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CHANGES IN LIFE EXPECTANCY AT BIRTH DURING THE COVID-19 PANDEMIC: A GLOBAL, REGIONAL, AND COUNTRY-LEVEL INTEGRATIVE REVIEW OF TRENDS, DETERMINANTS, AND PUBLIC HEALTH IMPLICATIONS

Dr. R.Ganesan*

Professor, Dept. of Pediatric Nursing, College of Nursing, Chengalpattu Govt. Medical College, Chengalpattu, Tamil Nadu, India.

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Corresponding Author
Dr. Ganesan R

Email: abiganesh68@gmail.com

ABSTRACT

The COVID-19 pandemic has exerted a profound and unprecedented impact on global mortality patterns, resulting in significant changes in life expectancy at birth across countries and regions. This integrative review synthesizes evidence from global, regional, and country-level studies to examine the magnitude, trends, and determinants of life expectancy changes during the pandemic. The findings reveal substantial declines in life expectancy in many parts of the world, reversing years of steady progress in population health. These reductions were primarily driven by excess mortality associated with COVID-19, particularly among older adults and individuals with comorbidities, as well as indirect effects such as disruptions to healthcare services, delayed treatment of chronic conditions, and socioeconomic instability. Considerable heterogeneity was observed across regions and countries, reflecting differences in demographic structures, healthcare system capacity, public health responses, and vaccine coverage. High-income countries experienced notable declines despite advanced healthcare infrastructure, while low- and middle-income countries faced compounded challenges due to limited resources and inequitable access to healthcare and vaccines. The review also highlights demographic disparities, with marginalized populations disproportionately affected. Methodological approaches, including life table analysis and excess mortality models, provided critical insights but were constrained by data limitations and reporting inconsistencies. Public health interventions and vaccination campaigns played a crucial role in mitigating mortality and facilitating partial recovery in life expectancy in some settings. The findings underscore the importance of resilient health systems, robust data infrastructure, and equitable global health strategies. This review provides comprehensive insights into the pandemic's impact on life expectancy and offers evidence-based implications for strengthening preparedness, policy planning, and health system resilience in future global health emergencies.

Key words: Life expectancy, COVID-19, Global health, Mortality trends

INTRODUCTION

Life expectancy at birth is a fundamental indicator of population health, reflecting the cumulative impact of mortality patterns, healthcare access, socioeconomic conditions, and public health interventions across the lifespan. Over recent decades, steady improvements in life expectancy have been observed globally due to advancements in medical science, disease prevention, sanitation, and economic development.

However, the emergence of the COVID-19 pandemic in late 2019, caused by the novel coronavirus SARS-CoV-2, profoundly disrupted these gains and triggered an unprecedented global health crisis.[1] The pandemic resulted in widespread morbidity and mortality, overwhelming healthcare systems, disrupting essential health services, and exposing deep-seated inequalities within and between countries. As a consequence, many nations experienced significant declines in life expectancy at birth, reversing years or even decades of progress. These changes were not uniform; rather, they varied considerably across regions and countries depending on factors such as the severity of infection waves, public health responses, healthcare infrastructure, demographic composition, and socioeconomic resilience. High-income countries with advanced healthcare systems were not immune, often experiencing substantial reductions in life expectancy due to high infection rates among vulnerable populations, particularly the elderly and those with comorbidities[2]. Conversely, some low- and middle-income countries demonstrated resilience in early phases but later faced severe impacts due to limited healthcare resources, delayed vaccination rollout, and challenges in implementing effective containment measures. Beyond direct mortality caused by COVID-19, indirect effects such as delayed diagnosis and treatment of non-communicable diseases, reduced access to maternal and child health services, mental health crises, and socioeconomic disruptions further contributed to excess mortality. Moreover, disparities based on age, gender, ethnicity, and socioeconomic status became increasingly evident, highlighting the unequal burden of the pandemic. Given the complexity and global scale of these changes, there is a critical need to synthesize evidence from diverse studies to better understand the magnitude, patterns, and determinants of life expectancy shifts during the pandemic[3,4]. This integrative review aims to consolidate findings from global, regional, and country-level research to provide a comprehensive assessment of how life expectancy at birth has been affected by COVID-19. By examining variations across populations, identifying key contributing factors, and evaluating methodological approaches used in existing studies, this review seeks to generate insights that can inform future public health strategies, strengthen health system preparedness, and guide policy interventions aimed at mitigating the long-term consequences of the pandemic on population health.

