Idiographic Analysis of Health Systems Reponses against COVID – 19 across three countries

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by

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Abstract

In the wake of the currently ongoing COVID – 19 pandemic, chronically underfunded health systems worldwide have had to mitigate several unforeseen challenges. While perceptions about the crisis and subsequent responses have generally responded with lags, the interconnected strategies to mitigate viral transmission have inevitably been shaped by the observed experiences of the global response. As the response to the initial acute phase of the COVID – 19 pandemic transitions to a protracted phase, the importance of reviewing and analyzing response indicators is increasingly important. It is quintessential not only to ensure that countries can identify gaps across national and sub-national responses but also to capitalize on critical opportunities for enhancing response capacities to the increasingly probabilistic occurrence of future infectious disease outbreaks. The study undertaken is an idiographic analysis of the functional capacity of health and emergency response systems at the national and sub-national levels across three countries to support single-case series research across broad geographies. By reviewing and synthesizing key insights from country-specific COVID – 19 health systems response efforts, identification of challenges, and best practices, a basis for updating and validating COVID – 19 preparedness and response plans is potentiated. Study findings underscore, among others, the importance of increased investment in public health infrastructure, leveraging multisectoral partnerships in health and social capital during a public health crisis. The analysis also provides an impetus for future research to examine the many interconnected dimensions of pandemic preparedness and response as well as the need to update currently available assessment tools available for estimating a country's health security capabilities like the Global Health Security (GHS) index.

Keywords: *COVID – 19, Health systems, Pandemic preparedness and response, idiographic approach, GHS index*

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1. Introduction

The currently ongoing COVID – 19 pandemic has constituted a global public health crisis hitherto incomparable to all the infectious disease outbreaks that have preceded it. SARS – CoV – 2, the causal agent of the disease, has spread to 214 countries and territories worldwide(1). At the time of writing this paper, an estimated 36,796,400 people have contracted the virus, and 1,066,200 people have died from the virus (1). While certain countries are experiencing higher rates of infection than others that have been able to mitigate its spread, the number of new cases worldwide is growing at an alarming rate, with an average of 200,000 cases being reported each day (1). According to W.H.O. estimates, as much as 10 percent of the global population has already been infected by the virus(2). Circumventing the many unforeseen challenges caused by the pandemic has taken a significant toll on chronically underfunded health systems worldwide. Despite the seminal work by countless polygonal organizations, social enterprises, and governments, the pandemic has revealed glaring fragilities and shortcomings in global health systems responses (3,4). The spread of the virus has emphasized the significance of interconnectedness among diverse regions. With the advent of globalization, the virus has rapidly spread across borders (5). While perceptions about the crisis and multiple components of country responses have generally responded with lags, they have been inevitably shaped by each other's practical experiences. Countries have had the opportunity to learn from each other and make incremental improvements to their containment strategy (6). In addition to the Intra-Action Review (I.A.R.) (7) and a myriad of supplementary tools developed by the W.H.O. (8,9), the importance of reviewing and analyzing country-specific COVID – 19 response indicators to identify gaps across national and subnational COVID – 19 outbreak responses is palpable across the globe

(10). As the global health response to the acute, initial phase of the outbreak transitions into a protracted phase, there is an opportunity for countries to reflect on and improve their national responses to the COVID- 19 outbreak as needed (11). It is quintessential for ensuring that countries can capitalize on critical opportunities for enhancing their response to the COVID-19, especially as future infectious disease outbreaks become an increasingly probabilistic occurrence in the times to come(12).

2. Rationale

This study sets out to conduct an idiographic analysis of the functional capacity of health and emergency response systems at the national and sub-national levels across three countries to identify functional areas requiring immediate remediation as well as in the identification of potential areas for sustained improvement of the current and future infectious disease outbreak responses across broad geographies. By reviewing and synthesizing key insights from country-specific COVID – 19 health systems response efforts, identification of challenges, and best practices, a basis for updating and validating COVID-19 strategic preparedness and response plans is potentiated (13). The study aims to serve as a vital resource for facilitating consensus-building among the many stakeholders involved across the various health system tenets and understanding the global interrelationships shaping health systems responses to COVID-19.

