al. 92020); Ahmad et al., 2020; Patel et al. (2020)

5. Health Outcomes in Vulnerable Populations

5.1 Infection Rates and Trends

Vulnerable populations including the elderly, racial and ethnic minorities, individuals with chronic illnesses, and those living in congregate settings have consistently experienced higher rates of COVID-19 infection compared to the general population (Mackey et al., 2021; Tai et al., 2021). For instance, data from the United States and United Kingdom have shown that Black, Hispanic, and Indigenous communities have infection rates two to three times higher than their White counterparts, a disparity attributed to social determinants such as crowded housing, frontline employment, and limited

healthcare access (Mathur et al., 2021; CDC, 2022). Outbreaks in nursing homes, correctional facilities, and shelters have also contributed to surges in infection among residents and staff (Salcher-Konrad et al., 2022). These trends have persisted across multiple waves of the pandemic, underscoring the persistent risk facing these groups.

Temporal trends indicate that infection rates can spike rapidly in vulnerable communities during periods of high community transmission or when public health measures are relaxed. Variants of concern, such as the Delta and Omicron strains, have demonstrated increased transmissibility, raising infection risks further, particularly in under-vaccinated populations and in settings where preventive measures are difficult to maintain (Madhi et al., 2022; Twohig et al., 2022). Ongoing surveillance and targeted outreach are crucial for early detection and mitigation of outbreaks among these populations.

5.2 Clinical Severity and Progression

Hospitalization rates for COVID-19 are markedly higher among vulnerable populations. Elderly individuals, people with pre-existing conditions (such as diabetes, cardiovascular disease, and obesity), and immunocompromised persons are more likely to develop severe symptoms requiring hospital admission (Petrilli et al., 2020; Zhou et al., 2020). Studies from multiple countries report that individuals over 65 account for the majority of COVID-19 hospitalizations, and those with multiple comorbidities face a substantially higher risk of severe disease progression (Williamson et al., 2020; CDC, 2022).

Intensive care unit (ICU) admissions are also disproportionately higher in these groups. For example, data from the UK's ISARIC study found that among hospitalized patients, those from ethnic minority backgrounds and the elderly were more likely to require ICU care and advanced respiratory support (Docherty et al., 2020). The requirement

for mechanical ventilation is similarly elevated among these populations, especially for residents of long-term care facilities and those with chronic respiratory or cardiac conditions (Grasselli et al., 2020). These trends reflect both the underlying vulnerability and the increased risk of rapid clinical deterioration in these groups.

5.3 Mortality and Case Fatality Rates

Mortality rates from COVID-19 have been significantly higher among vulnerable populations worldwide. Age remains the most significant predictor of death, with case fatality rates exceeding 10% in those over 80 years old, compared to less than 0.5% in adults under 50 (Williamson et al., 2020; O'Driscoll et al., 2021). Racial and ethnic minorities, particularly Black and Hispanic populations in the United States, have experienced higher age-adjusted mortality rates, reflecting an interplay of biological, social, and healthcare access factors (Mackey et al., 2021; Mathur et al., 2021).

Residents of nursing homes and other long-term care facilities represent a disproportionate share of COVID-19 deaths. In the early stages of the pandemic, these settings accounted for over 40% of all COVID-19-related deaths in some countries (Salcher-Konrad et al., 2022). Pre-existing health conditions, delayed access to care, and outbreaks in closed environments have contributed to the high case fatality rates seen in these populations.

5.4 Long-term Consequences and "Long COVID"

Many individuals, especially those from vulnerable groups, experience prolonged and sometimes debilitating symptoms after recovery from acute COVID-19. This condition commonly referred to as "long COVID" or post-acute sequelae of SARS-CoV-2 infection (PASC) can include fatigue, shortness of breath, cognitive impairment, and mental health issues lasting for weeks or months after the initial infection (Nalbandian et al., 2021; Huang et al., 2021). Prevalence estimates for long COVID vary, but studies have found that up to 30% of hospitalized patients report persistent symptoms six months post-discharge (Huang et al., 2021).