Overview of the COVID-19 Pandemic and Global Health Impact

The coronavirus disease 2019 (COVID-19) pandemic represents one of the most significant global health emergencies of the 21st century, profoundly affecting health systems, economies, and societies worldwide. First identified in late 2019 in Wuhan, China, COVID-19 is caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), a highly transmissible pathogen capable of causing a wide spectrum of clinical manifestations ranging from asymptomatic infection to severe respiratory failure and death. Within a few months, the rapid international spread of the virus prompted the World Health Organization to declare COVID-19 a pandemic in March 2020, marking the beginning of an unprecedented global response involving public health interventions, clinical management strategies, and research efforts. The pandemic led to millions of confirmed cases and deaths worldwide, exerting immense pressure on healthcare systems, particularly during successive waves driven by emerging variants of concern such as Alpha, Delta, and Omicron. Hospitals in many countries experienced critical shortages of beds, oxygen supplies, essential medicines, and healthcare personnel, revealing structural vulnerabilities in health infrastructure and emergency preparedness. Beyond its direct health effects, COVID-19 significantly disrupted routine healthcare services, including immunization programs, maternal and child health services, and the management of chronic diseases, thereby contributing to indirect morbidity and mortality.[5] The global health impact was further compounded by socioeconomic consequences, including widespread unemployment, poverty, educational disruptions, and mental health challenges, disproportionately affecting vulnerable and marginalized populations. Public health measures such as lockdowns, social distancing, travel restrictions, mask mandates, and mass vaccination campaigns were implemented to curb transmission, with varying degrees of success across different regions. While the rapid development and deployment of vaccines provided a critical tool in reducing severe disease and mortality, inequitable access to vaccines highlighted stark global disparities between high-income and low- and middle-income countries[6]. Additionally, the pandemic exposed underlying health inequities related to age, gender, socioeconomic status, and comorbid conditions, which influenced both susceptibility to infection and clinical outcomes. The long-term health implications of COVID-19, including post-acute sequelae or “long COVID,” continue to pose challenges for healthcare systems and policy planning. Collectively, the COVID-19 pandemic has reshaped global health priorities, underscored the importance of resilient health systems, and emphasized the need for coordinated international responses to emerging infectious diseases.

Global Trends in Life Expectancy During COVID-19

The COVID-19 pandemic has had a profound and unprecedented impact on global mortality patterns, leading to notable shifts in life expectancy at birth across many countries and regions. Prior to the pandemic, life expectancy had been steadily increasing worldwide due to improvements in healthcare, disease prevention, nutrition, and socioeconomic development. However, the emergence of COVID-19 in 2019 and its rapid global spread resulted in a sharp rise in mortality, reversing years of progress within a short period. Global trends indicate that life expectancy declined significantly in numerous countries during 2020 and 2021, with some nations experiencing the largest single-year reductions since major historical events such as world wars or previous pandemics. These declines were primarily driven by excess mortality associated with COVID-19, particularly among older adults and individuals with underlying health conditions, although younger populations were also affected in certain regions.[1,7] High-income countries, including those in North America and Europe, recorded substantial reductions in life expectancy due to high infection rates, aging populations, and initial challenges in pandemic containment. In contrast, some low- and middle-income countries initially reported smaller declines, partly due to younger population structures and potential underreporting of deaths, but later experienced significant impacts as healthcare systems became overwhelmed. The magnitude and pattern of life expectancy changes varied widely across regions, reflecting differences in public health responses, healthcare infrastructure, timing of infection waves, and access to vaccines[8,9]. Countries that implemented early and stringent control measures, such as widespread testing, contact tracing, and mobility restrictions, were relatively more successful in mitigating mortality and preserving life expectancy. Conversely, regions with delayed responses, limited healthcare resources, or high levels of social inequality experienced greater mortality burdens. In addition to direct COVID-19 deaths, indirect effects—including disruptions to routine healthcare services, delayed treatment of chronic diseases, mental health crises, and socioeconomic stressors—contributed to excess mortality and further influenced life expectancy trends. The pandemic also exposed and amplified existing disparities, with marginalized populations often experiencing greater reductions in life expectancy due to unequal access to healthcare and higher exposure risks. As vaccination campaigns expanded globally, some countries began to observe partial recovery in life expectancy; however, the extent of recovery has been uneven and remains uncertain due to the continued circulation of new variants and long-term health consequences.[10] Overall, global trends in life expectancy during the COVID-19 pandemic highlight the vulnerability of population health gains to large-scale health crises and underscore the importance of resilient health systems, equitable healthcare access, and effective public health interventions in safeguarding long-term demographic progress.