An idiographic approach for the country-specific health systems analysis was selected due to the merit of the approach in detecting “meaningful intra-unit differences in health systems response across contexts and time along with a nuanced understanding of the factors accounting for these differences.” (14). “Idiographic studies are useful for progress monitoring (e.g., across implementation phases or throughout an event) as they place greater emphasis on situational specificity (processes that vary across contexts) and temporal instability (processes that vary over time) when compared to their nomothetic

counterparts." (15). The rapidly changing nature of the pandemic regarding its epidemiology, transmission rate, and distribution has forced public health experts and policymakers to continuously reshape their collective approach toward proposed strategies for mitigating the spread of the virus. While country-specific health system responses against COVID – 19 have primarily centered around adherence to some form of social distancing to abet disease spread and diminish the strain on medical services, they have remained subjective to their unique operational contexts. As such, broad generalizations on effective containment strategies cannot be conclusively stated. (16). This provided further impetus to adopt this approach for supporting single-case series research whereby independent health systems of a country are analyzed in the context of the ongoing COVID – 19 pandemic. Lastly, the approach potentiates implications for implementation research, which, in recent years, has begun to explore the use of idiographic single-case experimental designs to support the formulation of policy and decision-making frameworks (15).

3. Methodology

3.1 Country selection criteria

To ensure the inclusion of countries across a broad range of geographies and specific to health security indicators reflective of varying ability of a country's ability to overcome infectious disease outbreaks, countries were selected across three different Global Health Security (GHS) Index scores.(17) The GHS Index is a comprehensive tool that aims to measure changes in public wellbeing, security and capacity to address infectious disease outbreaks that have the potential of becoming international epidemics and pandemics. "The index consists of 6 categories, 34 indicators, and 85 sub-indicators. The categories comprise prevention, detection and reporting, rapid response, health system, compliance with international norms, and risk environment"(18). As per the 2019 GHS Index, the

overall global average preparedness score was 40.02 (19). For the study, one country across a high, medium, and low GHS score was considered to assess preparedness and response as per the GHS index. The deliberate selection of countries with varying scores was also made to assess the applicability of the index itself in the context of COVID – 19.

The inclusion criteria for shortlisting a country most prepared for overcoming infectious disease epidemics were defined as a country with a high GHS Index score (>50). Similarly, the criterion for defining a country having an 'above average' preparedness was one that had a GHS score >40.02. Similarly, the criterion for defining a country ranking below average on infectious disease preparedness was one that had a GHS of <40.02. Subsequently, a geographical exclusion criterion was applied to ensure that no two shortlisted countries belonged from the same regions as defined by the World Health Organization (W.H.O.) *viz.*, AMRO, SEARO, WPRO, EMRO, EURO, and AFRO. With these considerations, the following countries were shortlisted for the study:

The United States of America

Region: AMRO

Overall GHS Score: 83.5

Classification: Most Prepared

India

Region: SEARO

Overall GHS Index score: 46.5

Classification: Above average preparedness

Nigeria

Region: AFRO

Overall GHS Index score: 37.8

Classification: Below average preparedness

3.2 Review of literature

For defining input and outcome indicators to analyze country-specific health systems response against COVID – 19, a narrative literature review was conducted onward from January to September 2020. With an ever-expanding number of news articles, data, and information on the global novel coronavirus pandemic, obtaining high quality, credible information for reviewing health systems responses was emphasized. In addition to the resources available at W.H.O., a review of publications specific to health systems preparedness and response against COVID – 19 available at the PubMed Central (NCBI) databases, Centres for Disease Control (C.D.C.), and local ministries of health was conducted. Boolean expressions specific to search queries enabled narrowing the search parameters to generate pointed results to inform the literature review.

