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Review

# Socioeconomic Conditions and Severe COVID-19 Outcomes: The Role of Chronic Stress and Health Behaviors

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**Abstract:** Despite extensive research on COVID-19, few scientific contributions have explored the role of health behaviors and chronic stress and their socioeconomic determinants in exacerbating the health effects of COVID-19. This paper aims to review mechanisms and strategies that explain how socioeconomic conditions contribute to severe COVID-19 outcomes through chronic stress and biological mechanisms such as immune responses, systemic inflammation, gut microbiota dysbiosis and impaired antiviral defences. It also examines how these effects are exacerbated by unhealthy behaviors (e.g. poor diet, smoking, alcohol consumption, physical inactivity, and sleep deprivation) that are more prevalent in populations experiencing higher levels of chronic stress and living in poorer socioeconomic circumstances. A conceptual framework is proposed to explain the multiple links between policies, socioeconomic conditions, chronic stress, and the mediating effects of behavioral and biological mechanisms in exacerbating the health effects of COVID-19. Interventions to reduce the impact of these risk factors must address both individual-level behaviors and structural determinants of health. This paper highlights the importance of using complementary strategies to vaccination and prevention when tackling COVID-19, based on a syndemic approach that considers the interplay between biological, behavioral, and socioeconomic factors. Policies that reduce poverty and financial strain and improve access to basic needs such as housing, healthy food, safe jobs, education, and healthcare, while promoting healthier lifestyles by addressing their structural determinants, can significantly reduce the health burden of future pandemics such as COVID-19.

**Keywords:** socioeconomic status; COVID-19; stress; health behaviors

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## 1. Introduction

The profound impact of socioeconomic status (SES) on health outcomes has been a persistent theme in epidemiological research for decades. This association remained a relevant aspect during the recent COVID-19 pandemic [1,2]. SES is a multifaceted construct encompassing income, education, employment and access to essential resources [3], all of which significantly influence an individual's vulnerability to illness [4].

COVID-19 did not affect all populations equally. While the virus itself was the immediate cause of illness, the severity and the consequences of infection were heavily influenced by underlying health conditions, access to healthcare, and lifestyle choices, factors that are deeply shaped by SES. Individuals from lower socioeconomic backgrounds were disproportionately affected by severe complications [5].

A key factor mediating the relationship between SES and health outcomes is chronic stress. Long-term exposure to socioeconomic hardship has been shown to result in elevated cortisol levels and dysregulated stress responses levels [6,7]. Stress is triggering when individuals perceive a situation as harmful and when environmental demands exceed their resources and adaptive capacity

[8], and this condition is more common in disadvantaged populations, who face psychosocial stressors due to their social position [9]. Thus, chronic socioeconomic stress may help explain the higher rates of severe disease observed in these groups.

The World Health Organization (WHO) consistently emphasizes the existence of a social gradient in health: lower SES is associated with poorer health outcomes [10]. This implies that people with higher SES benefit from protective factors such as better healthcare, healthier lifestyles and safer living conditions, that are less accessible to those with lower SES.

Social injustice kills on a large scale [11].

These disparities are deeply embedded in the social determinants of health, which are emphasized in the Ottawa Charter for Health Promotion. The Charter outlines the fundamental conditions and resources for health such as shelter, education, food, income and social justice [12], all of which are unequally distributed and closely linked to SES.

Although the emergence of SARS-CoV-2 was sudden in terms of timing and virulence, the risk of a future pandemic had been foreseen by the scientific community [13]. Despite these warnings, many countries, were unprepared and lacked effective pandemic response strategies [14]. The outbreak, widely believed to have originated from the Huanan seafood market in Wuhan, China [15] led to the first recorded cases of pneumonia of unknown origin in December 2019 [16]. By March 2020, the WHO has declared COVID-19 a Public Health Emergency of International Concern.