Vulnerable populations may be at increased risk for long-term complications due to pre-existing health conditions and limited access to rehabilitative care. Long COVID can exacerbate existing disabilities, impair daily functioning, and worsen mental health, especially among older adults and those with chronic illnesses (Sudre et al., 2021). Addressing the burden of long COVID in vulnerable groups requires coordinated multidisciplinary care and ongoing public health support.

6. Public Health Implications

6.1 Surveillance and Data Collection in High-Risk Groups

Surveillance and data collection are foundational to understanding and addressing the burden of COVID-19 among vulnerable populations. Early in the pandemic, significant gaps in surveillance hampered the ability to identify outbreaks and respond rapidly among high-risk groups such as racial and ethnic minorities, people experiencing homelessness, and residents of long-term care facilities (Artiga et al., 2020; Bibbins-Domingo, 2020). Accurate and timely data, disaggregated by social determinants like age, ethnicity, disability, and socioeconomic status, enable public health authorities to track infection trends, detect disparities, and allocate resources effectively (Mackey et al., 2021; Mathur et al., 2021).

Enhancing surveillance requires both technological and social innovation. Community-based participatory research and partnerships with trusted organizations are crucial for gathering reliable data in populations that may distrust

government or healthcare systems (Figueroa et al., 2021). Mobile testing units, syndromic surveillance in healthcare and community settings, and wastewater monitoring have been used to supplement traditional case reporting, providing early warnings of outbreaks, especially in congregate environments (Peccia et al., 2020; Del Brutto et al., 2021). However, underreporting and diagnostic delays remain a challenge, particularly where access to testing is limited by financial, geographic, or language barriers (Mude et al., 2021; CDC, 2022). To address these gaps, public health agencies must invest in outreach, culturally competent communication, and infrastructure that supports comprehensive, real-time data collection.

6.2 Targeted Preventive Interventions

Vaccination strategies have been central in mitigating the impact of COVID-19 in vulnerable populations. Prioritizing the elderly, immunocompromised, and frontline workers for early vaccination has markedly reduced the rates of severe disease and mortality in these groups (Dooling et al., 2021; Suthar et al., 2022). However, vaccine hesitancy, misinformation, and logistical challenges have led to persistent disparities in vaccine uptake, especially in minority and low-income communities (Fisher et al., 2021; Razai et al., 2021). Addressing these issues requires targeted outreach, community engagement, and the deployment of mobile or pop-up vaccination clinics to reach underserved areas (Omer et al., 2021). In some countries, vaccination campaigns have also been integrated with broader health and social services, providing incentives and reducing barriers to access (WHO, 2022).

Widespread and equitable access to testing remains critical for early identification and isolation of cases among at-risk groups. Rapid antigen and PCR tests deployed in community centers, shelters, schools, and workplaces have enabled more timely outbreak response (Mina et al., 2020; CDC, 2022). Effective contact tracing, while resource-intensive, is essential for interrupting transmission chains, especially in settings where asymptomatic or pre-symptomatic spread is common (Kretzschmar et al., 2020). Ensuring the distribution of personal protective equipment (PPE), cleaning supplies, and hygiene resources is equally important, particularly for frontline workers and residents of high-density environments (Nguyen et al., 2020; Patel et al., 2020). Programs that provide PPE free of charge, along with training in its correct use, have been shown to lower infection rates in institutional and occupational settings.

6.3 Policy Responses

Policy responses to the COVID-19 pandemic have included a range of public health and social measures, each with unique implications for vulnerable groups. Social distancing mandates, lockdowns, and restrictions on gatherings have been effective at slowing viral transmission, but they have also imposed significant economic and psychosocial burdens especially for low-wage workers, people with disabilities, and families lacking access to childcare or remote education (Abrams & Szefler, 2020; Patel et al., 2020). Policymakers have increasingly recognized the need to pair restrictions with robust support systems, such as paid sick leave, unemployment benefits, food and housing assistance, and mental health services (Tsai & Wilson, 2020; Marmot et al., 2020).

Housing, income, and food security initiatives are essential to ensuring that vulnerable populations can comply with public health measures and maintain their well-being. Eviction moratoriums, rental assistance, expanded food distribution programs, and direct cash transfers have helped prevent homelessness and hunger during periods of economic upheaval (Benfer et al., 2021; Fitzpatrick et al., 2021). In some regions, governments have provided isolation facilities for people who cannot safely quarantine at home an intervention that has reduced household transmission in crowded living situations (Figueroa et al., 2021). Such supports not only address immediate needs but also build trust and cooperation with public health authorities, which is crucial for successful pandemic response.