Taking into account the rapid changes occurring with the pandemic's progression and for overcoming publication lag times, information disseminated through reputable news sites, social media handles, and press briefings of the W.H.O., C.D.C., National Institutes of Health (N.I.H.) and local health ministries were also reviewed. Beyond publications, expert opinions by leading public health professionals were condensed via the B.B.C. Coronavirus global update podcast, the New Scientist Podcast, The London School of

Tropical Health & Hygiene viral podcast, the Guardian science weekly podcast, among others.

To circumvent biases in scientific reporting and unreliable information about the virus (20), all platforms and red-rated news and information sites identified by Newsguard's Coronavirus Misinformation Tracking Center (21) were excluded from informing the review. Social media accounts of individual persons, companies, special interest groups, journalists, politicians, and media houses were also excluded from the study. Additionally, the guidelines put forth by the COVID – 19 Infodemics Observatory were adhered to while accruing information from news sources.(22)

A total of 55 health systems response indicators were identified as a consequence of the literature review undertaken for the study. The exclusion criteria of data availability, accessibility, and frequency of updating were applied, and 23 indicators were shortlisted for the study. Most of the shortlisted indicators have also been used for analyzing health system responses in infectious disease outbreaks of the past. A detailed breakup of the indicators is enclosed in Annexure A.

3.3 Proposed framework for county-specific analysis

To uniformly structure the analysis of the proposed indicators across all countries, shortlisted indicators were classified across five distinct sub-indices reflective of a country's response capacity. The sub-index classification was consolidated by a reviewing classification of emerging strategies that have shown promise in alleviating the spread of COVID – 19 in its initial months through independent case study country analysis of China(23), South Korea(24), Taiwan(25), Vietnam(26), and Singapore(27). Additionally, the indicators' classification was aligned with guidelines proposed within the W.H.O.'s monthly COVID – 19 strategy update documents and the "Strategic

Preparedness and Response Plan (SPRP) intended to aid the assessment(s) of public health response to COVID-19 at national and sub-national levels" (28).

SUB – INDICES				
Diagnosis & testing	**Mobility restrictions**	**Lockdown measures**	**Policy and legislation**	**Scale-up of infrastructure**
INDICATORS				
No. of COVID – 19 tests conducted Timely adoption of comprehensive contact tracing measures Setting up of isolation wards and COVID – 19 specific treatment centers Changes of COVID – 19 case density Changes to the Case Fatality Rate (CFR)	Measures on public transport closures Measures for restrictions on interstate mobility Measures for Airline/International travel restrictions Changes in mobility trends across sectors The severity of restrictions imposed on national events/gatherings	Cancellation of public events Stay at home restrictions Measures for school closures Workplace closures Closures of places of worship	Coordination of public information campaigns COVID – 19 specific policy changes Jobs, income, and enterprise support Economy & employment stimulation packages The stringency of measures adopted by government authorities	Scale-up of protective equipment (PPE) and ventilator manufacturing Scale-up of laboratory/testing capacities Increased vaccination and drug research engagements

Table 1: To uniformly structure the analysis of the proposed indicators across all countries, the 23 shortlisted indicators were classified across five distinct sub-indices by the researcher following the review. Sub-indices were reflective of a country's response capacity

3.4 Data collection strategy

Data on the qualitative and quantitative indicators across the subindex of diagnosis and testing was procured from publicly accessible, open-source, COVID – 19 tracker databases. For this, a total of eleven open-source COVID – 19 tracking databases related to the indicators within the subindex were reviewed. Out of the eleven COVID – 19 trackers, an exclusion criterion based on data availability, updates, and replicability was applied, and two trackers *viz*., the "Johns Hopkins COVID – 19 tracker" and "Our World in Data" were selected. For a detailed – break up of the trackers considered for the study, kindly refer to Annexure B. For specific indicator information about the other subindices of mobility restrictions, lockdown measures, policy, and legislation, and scale-up of infrastructure, other sources specific to those variables were considered using the same exclusion criteria. A detailed list of indicator specific data sources can be found in Annexure C.