The disease caused by SARS-CoV-2 termed COVID-19, exhibited a wide spectrum of severity, from mild to life-threatening [17]. Common initial symptoms included cough, fever, fatigue, myalgia, headache, ageusia, anosmia and gastrointestinal symptoms [18]. Clinical worsening often occurred 7-10 days post-symptom onset, frequently manifesting as dyspnea and hypoxemia, indicative of lung damage [19]. In the most severe cases, patients developed ARDS, septic shock, sepsis, multi-organ failure and coagulopathy [20,21]. Other complications included lymphopenia, a significant reduction in lymphocytes, [22], liver and kidney dysfunction [23], blood clotting disorders [24] and central and peripheral nervous system disorders [25]. People also experienced a multi-systemic condition with prolonged symptoms, known as Long Covid [26], which added a persistent dimension to the pandemic's impact.

Among the strongest risk factors of severe COVID-19 outcomes were age, sex and pre-existing chronic conditions such as diabetes, hypertension and obesity [27]. These comorbidities were not found randomly but were common among socioeconomically disadvantaged populations [28] further reinforcing the role of SES in shaping the course and severity of the pandemic.

To date, although the end of the health emergency has been declared, the global toll of the pandemic sees more than 7 million deaths [29], a decrease of 1.6 years in global life expectancy [30] and more than 400 million people who live in low-income countries that are at high risk from COVID-19 due to their poor socioeconomic conditions [31].

Recent studies underscore the scale of this inequality. A comprehensive review across five of the WHO's regions found that 91% of 95 studies reported significantly higher COVID-19 mortality rates in disadvantaged communities compared to wealthier ones [32]. Moreover, the global impact of the pandemic on mortality may be even more severe than official figures suggest. Estimates by *The Lancet* and *The Economist* show that the actual number of COVID-19-related deaths could be three to four times higher than reported, pointing to a substantial underestimation of the pandemic's true toll [33,34]

## 2. The Syndemic Framework

To fully understand the disproportionate impact of COVID-19 on certain populations, the concept of a 'syndemic' provides a more comprehensive framework than the conventional notion of a 'pandemic'. Coined by medical anthropologist Merrill Singer, the term blends 'synergy' with 'epidemic' to describe the interaction of multiple, co-occurring diseases within specific social, economic, and environmental contexts [35]. Unlike the biomedical model, which tends to view

diseases in isolation, the syndemic framework recognizes that illnesses do not occur independently of each other or of the broader conditions in which people live [36,37].

This perspective is particularly relevant in the context of COVID-19 where the impact of the virus was amplified by existing structural inequalities. Prevalent non-communicable diseases such as cardiovascular disease, obesity, diabetes and chronic respiratory conditions, interacted biologically with SARS-CoV-2 to produce more severe clinical outcomes. However, these conditions are not distributed randomly across populations [38].

The syndemic nature of COVID-19 became widely recognized when Richard Horton, Editor-in-Chief of *The Lancet*, stated that 'COVID-19 is not a pandemic. It's a 'syndemic', referring to the convergence of SARS-CoV-2 with non-communicable conditions [39]. These interactions between the virus, its impact on pre-existing health conditions and the socioeconomic determinants of health have amplified the severity and complexity of the pandemic's consequences [40].

Fronteira et al. [41] emphasize that responding to COVID-19 effectively requires embracing a syndemic policy framework, one that not only manages the viral infection but also addresses the burden of chronic diseases and the social conditions that shape health. This approach calls for a shift from short-term health interventions to more proactive, integrated strategies that recognize the interconnected nature of biological and social risk factors. As Singer and Mendenhall argue, the syndemic framework equips researchers and policymakers with essential tools to improve prevention, prognosis, treatment and it also supports the development of health policies that are better aligned with the realities of people's lives [42].