Regional Variations in Life Expectancy Changes

The impact of the COVID-19 pandemic on life expectancy at birth has not been uniform across the globe, with significant regional variations reflecting differences in demographic structures, healthcare capacity, public health responses, and socioeconomic conditions. Prior to the pandemic, many regions were experiencing gradual improvements in life expectancy; however, the onset of COVID-19 disrupted these trends in diverse ways. Europe and North America recorded some of the most pronounced declines in life expectancy, particularly during the initial waves of 2020 and 2021, driven by high transmission rates, aging populations, and substantial mortality among older adults and individuals with pre-existing conditions.[1,7] In contrast, several countries in East Asia and Oceania demonstrated relatively smaller reductions or maintained stable life expectancy levels, largely due to early implementation of stringent containment measures, effective testing and contact tracing systems, and strong public compliance with preventive strategies. Latin America and the Caribbean experienced severe declines in life expectancy, reflecting a combination of high infection rates, socioeconomic inequalities, urban crowding, and limited healthcare resources, which collectively amplified the mortality burden. Similarly, parts of South Asia and Sub-Saharan Africa showed variable patterns; while some countries initially reported modest changes due to younger population demographics, subsequent waves exposed vulnerabilities such as limited healthcare infrastructure, under-resourced health systems, and challenges in data reporting, leading to underestimation or delayed recognition of life expectancy declines. The Middle East and North Africa region exhibited mixed outcomes, influenced by differences in economic capacity, health system preparedness, and political stability. Vaccine distribution further contributed to regional disparities, with high-income regions achieving earlier and broader vaccine coverage, thereby reducing mortality in later stages of the pandemic, while low- and middle-income regions faced delays and inequities in access, prolonging adverse impacts on life expectancy. Additionally, variations in excess mortality reporting, differences in cause-of-death classification, and the availability of reliable demographic data have influenced regional assessments of life expectancy changes.[11] Indirect effects, including disruptions to essential health services,

economic downturns, and social determinants of health, also varied across regions and contributed to differing mortality patterns. These regional variations underscore the complex interplay of epidemiological, health system, and socioeconomic factors in shaping life expectancy outcomes during the pandemic. Understanding these differences is critical for identifying context-specific strategies, strengthening regional health resilience, and informing targeted policy interventions aimed at mitigating the long-term demographic and health consequences of COVID-19.

Table 1: Global and Regional Patterns in Life Expectancy Changes During the COVID-19 Pandemic

Region/Setting	General Trend in Life Expectancy	Major Contributing Factors	Key Observations	Public Health Implication
North America	Marked decline	High COVID-19 mortality, comorbidities, health inequities	Large losses in life expectancy, especially in vulnerable groups	Need for equity-focused health interventions
Europe	Significant decline	Aging population, severe early waves, healthcare strain	Major reversals in mortality gains in several countries	Strengthen emergency preparedness and elderly care
Latin America and Caribbean	Severe decline	Urban crowding, inequality, limited health resources	High excess mortality and prolonged recovery	Improve health system resilience and access
East Asia and Oceania	Minimal decline or relative stability	Early containment, testing, tracing, compliance	Better preservation of life expectancy in some countries	Importance of rapid coordinated response
South Asia	Variable decline	Overwhelmed health services, delayed vaccination, dense population	Heterogeneous country-level outcomes	Expand public health infrastructure and surveillance
Sub-Saharan Africa	Underestimated or variable decline	Weak mortality data, limited healthcare capacity, younger population	Possible underreporting of mortality burden	Strengthen CRVS systems and emergency response

Country-Level Evidence and Comparative Analysis

Country-level analyses of life expectancy changes during the COVID-19 pandemic provide critical insights into the heterogeneous impact of the crisis and highlight the influence of national policies, healthcare capacity, demographic composition, and socioeconomic resilience on mortality outcomes. Evidence from high-income countries such as the United States, the United Kingdom, Italy, and Spain demonstrates substantial declines in life expectancy during 2020 and 2021, largely driven by high infection rates, significant mortality among older adults, and the presence of comorbid conditions[12]. In the United States, for instance, life expectancy experienced one of the sharpest declines in recent history, with disproportionate effects observed among minority populations, reflecting longstanding health inequities and differential access to healthcare. Similarly, European countries faced severe early waves, with variations in outcomes depending on the timing and stringency of public health interventions, including lockdowns and healthcare system preparedness. In contrast, countries such as Japan, South Korea, and New Zealand exhibited relatively stable or minimal reductions in life expectancy, attributed to early containment measures, strong public health infrastructure, effective risk communication, and high levels of community compliance. Low- and middle-income countries presented a more complex picture; while some initially reported smaller declines due to younger population structures, countries like Brazil, India, and South Africa later experienced significant mortality surges as healthcare systems became overwhelmed and pandemic waves intensified.[9,10,12,13] Variations in