4. Country specific analysis

4.1 India

As of 30th September 2020, there were 6.23 million cases, with 97,497 deaths and a Case Fatality Rate (CFR) of 1.6 percent in India. The recovery rate was 82 percent (29).

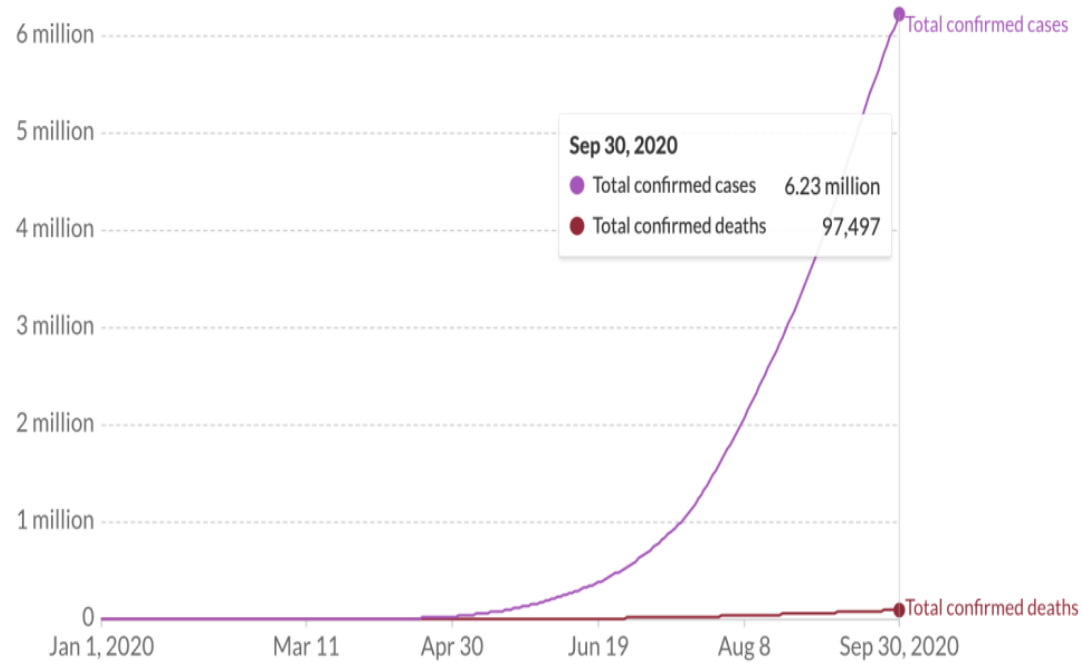

Fig 1: Total confirmed COVID – 19 cases and total number of recorded deaths in India onward of January 2020 to September 2020 (Source: OurWorldinData)(30)

Diagnosis & Testing

India started thermal screening of travelers from China, Hong Kong, Japan, the Republic of Korea, Singapore, and Thailand from January seventeenth, which was extended to seven of the nation's air terminals in the subsequent weeks (31). India detected its first confirmed COVID – 19 case on 30th January 2020, "a student studying at Wuhan University was reported in Kerala's Thrissur district"(32). This initial reporting of the case coincided with the W.H.O. declaring COVID – 19 "A public health emergency of international concern(33)". After detecting cases in the surrounding districts of Alappuzha and Kasaragod, "the Kerala government declared a state of emergency"(34).