### 3. Psychological Stress and Socioeconomic Disadvantage

Stress, a ubiquitous feature of modern life, has been described as the 'health epidemic of the 21<sup>st</sup> century' [43]. Originally defined by Hans Selye as a non-specific response to any demand [44], contemporary understanding frames it as a complex psychobiological process triggered by perceived threat. While 'eustress' (positive stress) can motivate growth and adaptation, 'distress' (negative stress), particularly when chronic, can severely impact both mental and physical health. Selye's General Adaptation Syndrome (GAS) describes three phases of the stress response: alarm (initial reaction), resistance (adaptation), and exhaustion (depletion of resources) [45]. Chronic stress disrupts this balance, leading to maladaptation and impairing the return to homeostasis.

At the neurobiological level, stress begins in the amygdala, the brain's emotional center, which processes perceived threats and activates the hypothalamic-pituitary-adrenal (HPA) axis and sympathetic-adrenal-medullary (SAM) axis; this triggers the release of cortisol and adrenaline, triggering the 'fight-or-flight' response [46,47]. While this response is essential in acute situations, prolonged activation can lead to important consequences such as anxiety, depression, cognitive impairment, cardiovascular diseases and immune system dysregulation [48,49]. The concept of allostasis captures the dynamic physiological process of achieving stability through change [50], allostatic load reflects the cumulative toll of repeated stressors and maladaptive coping mechanisms such as poor sleep, substance use and unhealthy diet [51].

Earlier theories often emphasized the stress experienced by high-level executives or professionals due to intense pressure and responsibility [52] but more recent research has shifted this perspective. Individuals from lower socioeconomic backgrounds are disproportionately exposed to chronic psychological stressors including financial insecurity, unstable housing, low levels of education and high unemployment rates [53].

A key psychological mechanism underlying this disparity is the locus of control (LOC), the degree to which individuals believe they have control over their own lives. Disadvantaged populations tend to have less perceived control, relying on fate or other determinants of outcome while individuals with high SES have greater perceived control over events [54]. Closely related is the 'Status Syndrome' described by Michael Marmot [55], which highlights how a perceived lack of control and limited social participation – common among socioeconomically disadvantaged groups – intensifies the health consequences of stress.

These disparities became even more pronounced during the COVID-19 pandemic, which did not affect all populations equally. A CDC report found that Hispanic adults experience higher psychosocial distress due to food and housing insecurity compared to white adults. When combined with stigma and poor socioeconomic conditions, these stressors heighten chronic stress risk among racial and ethnic minorities potentially worsening both mental and physical health, including COVID-19 outcomes [56]. Furthermore, prolonged symptoms of COVID-19 have been associated with financial insecurity and unemployment, common among vulnerable populations [57]. Neighborhood environments also play an important role in shaping chronic stress exposure. Individuals living in socioeconomically disadvantaged areas facing chronic stress due to overcrowding, high crime rates, inadequate transport, infrastructure and housing experience increased COVID-19 severity [58,59]. In addition, the pandemic has underscored the significance of education and health literacy. Individuals with low levels of education may experience increased stress when confronted with complex public health communications or preventive guidelines, especially if they lack the digital tools or literacy to access and interpret such information

#### 4. Mechanisms Linking Socioeconomic Stress to Severe Covid-19 Outcomes

The adverse effects of chronic stress manifest through both direct pathways on the immune system and indirect behavioral mechanisms.

##### 3.1. Immune system

The COVID-19 pandemic has significantly increased awareness of how the body responds to viral infections, highlighting the crucial role of the immune system. Often described as a battlefield, the immune system protects the body from external threats like viruses and bacteria by maintaining internal balance or homeostasis. The immune system operates through recognition, communication and memory – identifying harmful agents, transmitting information effectively and remembering invaders for faster responses in the future. It consists of two interconnected subsystems: innate immunity which provides a rapid non-specific defense and adaptive immunity which evolves over time and remembers specific pathogens [60]. Key immune cells include neutrophils, abundant and crucial in early inflammation and T lymphocytes, essential for orchestrating immune responses and producing cytokines, proteins that help regulate immune activity. Among these, interleukin-6 (IL-6) is associated with a high perception of chronic stress [61] and has both pro and anti-inflammatory effects. Its high values are associated with increased risk of COVID-19 mortality and ICU admission [62]. Additionally, reduced type I interferon activity, which helps control viral replication and inflammation, is also linked to more severe COVID-19 cases [63].