6.4 Healthcare Delivery Adaptations

Healthcare systems have rapidly adapted to meet the needs of vulnerable populations during the pandemic. Telemedicine has emerged as a vital tool for ensuring continuity of care, particularly for individuals at high risk of severe COVID-19 or those living in remote or underserved areas (Reed et al., 2020; Wosik et al., 2020). The expansion of virtual visits, remote monitoring, and digital health platforms has allowed patients to access primary care, mental health services, and specialty consultations without risking exposure in clinical settings. However, disparities in digital literacy, access to reliable internet, and the availability of translation services have limited the benefits of telehealth for some groups, underscoring the need for ongoing investment in digital infrastructure and equitable service provision (Nouri et al., 2020).

Beyond telemedicine, healthcare systems have implemented triage protocols, surge capacity planning, and workforce expansion to accommodate increased demand for acute and intensive care. Flexible staffing models, cross-training, and redeployment of healthcare workers have been key in managing surges, especially in regions with high concentrations of vulnerable patients (Emanuel et al., 2020; Ranney et al., 2020). Community paramedicine, home-based care, and partnerships with local organizations have also helped deliver essential services, medications, and chronic disease management to those unable to access traditional healthcare facilities.

6.5 Addressing Health Disparities and Promoting Equity

Addressing health disparities and promoting equity are imperative for controlling COVID-19 and preventing future public health crises. The pandemic has exposed and exacerbated longstanding inequities in healthcare access, quality, and outcomes for racial/ethnic minorities, people with disabilities, the uninsured, and other marginalized groups (Bibbins-Domingo, 2020; Mackey et al., 2021). Culturally competent care, linguistically appropriate public health messaging, and the inclusion of community leaders in planning and implementation are critical to overcoming mistrust and ensuring that interventions reach those most in need (Marmot et al., 2020; Figueroa et al., 2021).

Long-term solutions require investment in the social determinants of health such as education, housing, employment, and environmental safety to build resilience against future pandemics and chronic disease burdens (Marmot et al., 2020). Policies that promote universal health coverage, strengthen primary care, and address systemic racism and discrimination are vital for achieving health equity. Pandemic recovery plans should not only restore, but also improve social and healthcare systems to ensure that no population is left behind in future health emergencies (Artiga et al., 2020; WHO, 2022).

7. Challenges and Gaps

7.1 Limitations in Available Data

One of the most persistent and consequential challenges in addressing COVID-19 among vulnerable populations is the lack of high-quality, timely, and disaggregated data. In the initial phase of the pandemic, many national and local health authorities did not collect data that accounted for race, ethnicity, occupational status, housing situation, disability, or immigration status, which resulted in an incomplete understanding of where the greatest needs existed (Artiga et al., 2020; Bibbins-Domingo, 2020). This lack of granularity in surveillance masked early signals of disproportionate infection and mortality rates among marginalized groups, delaying targeted interventions and resource allocation.

Even as awareness of health disparities grew, challenges in standardizing and sharing data have continued. In some countries, reporting requirements remain inconsistent between jurisdictions, and there are ongoing issues with underreporting due to limited testing capacity, insufficient healthcare access, or mistrust of authorities particularly among undocumented migrants, people experiencing homelessness, and racial/ethnic minorities (Figueroa et al., 2021; Mude et al., 2021). In low- and middle-income countries, weak health information systems and limited infrastructure further hinder comprehensive surveillance, making cross-national comparisons and coordinated global responses difficult (World Health Organization, 2022). Accurate, transparent, and comparable data remain foundational not only for pandemic response but also for building trust and accountability in public health systems.

7.2 Barriers to Implementation of Interventions

Interventions such as vaccination campaigns, mass testing, and the distribution of PPE are often hampered by logistical, infrastructural, and sociopolitical barriers, especially in resource-limited settings or among marginalized groups. The "last mile" problem delivering interventions to the most difficult-to-reach populations has been repeatedly encountered, with rural, remote, and informal settlements facing acute shortages of healthcare workers, transport, cold-chain storage, and basic supplies (Nguyen et al., 2020; Ranney et al., 2020). In urban slums and densely populated neighborhoods, implementing social distancing is practically impossible, and interventions such as lockdowns may deprive daily wage earners of their livelihoods, leading to unintended socioeconomic and health harms (Patel et al., 2020; Tsai & Wilson, 2020).