In the penultimate weeks of February, the Government of India (GoI) expanded universal screening at airports to flights arriving from Indonesia, Kathmandu, Malaysia, and Vietnam (35). An estimated 4,82,927 travelers were screened from 4,787 flights (29). Screening proceeded across 21 air terminals, 12 major, 65 minor seaports, and land

intersections circumscribing Nepal. An estimated 23,531 travelers were checked under network observation through the Integrated Disease Surveillance Program (IDSP) network per day(36). By March, screening was extended to all international passengers across all airports and seaports in the country. In the initial weeks, India had tested 500 community cases, and testing was limited to symptomatic individuals either with a recent travel history or known contact with a suspected individual/source (29). “The Indian Council of Medical Research (ICMR)” expanded the case definition to include individuals presenting with symptoms irrespective of travel history(37). By this time, the country had reported more than a thousand confirmed COVID – 19 cases. The cases were doubling every five days. IDSP primarily conducted contact tracing through community surveillance. Initially, contact tracing was performed for travel-related cases, which was later extended to cases being reported within the community as a part of the containment strategy. By the end of the month, the Nizammudin area in the National Capital Region (NCR) region of the country emerged as one of the first COVID – 19 hotspots following a large religious gathering of the ‘Tablighi Jamaat’ testing positive for the virus (38). 129 new cases in the capital city of New Delhi and 74 new cases in the southern state of Tamil Nadu were later linked to this congregation (39).

By mid-April, India had tested 2,30,000 individuals. The test positivity ratio was 4.7 percent. At the time, there were an estimated 10,000 confirmed COVID -19 cases. All states and union territories (except for Dadar Nagar Haveli and Sikkim) reported at least one COVID – 19 case. In the weeks following, the number of confirmed cases doubled to 20,000 with a doubling rate of 7 days (29). Periodic advisories were disseminated to expand the testing platform, testing strategy as per changing epidemiology of the disease, standard laboratory protocols, and reporting guidelines such as COVID – 19 testing guidelines in private labs across the country; “Advisory on Use of Rapid Antigen

Detection Test for COVID-19" (40); "Advisory to start Rapid Antibody-based Blood Test for COVID-19" (37); and "Advisory on the feasibility of using pooled samples for Molecular Testing of COVID-19"(41). These advisories were released to ensure all laboratories practiced uniform testing protocols.

Across the country, sports stadiums(42), railway coaches(43) and religious buildings were repurposed into temporary quarantine facilities to deal with the growing number of COVID cases. "The GoI earmarked 215 railway stations for the deployment of railways' isolation coaches to be used as 'COVID Care Centres' for suspected or confirmed patients categorized as mild or very mild cases. The stations were deployed across 23 states and union territories. During this month, the railway network had prepared 5,150 such coaches"(44). By the end of May, India had surpassed China in terms of the total number of reported cases with 85,940 cumulative cases(29).