Chronic stress, especially among socioeconomically disadvantaged individuals, can impair immune function. Research in social genomics has identified a pattern called the Conserved Transcriptional Response to Adversity (CTRA) [64] which shows increased inflammation-related gene activity and reduced antiviral defense in marginalized groups [65].

Chronic stress disrupts immune homeostasis mainly through inflammation, gut microbiota and impaired viral defenses.

##### 3.1.1. Inflammation

Inflammation is a vital immune response but when chronic, it signals immune dysregulation and worsens health outcomes. Severe COVID-19 disease is associated with a disproportionate systemic pro-inflammatory response; individuals with pre-existing chronic inflammatory processes may be susceptible to fatal outcomes due to altered immune response states that compromise the host's antiviral immune response mechanisms and/or activate hyperinflammatory responses [66]. SARS-CoV-2's entry into human cells hinges on the spike protein's high-affinity binding to ACE2, a receptor primarily located on lung, heart, artery, kidney and intestinal epithelial cells. This interaction is not merely a point of entry; it's a critical event triggering the cascade of inflammation. ACE2's role

in the renin-angiotensin system (RAS), responsible for blood pressure regulation increases, and vascular permeability [67]. The subsequent viral replication unleashes a 'cytokine storm', a surge of pro-inflammatory chemokines and cytokines that can lead to ARDS, multi organ failure, and death [68]. Moreover, a chronic low-grade inflammation is observed with increasing age with a consequent decline in immune function [69].

### 3.1.2. Gut Microbiota

Chronic stress significantly disrupts immune homeostasis, primarily by altering the composition and function of the gut microbiota [70,71]. The intestinal microbiota plays a vital role in maintaining overall health, contributing to digestion, vitamin production, immune response polarization, and pathogen preventions [72]. A healthy, balanced microbiota, known as eubiosis, support immune regulation, whereas an imbalanced state, or dysbiosis, is linked to increased inflammation and disease susceptibility.

Several factors influence microbiota composition, including diet, age, antibiotic use, and stress [73]. Stress-induced dysbiosis is closely tied to increased intestinal permeability, often referred to as 'leaky gut', which allows microbial products and pro-inflammatory molecules to enter the bloodstream and trigger systemic immune activation [74].

The interaction between the gut microbiota and the immune system is especially active at mucosal surfaces. In the intestinal mucosa, immune cells are concentrated in lymphoid structures called Peyer's patches, which serve as key sites of immune surveillance [75]. Disruption of this gut-immune balance has systematic effects – particularly through the gut-lung axis, a bidirectional communication pathway between the gastrointestinal and respiratory systems. Dysbiosis, founded in some COVID-19 patients, if persistent, it can also may impair lung immunity by altering immune cell recruitment and inflammatory responses, thereby increasing vulnerability to respiratory tract infections and contributing to prolonged or severe disease [76].

### 3.1.3. Impaired viral defenses

Chronic stress weakens the immune system, impairing its ability to fight viral infections like SARS-CoV2- This is partly due to the suppression of interferon production, crucial for viral control. Interferons, particularly type I (IFN- $\alpha$  and IFN- $\beta$ ), are essential members of the cytokine family that play a fundamental role in the activation of both the innate and adaptive immune systems [77] and are crucial for limiting viral replication and spread [78]. Chronic stress, through a high production of cortisol, inhibits T lymphocyte and NK cell production; since T lymphocytes are the main producers of interferon, this result in a diminished and impaired interferon response and reduced immune resistance to viral infections [79].