testing capacity, reporting accuracy, and death registration systems also influenced the reliability of country-level estimates, with underreporting potentially masking the true extent of life expectancy reductions in several regions. Comparative analysis reveals that countries with robust primary healthcare systems, universal health coverage, and rapid policy responses were better able to mitigate mortality impacts, whereas those with fragmented healthcare systems and delayed interventions experienced greater losses. Additionally, vaccination rollout emerged as a key determinant in later phases of the pandemic, with countries achieving high vaccine coverage demonstrating reduced mortality and signs of recovery in life expectancy trends. Socioeconomic factors, including income inequality, urban density, occupational exposure, and access to social protection measures, further contributed to differences in outcomes between countries. Indirect effects, such as disruptions in routine healthcare services and economic instability, also varied across national contexts, influencing excess mortality beyond direct COVID-19 deaths. Overall, country-level evidence underscores the importance of context-specific responses and highlights how policy decisions, healthcare system strength, and social determinants collectively shaped life expectancy trajectories during the COVID-19 pandemic, offering valuable lessons for future global health emergencies.

Impact of Healthcare System Disruptions

The COVID-19 pandemic caused widespread disruptions to healthcare systems globally, significantly influencing mortality patterns and contributing to declines in life expectancy at birth. As healthcare resources were rapidly reallocated to manage the surge of COVID-19 cases, routine medical services were often postponed, reduced, or temporarily suspended, leading to delays in diagnosis, treatment, and preventive care. Hospitals in many countries faced unprecedented strain due to increased patient admissions, shortages of intensive care unit beds, ventilators, oxygen supplies, and essential medicines, as well as burnout and infection among healthcare workers.[14] This strain compromised the capacity of health systems to deliver timely and effective care not only for COVID-19 patients but also for individuals with non-communicable diseases such as cardiovascular disorders, cancer, diabetes, and chronic respiratory conditions. Interruptions in elective surgeries, cancer screening programs, and follow-up care resulted in disease progression and increased mortality risk. Similarly, disruptions to maternal and child health services, including antenatal care, immunization programs, and nutritional support, posed serious threats to vulnerable populations, particularly in low- and middle-income countries. Mental health services were also affected, with increased prevalence of anxiety, depression, and substance use disorders compounded by reduced access to care. In addition, fear of infection and mobility restrictions discouraged individuals from seeking healthcare services, leading to underutilization of available facilities and worsening health outcomes.[15,16] The reallocation of public health resources toward pandemic control further weakened surveillance and management of other infectious diseases, increasing the risk of outbreaks of conditions such as tuberculosis, malaria, and vaccine-preventable diseases. Healthcare supply chains were disrupted due to global lockdowns and transportation restrictions, resulting in shortages of medications, diagnostic tools, and personal protective equipment. These systemic disruptions disproportionately affected marginalized and underserved populations, exacerbating existing health inequities and contributing to higher excess mortality. Countries with already fragile healthcare systems experienced more severe consequences, while those with resilient and well-integrated systems were better able to adapt through strategies such as telemedicine, task shifting, and decentralized care delivery.[17] Overall, the disruption of healthcare services during the COVID-19 pandemic played a critical role in increasing both direct and indirect mortality, thereby significantly influencing life expectancy trends and highlighting the urgent need for strengthening health system resilience, continuity of care, and preparedness for future global health emergencies.

Role of Public Health Interventions and Vaccination

Public health interventions and vaccination played a pivotal role in shaping the trajectory of the COVID-19 pandemic and its impact on mortality and life expectancy at birth across the globe. In the absence of immediate pharmaceutical solutions during the early stages of the pandemic, non-pharmaceutical interventions such as lockdowns, social distancing, mask mandates, travel restrictions, quarantine measures, and widespread testing and contact tracing were implemented to reduce viral transmission and prevent healthcare system overload. The effectiveness of these interventions varied across countries depending on the timing of implementation, public adherence, governance structures, and communication strategies[18,19]. Countries that acted swiftly with coordinated and evidence-based measures were generally more successful in flattening the epidemic curve, reducing infection rates, and limiting excess mortality, thereby mitigating declines in life expectancy. However, prolonged restrictions also had socioeconomic and psychological consequences, necessitating a balance between disease control and societal functioning. The development and deployment of COVID-19 vaccines marked a turning point in the global response to the