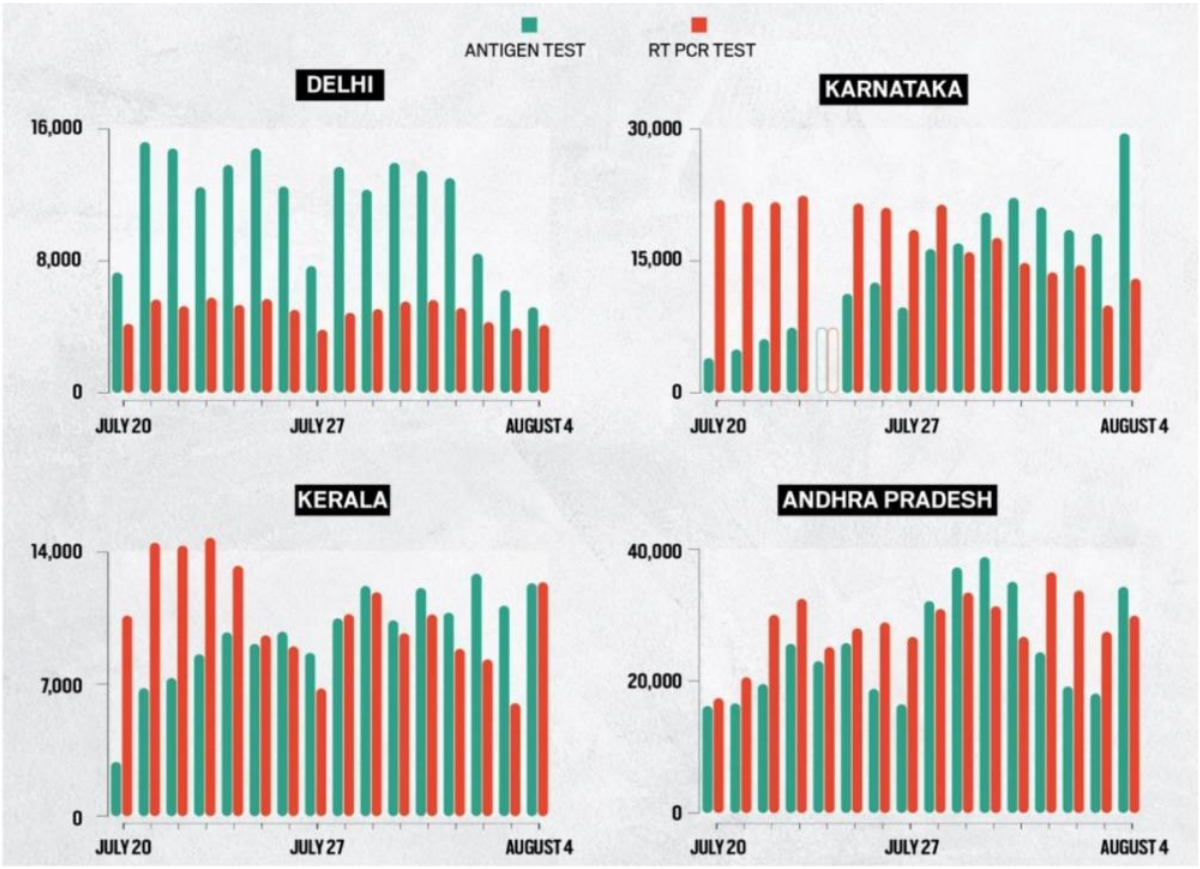

Fig 2: In the month of June, ICMR approved the use of rapid-antigen test for COVID – 19 diagnosis. Additionally, the body issued recommendations on the deployment of rapid antigen detection test for COVID-19 in combination with the RT-PCR test in all containment zones, private hospitals approved by the National Accreditation Board for Hospitals and Healthcare (NABH), central and state government medical colleges and government hospitals and all private labs accredited by the National Accreditation Board for Testing and Calibration Laboratories (NABL)(36). In the following weeks, multiple states suffering a high burden of COVID – 19 including Karnataka, Andhra Pradesh, Kerala and Delhi serological tests began to scale up testing with these tests in conjunction with traditional RT-PCR based testing.

In the following months, India's per day testing capacity rose from 1,50,000 in May to nearly 4,00,000 per day. As of September, the country conducted an estimated 14.5 lakh COVID – 19 tests in a single day (*Fig. 3*). Cumulative tests in the country reached close to 7 crores (6,88,27,439), and in conjunction with infrastructure scale-up, the daily testing capacity of several states and union territories also increased. Up to twenty-three states and union territories were conducting tests per million at a rate higher than the national average of 49,948 (29) (37) (45).