Financial constraints are a further barrier. Many at-risk individuals lack health insurance or steady income, which can deter them from seeking testing or treatment because of the potential for catastrophic out-of-pocket expenses (Marmot et al., 2020). In addition, legal and policy barriers such as lack of documentation among migrants or restrictive eligibility for social services can prevent vulnerable populations from accessing care or public health resources (Bibbins-Domingo, 2020). Political polarization and inconsistent messaging have occasionally led to poor compliance with public health guidance, fueling further disparities in disease outcomes.

7.3 Cultural and Linguistic Considerations

Cultural beliefs, practices, and language differences significantly influence the effectiveness of public health interventions. Standardized messaging and programming may fail to resonate with diverse populations, particularly if they do not reflect local realities or address community-specific concerns (Figueroa et al., 2021; Razai et al., 2021). For example, some communities may have a historical mistrust of government or healthcare authorities due to previous experiences of discrimination or unethical research, making them wary of vaccine campaigns, contact tracing, or even COVID-19 testing (Loomba et al., 2021).

Language barriers can further limit access to accurate information and services. Many public health campaigns and government updates were initially only available in dominant languages, excluding non-native speakers and recent immigrants (Mackey et al., 2021). Inadequate translation, lack of interpretation services, and culturally insensitive materials can lead to confusion, suspicion, or non-compliance. Community engagement, participatory planning, and the recruitment of local, trusted messengers have emerged as best practices to bridge these gaps and foster greater acceptance of interventions (Figueroa et al., 2021).

7.4 Misinformation and Health Communication Barriers

The COVID-19 pandemic has been accompanied by an "infodemic"—an overwhelming volume of information, including false or misleading content, particularly spread through social media and informal networks (Loomba et al., 2021). Vulnerable groups, often with lower health literacy or less access to credible sources, are at particular risk for misinformation about the virus, its transmission, prevention strategies, and the safety and efficacy of vaccines (Mackey et al., 2021; Razai et al., 2021). This can manifest as denial of the pandemic's seriousness, belief in conspiracy theories, or reliance on unproven treatments, all of which can undermine public health efforts.

Barriers to effective communication are amplified by limited internet and technology access, especially for older adults, rural residents, and the economically disadvantaged. Official channels may not reach these populations, and even when information is available, it may not be presented in accessible or actionable terms. Overcoming these challenges requires multi-pronged, trusted communication strategies, the use of diverse media (including radio, community bulletins, and mobile outreach), and the empowerment of community leaders to amplify accurate messages and counteract misinformation.

7.5 Research Needs for Future Preparedness

The COVID-19 pandemic has starkly exposed knowledge gaps and research needs that must be addressed to improve preparedness for future public health emergencies. There is a pressing need for more research on the unique risk factors, transmission dynamics, and clinical outcomes in subpopulations such as people with disabilities, those experiencing homelessness, refugees, and people living with HIV or other chronic conditions (Bibbins-Domingo, 2020; Nalbandian et al., 2021). Understanding the long-term consequences of COVID-19, including post-acute sequelae ("long COVID"), particularly in marginalized groups with multiple comorbidities, is another priority for research (Nalbandian et al., 2021).

Evaluations of public health interventions must go beyond efficacy in controlled settings to consider real-world effectiveness, acceptability, and equity. Implementation science, which focuses on translating research into practice in diverse community settings, is especially valuable for identifying and overcoming barriers to adoption of best practices (Mathur et al., 2021). Investments in inclusive, participatory research methodologies and the training of researchers from underrepresented communities will help ensure that future studies and policies address the needs of the most vulnerable. Finally, the creation of resilient, interoperable, and privacy-protecting data systems will be critical for timely surveillance and rapid response in future pandemics (World Health Organization, 2022).