Obesity, a chronic inflammatory condition, further complicates respiratory infections by impairing lung mechanics and hindering the interferon response [80], making individuals more susceptible to severe COVID-19. Additionally, immune imbalance in COVID-19 is reflected by high neutrophil levels and low lymphocyte counts, resulting in an elevated neutrophil-to-lymphocyte ratio [81]. Neutrophils release reactive oxygen species (ROS), which, in excess, contribute to lung tissue damage, promote cytokine storms and increase the risk of thrombosis [82].

## 3.2. Lifestyle behaviors

Chronic stress, particularly among socioeconomically disadvantaged communities, can contribute to adverse outcomes from COVID-19 through unhealthy lifestyle choices. These groups face a higher risk, as socioeconomic disadvantage is associated with an increased likelihood of engaging in unhealthy behaviors [83,84]. Adherence to healthy habits like a balanced diet, healthy BMI, abstaining from smoking, moderate alcohol consumption, regular physical exercise and adequate sleep are linked to milder forms of COVID-19 and lower mortality from infectious diseases

including COVID-19 [85]. Conversely, unhealthy lifestyle behaviors increase for instance the risk of hospitalization [86].

### 3.2.1. Diet

Over 2.500 years ago, Hippocrates famously stated '*Let food be thy medicine and medicine be thy food*' [87]. This timeless wisdom highlights the fundamental role of nutrition in maintaining health and immune homeostasis. However, access to healthy food remains limited for many people globally, especially during the COVID-19 pandemic when disruptions in agriculture and food distribution increased prices, making nutritious food less affordable for those most at risk of micronutrient deficiencies and malnutrition [88]. Malnutrition is often due to lack of resources rather than personal choice.

During the COVID-19 pandemic, studies have shown the importance of following healthy diets to strengthen the immune system and prevent severe forms of infection [89]. Healthy dietary patterns, such as the Mediterranean diet, are known for their anti-inflammatory properties and ability to support immune function through nutrients like vitamins B [90] and C [91] while their deficiency, especially of vitamin D has been associated with worse COVID-19 outcomes [92]. In addition, obesity, has been consistently linked with more severe COVID-19 cases including higher risks of hospitalization, intensive care admission and mortality [93]. This trend was observed also during previous viral outbreaks such as the 2009 H1N1 [94]. Obesity disproportionately affects disadvantaged populations due to limited access to healthy environments and education, combined with increased stress levels that drive people toward unhealthy, high-calorie comfort foods [95].

### 3.2.2. Smoke and Alcohol

Individuals facing chronic stress and status anxiety often adopt these behaviors as maladaptive coping strategies. Smoking is more prevalent among socioeconomically disadvantaged groups, such as the unemployed, homeless and marginalized groups often linked to perceived stress and a lack of control [96]; the lower the status, the higher the likelihood of smoking [97]. Recent research demonstrates that smoking increases the risk of severe COVID-19 [98], need for mechanical ventilation or death [99]. E-cigarettes, initially viewed as a safer alternative, are been shown to cause significant immediate toxicity [100] and increase COVID-19 complications [101].

Similarly, excessive alcohol use, a maladaptive coping mechanism for stress, increases the risk of complicated disease progression including hospitalization, the need for ventilation [102], symptomatic COVID-19 and ICU admission [103]. In addition, chronic alcohol consumption, dysregulates innate immune response to COVID-19 infection in the lung [104].

### 3.2.3. Physical Activity

Lower socioeconomic groups exhibit low physical activity levels [105] due to factors like limited access to facilities and resources, financial barriers to sports participation, lower health literacy and higher stress levels. Regular physical activity offers numerous health benefits, including improved brain health, stronger muscles and bones, weight management and reduced risk of chronic diseases such as cardiovascular disease, type 2 diabetes mellitus and respiratory diseases [106]. Researches indicate that physical inactivity is associated with a higher risk of hospitalization, intensive care admission and death [107]. Consistently active individuals, by contrast, show a lower risk of infection and complications [108]. Exercise also enhances immune function and helps mitigate the impact of stress on immunity by influencing immune cells and particular cytokine production [109]. However, while moderate exercise supports immunity, excessive activity without rest may increase inflammation and susceptibility to infectious diseases [110].