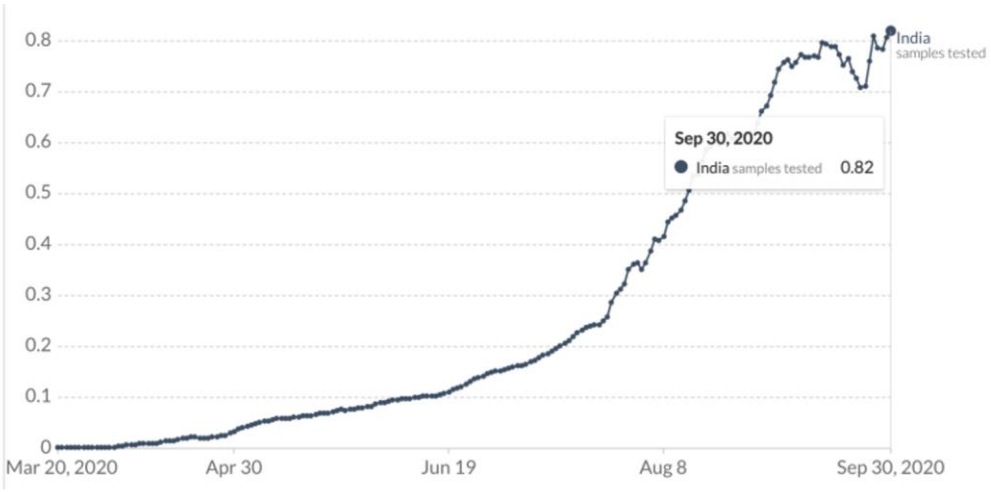

Fig 3: Daily COVID – 19 tests conducted per thousand people in India from start of tests till September. Because the number of tests is often volatile from day to day, the figures as a seven-day rolling average are shown. As of September, India was conducting 0.82 tests per thousand population. (Source: OurWorldinData)(44)

There was evidence to suggest that "higher numbers of testing subsequently led to a lowered positivity rate. The states that were testing the highest numbers also reported gradual declines in the positivity rate"(29).

Mobility Restrictions

Following reports of COVID – 19 related losses of life in China outperforming that of the 2002-2003 SARS outbreak, the GoI banned the entry of all Chinese visas in February(46). Onwards of March, GoI suspended all visas with exemptions only on diplomatic and official visas. Citizens returning home from international borders were advised to quarantine themselves for 14 days. Flights (international and domestic), passenger trains, metro, and road transport (except essential goods transportation) were suspended. Disease surveillance networks across states were strengthened to ensure coverage and compliance with the travel restrictions.

Additionally, other measures of precautionary guidelines on social distancing were issued by the GoI. Closure of educational institutions and avoidance of non – essential travel was suggested. Employees of all sectors were encouraged to work from home,

minimization or rescheduling of meetings, alternatives to biometric attendance, postponement of examinations, avoidance of sports events and religious gatherings were some of the aspects of the advisory(47)

Lockdown measures

Before revealing its first case, Odisha was the primary state to announce COVID – 19 a "calamity" and ordered prompt closure of education institutes, film halls, public pools, and exercise centers.(48). Subsequently, the Delhi Government followed suit by mandating the shutdown of all exercise centers, spas, night clubs, and theatres until March (49). On March 22nd, the GoI announced a 14 – hour voluntary lockdown entitled 'Janta Curfew' across the country. All sectors, markets, and establishments with the exception of essential goods remained closed for the day(50).

Two days after the Janta Curfew, the Prime Minister of India announced a 21 – day cross country lockdown, which later stretched out to the 31st of May, making it the most prolonged lockdown by any nation, worldwide (51). The move aimed to provide adequate preparation time for health systems response and ensure compliance with designated preventative guidelines. In the weeks leading up to the announcement, several states across the country had proposed local containment plans in addition to the national lockdown. In April, districts across the country were divided into three zones:(52)

- Red Zones: Hotspot/containment zones: Classified as areas with the highest caseload, contributing > 80 percent of cases. Or, the highest caseload districts contributing > 80 percent of cases for each state in the country. Or, the district with a doubling rate < 4 days (29).

- Orange Zones: Areas that revealed a predetermined number of cases previously and with no recent surge in cases (29).

- Green Zones: “Areas with zero confirmed cases or no confirmed case in the last 21 days” (29).

“At the time, out of the 733 districts across the country, 130 fell in the red zone, 284 in the orange zone and the remainder in the green zone” (*Fig. 4*) (29).