pandemic. Within an unprecedented timeframe, multiple vaccines were developed, tested, and authorized for emergency use, demonstrating high efficacy in preventing severe disease, hospitalization, and death. Mass vaccination campaigns became central to public health strategies, particularly in reducing mortality among high-risk populations such as older adults and individuals with comorbidities. Countries with rapid and widespread vaccine rollout experienced significant reductions in COVID-19-related deaths and began to observe stabilization or partial recovery in life expectancy trends.[20] In contrast, disparities in vaccine access and distribution between high-income and low- and middle-income countries contributed to unequal health outcomes, prolonging the pandemic's impact in resource-limited settings. Vaccine hesitancy, misinformation, logistical challenges, and supply constraints further influenced the effectiveness of vaccination programs. Additionally, booster doses and the adaptation of vaccines to emerging variants became important considerations in sustaining immunity and preventing subsequent waves of infection. Public health interventions also evolved over time, incorporating digital tools such as mobile health applications, surveillance systems, and telehealth services to enhance response capacity. Community engagement, risk communication, and trust in public health authorities played crucial roles in determining the success of both interventions and vaccination efforts. Overall, the combined impact of non-pharmaceutical interventions and vaccination significantly influenced mortality patterns during the COVID-19 pandemic, highlighting their critical importance in protecting population health, reducing excess deaths, and ultimately shaping changes in life expectancy at birth across different regions and countries.[21,22]

Table 2: Determinants Influencing Changes in Life Expectancy During the COVID-19 Pandemic

Determinant	Mechanism of Influence on Life Expectancy	Examples of Impact During Pandemic	Overall Effect
Direct COVID-19 mortality	Increased deaths across age groups, especially elderly	Severe waves of infection, ICU admissions, respiratory failure	Reduced life expectancy
Healthcare system disruptions	Delayed diagnosis and treatment of other diseases	Interrupted cancer care, cardiovascular treatment, maternal services	Increased indirect mortality
Demographic structure	Older populations faced higher mortality risk	High-income countries with aging populations showed greater losses	Amplified mortality burden
Public health interventions	Reduced viral spread and healthcare overload	Lockdowns, masking, testing, isolation, contact tracing	Helped preserve life expectancy
Vaccination coverage	Lowered severe disease and death rates	Early rollout in some countries led to partial recovery	Improved mortality outcomes
Socioeconomic inequality	Increased exposure, reduced healthcare access, poor living conditions	Marginalized populations had higher mortality	Widened disparities
Data quality and reporting systems	Affected accuracy of mortality estimation	Underreporting in low-resource settings	Limited precise assessment

Statistical Models and Data Sources Used in Studies

The assessment of changes in life expectancy at birth during the COVID-19 pandemic has relied heavily on robust statistical models and diverse data sources to accurately estimate mortality patterns and quantify excess deaths across populations. Given the unprecedented nature of the pandemic and the variability in reporting systems, researchers have employed a range of demographic and epidemiological methods to derive reliable estimates. Life table analysis remains the cornerstone approach, enabling the calculation of life expectancy by incorporating age-specific mortality rates derived from observed or estimated death counts. To account for the rapid fluctuations in mortality during the pandemic, many studies utilized excess mortality models, which compare observed deaths during the pandemic period with expected deaths based on historical trends[8]. These models often incorporate time-series analyses, such as autoregressive integrated moving average (ARIMA) models and Poisson regression, to project baseline mortality and identify deviations attributable to COVID-19. Bayesian hierarchical models have also been widely

used to adjust for uncertainty, underreporting, and incomplete data, particularly in regions with weak vital registration systems. Additionally, cause-deleted life tables and decomposition methods have been applied to isolate the contribution of COVID-19 and other causes of death to changes in life expectancy. Data sources used in these studies are diverse and include national civil registration and vital statistics (CRVS) systems, which provide official records of births and deaths, as well as international databases such as those maintained by the World Health Organization, the United Nations, and the Human Mortality Database.[23,24] Many researchers have also relied on real-time surveillance data, hospital records, and excess mortality datasets compiled by global research collaborations. In countries with limited data availability, indirect estimation techniques and model-based adjustments have been employed to compensate for underreporting and delays in death registration. Furthermore, stratified analyses by age, sex, and region have been conducted to better understand demographic differentials in mortality impact. Despite these methodological advancements, challenges such as inconsistencies in cause-of-death classification, variations in testing capacity, and delays in data reporting have required careful interpretation of results. Sensitivity analyses and cross-validation across multiple data sources have been used to enhance the robustness of findings. Overall, the integration of advanced statistical models with diverse and often imperfect data sources has been essential for generating credible estimates of life expectancy changes during the COVID-19 pandemic, enabling researchers and policymakers to better understand its demographic impact and inform evidence-based public health responses.