Moreover, pre-COVID-19 research indicated that regular exercise enhances antibody responses to vaccines [111]. Recent studies suggest that this also applies to COVID-19 vaccination, with increased antibody levels observed in those regularly exercising [112].

### 3.2.4. Sleep

Adverse life conditions influenced by SES are among the many important stressors that can affect sleep [113]. Individuals from lower socioeconomic backgrounds often experience sleep disturbance due to factors like crowded housing, noise and extreme temperatures, further exacerbated by work pressures demanding longer hours. Sleep deprivation is related to changes in the innate and adaptive immune system and is linked with various chronic diseases such as diabetes, by promoting chronic and systemic inflammation [114]. This is evidenced by a correlation between poor sleep and more severe COVID-19 cases, requiring intensive care and longer hospital stays [115]. Additionally, several sleep disorders such as sleep apnea are considered risk factors for severe COVID-19; it has been shown a correlation between sleep apnea and an increased risk of more severe disease, mortality, need for mechanical ventilation and admission to intensive care [116].

Sleep habits may also change with age. In older adults, a reduction in deep sleep with increased fragmentation and frequent awakenings can be observed. Older adults with pre-existing sleep disorders are more likely to have a worse prognosis when affected by SARS-CoV-2 [117].

The relationship between socioeconomic stress and lifestyle is cyclical. Socioeconomic disadvantages lead to chronic stress, which in turn promotes unhealthy behaviors. These behaviors further compromise health, increasing vulnerability to severe COVID-19 and other health problems perpetuating the cycle of disadvantage.

## 5. Mitigating Socioeconomic Stress to Improve Pandemic Preparedness

COVID-19 is not our first global pandemic, nor will it be the last. It starkly revealed the profound impact of socioeconomic disparities on health outcomes. The lack of fundamental resources such as food availability, education, access to health care, safe and affordable housing and employment opportunities in disadvantaged communities leads to a higher probability of hospitalizations and deaths [118]. This disparity is not simply a matter of chance; it's a consequence of the chronic stress associated with poverty, lack of access to resources, and systematic inequalities. Addressing this requires a multi-pronged approach focusing on both lifestyle interventions and direct actions to alleviate socioeconomic stressors.

Lifestyle interventions are crucial, but their effectiveness is significantly hampered by the very conditions that create vulnerability. While promoting healthy diets, regular exercise and smoking cessation is essential [119], these interventions must be tailored to the specific challenges faced by disadvantaged communities. Simply providing information is insufficient; access to affordable, nutritious food, safe spaces for physical activity and support for quitting smoking are all necessary components. Community-based initiatives such as collaborating with local businesses to improve access to healthy food options and creating safe, accessible green spaces are vital. Policy interventions, such as taxing unhealthy foods and subsidizing healthy ones, can also play a significant role [120]. Furthermore, effective communication strategies are needed, personalized messages delivered through appropriate channels and considering the peer support effect [121]. These interventions must acknowledge and address the structural barriers that prevent individuals from adopting healthier lifestyles.

Beyond lifestyle changes, directly tackling socioeconomic stress is paramount. Psychological intervention such as cognitive-behavioral therapy [122] and mindfulness-based stress reduction can equip individuals with coping mechanisms [123]. However these interventions should not overshadow the need to address the root causes of chronic stress; initiatives like 'Mobility Mentoring' which focus on empowering individuals to take control of their lives [6], are promising but they must be complemented by broader societal changes.

Education is a fundamental social determinant of health. Higher education levels correlate with better health outcomes, improved health literacy and increased access to resources [124]. Addressing educational inequalities through increased access to quality education and health literacy programs is crucial. Highly educated people are likely to have higher levels of health literacy [125], which is important in the spread of misinformation during the pandemic [126] because socioeconomically

disadvantaged individuals with lower levels of education are more susceptible to misinformation, supported by lower COVID-19 vaccination rates among communities with low levels of education [127].