8. Recommendations

To mitigate the disproportionate impact of COVID-19 on vulnerable populations, it is imperative that governments and health systems strengthen surveillance and data collection. This means investing in real-time, granular data systems that capture information on age, race, ethnicity, disability status, housing situation, and other social determinants of health. Engaging community organizations and leaders in this process will help build trust and improve the completeness and accuracy of collected data.

Preventive interventions must be both expanded and tailored to meet the needs of high-risk groups. Vaccination, testing, and the distribution of personal protective equipment should be prioritized for those most at risk, including the elderly, people with chronic illnesses, racial and ethnic minorities, and individuals living in congregate settings. Efforts to increase vaccine uptake and testing participation should include culturally and linguistically appropriate outreach, leveraging trusted community figures, mobile clinics, and flexible appointment systems to overcome logistical and informational barriers.

Policy-makers also need to enhance social and economic supports. This includes maintaining eviction moratoriums, expanding food and income assistance, and ensuring paid sick leave to reduce the economic and social harms exacerbated by the pandemic. Special initiatives should provide secure housing options for individuals who are unable to isolate safely in their current living arrangements.

Advancing health equity must be at the core of all public health policy. Addressing structural barriers such as systemic racism, discrimination, and inequitable access to healthcare and social services is essential. Investments in education, employment, and safe housing will not only support pandemic response but also improve long-term health outcomes for vulnerable communities. Building ongoing relationships with community leaders will help ensure interventions are designed and implemented in ways that are both effective and culturally respectful.

Healthcare delivery systems should continue to adapt by increasing support for telemedicine, community health workers, and mobile health units, ensuring those who cannot access traditional care are not left behind. Investments in digital infrastructure, provider and patient training, and language access services are crucial for maximizing the benefits of these innovations. Triage and resource allocation protocols should be transparent, equitable, and prioritize those at greatest risk.

Combating misinformation requires proactive, clear, and culturally relevant communication from trusted sources. Public health authorities should partner with community leaders, educators, and faith-based organizations to

disseminate accurate information and counteract myths, rumors, and vaccine hesitancy.

Finally, there is a pressing need for continued research to better understand the unique challenges faced by vulnerable groups, the long-term effects of COVID-19, and the effectiveness of public health interventions in real-world settings. Investments in implementation science, resilient data systems, and multi-sectoral collaboration will enhance preparedness for future pandemics and health emergencies.

Conclusion

The COVID-19 pandemic has laid bare the deep and persistent health inequities faced by vulnerable populations around the world. It has demonstrated that factors such as age, chronic disease, poverty, racism, and inadequate access to healthcare profoundly shape the risks and outcomes of infectious diseases. While advances in vaccine development and public health policy have saved many lives, significant challenges remain in ensuring that these benefits are equitably distributed. To truly address the impact of COVID-19 on vulnerable populations, public health efforts must adopt a holistic and equity-driven approach. This includes not only controlling the spread of the virus through robust surveillance and targeted interventions, but also addressing the underlying social determinants of health that leave certain communities more exposed and less protected. Effective solutions will depend on meaningful community engagement, transparent and inclusive policy-making, and a long-term commitment to social justice. Only by prioritizing the needs of the most at-risk and dismantling the barriers that perpetuate health disparities can we build the resilience necessary to confront future pandemics—and, ultimately, create a healthier and more equitable society for all.

Authors' Contributions
Author Contributions

The author has significantly contributed to the study's conception, design, data collection, analysis, and interpretation. All authors were involved in writing the manuscript or critically reviewing it for its intellectual value. They have reviewed and approved the final version for submission and publication and accept full responsibility for the content and integrity of the work.

Financial Support

The authors declare that no external funding was received for this study.

Conflicts of Interest

The authors state that there are no financial, personal, or professional conflicts of interest associated with this research.

Ethical Approvals

This research did not involve the use of human participants or animal subjects and therefore did not require ethical clearance

Publisher's Note

The Journal stays neutral about jurisdictional claims in published maps and institutional affiliations

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How to cite this article

Azubuike, N. C., Nonye, E. C., Victor, I. U., & Rahman, M. A. (2025). *Epidemiology of COVID-19 in vulnerable populations: A review of the risk factors, outcomes, and implications for public health*. *Microbial Science Archives, 6*(3), 60–75. https://doi.org/10.47587/MSA.2026.6301