Challenges and Limitations in Measuring Life Expectancy Changes

Measuring changes in life expectancy at birth during the COVID-19 pandemic presents several methodological and practical challenges that can affect the accuracy, comparability, and interpretation of findings across studies. One of the primary limitations arises from the quality and completeness of mortality data, particularly in countries with weak civil registration and vital statistics systems, where underreporting of deaths and delays in death registration are common. In many low- and middle-income countries, a substantial proportion of deaths occur outside formal healthcare settings and may not be systematically recorded, leading to underestimation of mortality and biased life expectancy calculations[25]. Even in high-income settings, discrepancies in cause-of-death classification and reporting practices, especially during the early stages of the pandemic, created inconsistencies in attributing deaths directly to COVID-19 versus underlying comorbidities. Another significant challenge is the reliance on provisional or incomplete data, which are often subject to revision as more accurate information becomes available, thereby affecting the stability of life expectancy estimates. The use of excess mortality as a proxy for pandemic impact, while valuable, also introduces uncertainty due to variations in baseline mortality estimation methods and the influence of external factors such as seasonal variations, environmental conditions, and concurrent health crises. Additionally, differences in statistical modeling approaches, including the choice of life table construction, smoothing techniques, and adjustment for age-specific mortality, can lead to variability in results across studies[26]. Population heterogeneity further complicates measurement, as life expectancy changes are not evenly distributed across age groups, genders, or socioeconomic strata, yet aggregated national estimates may mask these disparities. Migration patterns during the pandemic, including internal displacement and reduced international mobility, can also distort population denominators used in life expectancy calculations. Furthermore, indirect effects of the pandemic, such as disruptions in healthcare services, economic stress, and behavioral changes, contribute to mortality in ways that are difficult to disentangle from direct COVID-19 deaths. The dynamic and evolving nature of the pandemic, with multiple waves and emerging variants, adds temporal complexity to measurement, making it challenging to determine whether observed changes are temporary fluctuations or indicative of long-term trends. Data comparability across countries is also limited by differences in testing capacity, surveillance systems, and public health reporting standards[27]. Overall, these challenges highlight the need for cautious interpretation of life expectancy estimates during the COVID-19 period and underscore the importance of improving data systems, standardizing methodologies, and incorporating uncertainty analyses to enhance the reliability and comparability of findings.