Income and employment are also key factors. Many low-income individuals work in essential, often demanding jobs with limited protection. Providing paid sick leave is vital to prevent workers from facing financial hardship when they are ill, thus encouraging them to stay home and prevent further spread. Raising the minimum wage can improve overall health outcomes by increasing access to resources and reducing financial stress [128]. In fact, in addressing the socioeconomic crisis triggered by COVID-19, targeted social protection initiatives such as expanding guaranteed minimum income programs and creating dedicated relief funds have been essential; these efforts can be financed through progressive taxation [129].

Access to affordable healthcare is another critical aspect and it is essential to promote healthy living and prevent diseases [130]. High healthcare costs create barriers to care, particularly for those in need. Ensuring equitable access to preventive and treatment services including COVID-19 vaccination, is essential. This requires addressing systemic inequalities in healthcare access and affordability. International cooperation is also vital. The equitable distribution of resources, including vaccines, is crucial for global health security. If vaccines had been shared more equitably with low-income countries in 2021, more than one million lives could have been saved [131]. Initiatives like the UN's 2030 Agenda for Sustainable Development, while ambitious, provide a framework for addressing global inequalities and promoting sustainable development. None of us are truly prepared unless all of us are prepared in the pursuit of global health security and resilience against future crises [132].

Since economic, political, cultural, social, environmental and behavioral factors can promote health or be harmful to it; the syndemic approach aims to investigate precisely this and arises from the need to highlight a systemic and holistic vision going beyond mere healthcare in the fight against diseases. This concept would seem to embrace the often mentioned One Health approach, defined as a 'silver bullet' solution to challenges such as COVID-19 [133]. A Structural One Health approach, by Rob Wallace is closer to the syndemic concept because unlike the biomedical model, this approach examines disease by considering all living organisms such as humans, animals and plants, while also accounting for local histories, cultures and economies that influence how diseases emerge. Neoliberal policies which emphasize privatization, market-driven healthcare and reduced public spending, have exacerbated social and economic inequalities, undermining public health systems and worsening the impact of health crises on vulnerable communities [134]

Without addressing the root causes of health disparities, interventions will remain insufficient to protect vulnerable populations from future health crises. This perspective is reinforced by recent research highlighting how neoliberal models, environmental degradation and structural inequalities have jointly fueled both the COVID-19 pandemic and the ecological crisis, emphasizing the need for a more systemic, structural approach to public health.[135].

## 5. Conclusions

The COVID-19 pandemic highlighted the profound impact of socioeconomic stress on health outcomes. Chronic stress, a consequence of persistent socioeconomic disadvantage, acts as a key mediator, exacerbating the severity of COVID-19 through its effects on the immune system and lifestyle choices. Addressing this syndemic requires a comprehensive approach that targets both lifestyle factors and socioeconomic inequalities. Future pandemic preparedness must prioritize equity and social justice to ensure that all populations have equal access to resources and opportunities for health and well-being. Further research is needed to refine our understanding of the complex interplay between socioeconomic stress, immune function and COVID-19 outcomes, informing the development of more effective interventions.

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## Abbreviations

The following abbreviations are used in this manuscript:

SES	Socioeconomic Status
WHO	World Health Organization
GAS	General Adaptation Syndrome
HPA	Hypothalamic-pituitary-adrenal
SAM	Sympathetic-adrenal-medullary
LOC	Locus of Control
CDC	Centers for Disease Control and Prevention
IL-6	Interleukin-6
ICU	Intensive care unit
CTRA	Conserved Transcriptional Response to Adversity
ACE	Angiotensin-converting enzyme
RAS	Renin-angiotensin system
IFN	Interferon
NK	Natural killer
ROS	Reactive oxygen species
BMI	Body Mass Index

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