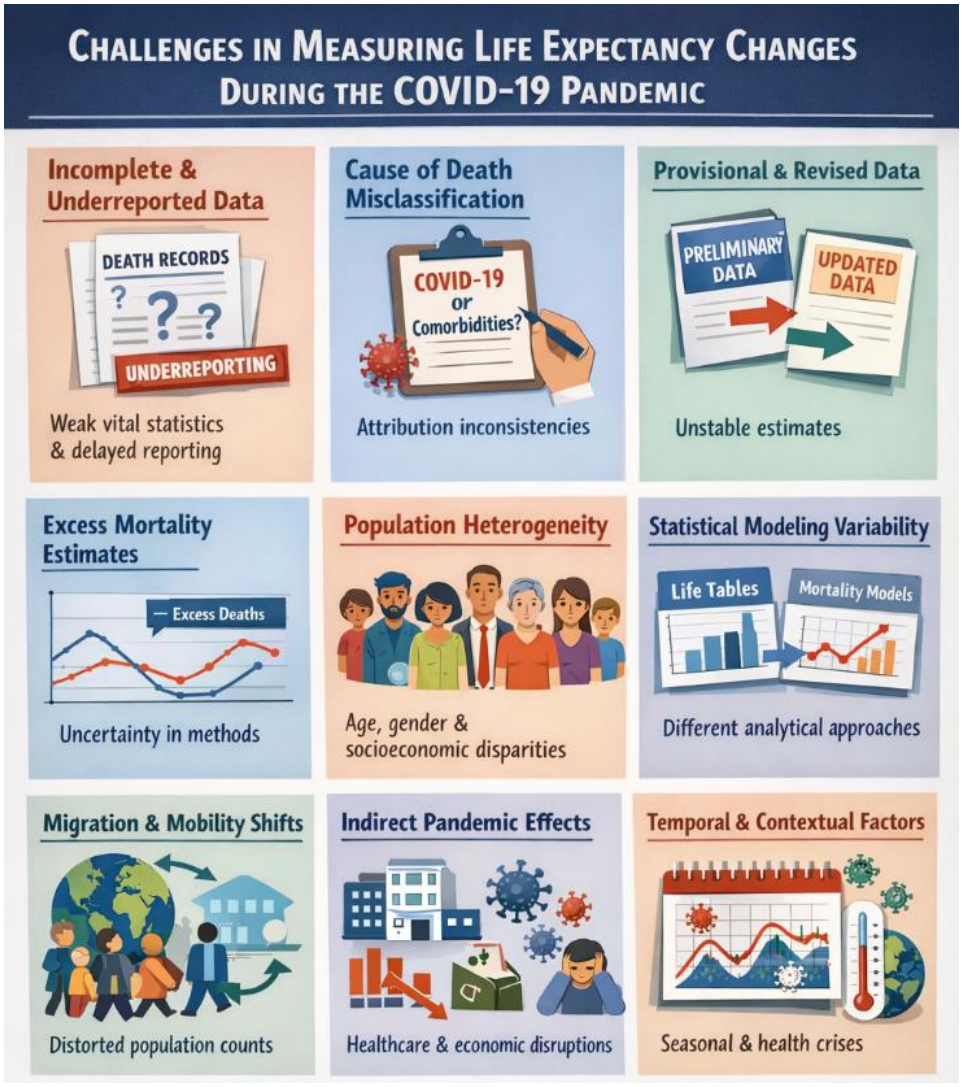

Figure:1 Challenges and Limitations in Measuring Life Expectancy Changes

Implications for Global Health Policy and Planning

The observed changes in life expectancy at birth during the COVID-19 pandemic carry profound implications for global health policy and planning, underscoring the urgent need for resilient, equitable, and adaptive health systems capable of responding to large-scale public health emergencies. The widespread declines in life expectancy, particularly in regions heavily affected by excess mortality, highlight vulnerabilities in healthcare infrastructure, emergency preparedness, and disease surveillance systems, necessitating comprehensive reforms at national and international levels. Policymakers must prioritize strengthening primary healthcare systems, ensuring universal health coverage, and enhancing surge capacity to manage both routine care and crisis situations simultaneously[1,28]. The pandemic has also emphasized the importance of robust civil registration and vital statistics systems for accurate and timely mortality data, which are essential for informed decision-making and resource allocation. Addressing health inequities must be a central component of future policy frameworks, as marginalized populations experienced disproportionate declines in life expectancy due to limited access to healthcare, higher exposure risks, and socioeconomic disadvantages. Strategies aimed at reducing these disparities should include targeted interventions, improved access to essential services, and the integration of social determinants of health into policy planning. Furthermore, the role of global cooperation has become increasingly evident, as coordinated international responses, data sharing, and equitable distribution of medical resources—particularly vaccines—are critical in managing transnational health threats. Investment in public health infrastructure, including workforce

development, digital health technologies, and research capacity, is essential to enhance preparedness and response capabilities. The pandemic has also demonstrated the need for flexible and evidence-based policymaking that can rapidly adapt to evolving epidemiological conditions, incorporating real-time data and predictive modeling to guide interventions. In addition, integrating pandemic preparedness into broader health and development agendas will be crucial for achieving long-term sustainability and resilience. Health systems must also be designed to maintain continuity of essential services during crises, minimizing indirect mortality and preserving population health gains. The experience of COVID-19 further calls for strengthening risk communication strategies and community engagement to build public trust and ensure compliance with health interventions. Ultimately, the impact of the pandemic on life expectancy serves as a critical reminder that health security is integral to social and economic stability, and that proactive, inclusive, and well-coordinated policy approaches are necessary to safeguard global health and mitigate the consequences of future pandemics.

Future Directions and Research Gaps

The COVID-19 pandemic has exposed critical gaps in knowledge and methodological approaches related to the measurement and interpretation of life expectancy changes, thereby highlighting several important directions for future research. One of the foremost priorities is the strengthening of global mortality surveillance systems, particularly in low- and middle-income countries where data incompleteness and underreporting remain significant challenges. Future studies should focus on improving the accuracy, timeliness, and standardization of civil registration and vital statistics systems to enable more reliable cross-country comparisons and real-time monitoring of mortality trends.[29] There is also a need to develop and refine advanced statistical models that can better account for uncertainties, reporting delays, and variations in cause-of-death classification, including the integration of machine learning and artificial intelligence techniques to enhance predictive accuracy. Longitudinal research is essential to assess the long-term effects of the pandemic on life expectancy, including the potential persistence of mortality shifts due to post-acute sequelae of COVID-19, commonly referred to as long COVID, as well as the indirect consequences of disrupted healthcare services and socioeconomic instability. Additionally, more granular analyses are required to understand disparities across subpopulations, including differences based on age, gender, ethnicity, geographic location, and socioeconomic status, as aggregate national estimates often obscure important inequities. Future research should also explore the interaction between COVID-19 and pre-existing health conditions, particularly non-communicable diseases, to better understand their combined impact on mortality and life expectancy. Comparative studies examining the effectiveness of different public health strategies, healthcare system responses, and vaccination policies across countries can provide valuable insights into best practices for mitigating mortality during future health crises[30]. Another critical research gap lies in understanding the indirect effects of the pandemic, such as mental health disorders, substance abuse, delayed medical care, and changes in health-seeking behavior, which may contribute to long-term mortality trends beyond the immediate impact of the virus. Furthermore, interdisciplinary research integrating epidemiology, demography, economics, and social sciences is needed to capture the multifaceted nature of the pandemic's impact on population health. The role of digital health technologies, telemedicine, and data-driven decision-making in improving health system resilience also warrants further investigation. There is also a need to evaluate the sustainability and equity of global vaccine distribution mechanisms and their long-term implications for mortality reduction and life expectancy recovery. Importantly, future studies should incorporate scenario-based modeling to predict potential outcomes under different policy and intervention strategies, thereby aiding preparedness planning. Ethical considerations, including data privacy, equitable access to healthcare, and the prioritization of vulnerable populations, should also be central to future research agendas. Overall, addressing these research gaps will be essential for developing a comprehensive understanding of the pandemic's impact on life expectancy and for informing evidence-based policies that enhance global health resilience and preparedness for future public health emergencies.

CONCLUSION

The COVID-19 pandemic has profoundly disrupted global health progress, leading to significant and, in many cases, unprecedented declines in life expectancy at birth across countries and regions. This integrative review highlights that the pandemic not only caused direct mortality through widespread infection but also triggered a cascade of indirect effects that collectively reshaped mortality patterns and population health outcomes. The magnitude of life expectancy reductions varied considerably across global, regional, and country levels, reflecting differences in demographic structures, healthcare system capacity, public health preparedness, policy responses, and socioeconomic conditions. High-income countries, despite having advanced healthcare systems, experienced notable declines due to high transmission rates and aging

populations, while many low- and middle-income countries faced compounded challenges of limited resources, delayed response mechanisms, and inequitable access to vaccines and healthcare services. Regional disparities further underscored the role of timely interventions, governance, and public compliance in mitigating mortality impacts, with some regions demonstrating resilience through effective containment strategies and others experiencing severe setbacks due to systemic vulnerabilities. At the country level, comparative analyses revealed that robust health systems, universal healthcare coverage, and proactive public health policies were critical in reducing excess mortality and preserving life expectancy, whereas fragmented systems and delayed interventions contributed to greater losses. The review also emphasizes the significant role of healthcare system disruptions in exacerbating mortality beyond COVID-19-related deaths, as interruptions in routine care, preventive services, and chronic disease management led to increased indirect mortality. Public health interventions and vaccination campaigns emerged as key determinants in altering the trajectory of the pandemic, with early and widespread implementation proving effective in reducing severe outcomes and facilitating recovery in life expectancy trends. However, persistent global inequities in vaccine distribution and healthcare access highlighted the need for more inclusive and coordinated international responses. Methodological approaches used in assessing life expectancy changes, including life table analysis and excess mortality modeling, provided valuable insights but were also subject to limitations related to data quality, reporting inconsistencies, and model assumptions. These challenges underscore the importance of strengthening global health data systems and standardizing methodologies to improve the reliability and comparability of future research. Furthermore, the pandemic exposed deep-rooted social and health inequities, disproportionately affecting vulnerable populations defined by age, socioeconomic status, occupation, and pre-existing health conditions, thereby amplifying disparities in life expectancy outcomes. Looking forward, the findings of this review carry important implications for global health policy and planning, emphasizing the need to build resilient, adaptable, and equitable health systems capable of withstanding future public health emergencies. Strengthening primary healthcare, enhancing surveillance systems, investing in workforce capacity, and ensuring continuity of essential services are critical priorities. Additionally, fostering global collaboration, promoting equitable access to vaccines and medical resources, and integrating social determinants of health into policy frameworks are essential for mitigating the long-term consequences of such crises. Future research should focus on longitudinal assessments of life expectancy recovery, deeper exploration of indirect mortality effects, and evaluation of intervention strategies to inform evidence-based decision-making. Ultimately, the COVID-19 pandemic serves as a stark reminder that gains in population health are fragile and can be rapidly reversed in the face of global crises. A sustained commitment to health system strengthening, data-driven policymaking, and international solidarity will be essential to safeguard and advance life expectancy improvements in the post-pandemic era and beyond.

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