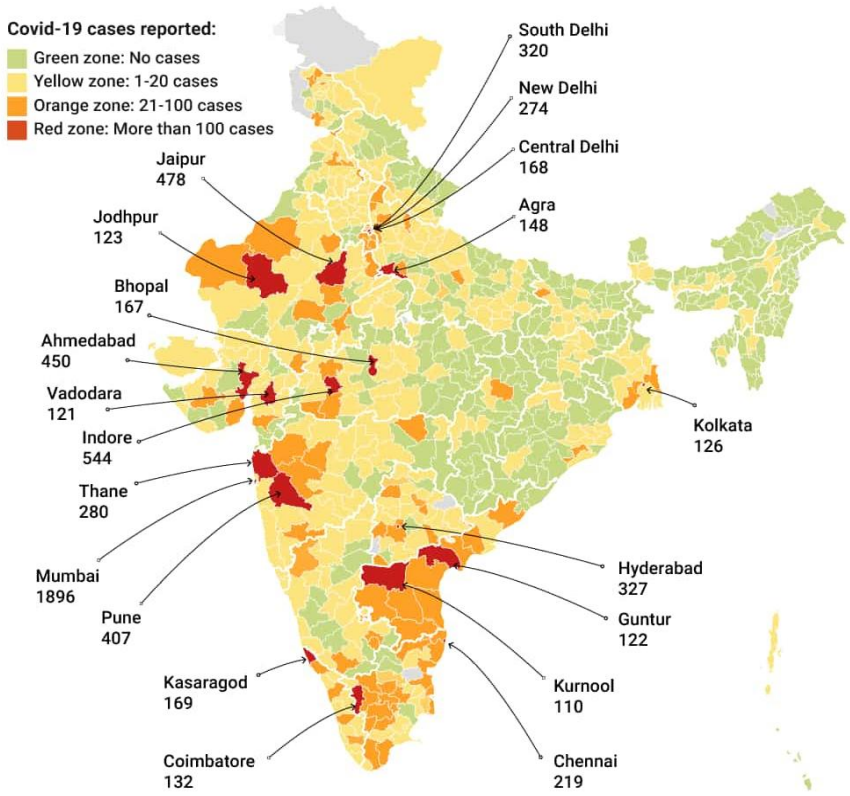

Fig 4: Schematic representation of the distribution of the various containment zones across the country as of April 2020. Source: Ministry of Health & Family Welfare (29)

Before lockdown measures, the doubling rate of the virus was 3.4, which improved to 7.5 by the second week of April and then to 12.9 in the second week of May (29). However, the GoI, taking stock of the extended lockdown impact on the country’s economy, decided to commence preparations for unlocking procedures in three stages. Despite a

surge in the number of COVID – 19 cases (>2,50,000 confirmed cases and 7,200 deaths), India began a phased reopening of various sectors by the end of May.

From June, the first phase of lockdown relaxations entitled ‘Unlock 1.0’ began. Most of the activities restricted before were opened in territories outside regulation zones in a staggered manner(53). These included a conditional reopening of shopping malls, religious places, and other establishments. By the end of the month, COVID – 19 death count had reached 17,409, and the cumulative number of cases was 0.585 million. Closer examination of the growth rate data showed that the month of June contributed a 210.54 percent increase in the total COVID – 19 related fatalities and a 195.3 percent increase in the total number of COVID – 19 cases. Onwards July, the GoI allowed the reopening of domestic flights and passenger trains on a routine basis as part of the second phase, ‘Unlock 2.0’(54). By the end of the month, the government issued ‘Unlock 3.0’ guidelines, further relaxing restrictions and limiting lockdowns only to containment zones until August (55).

By the end of the month, COVID -19 related fatalities were estimated at 36,551, and the cumulative cases at 1.687 million. (29) July alone contributed a 104.8 percent increase in mortality and 180.4 percent increase in the total number of cases compared to figures from March. With more than 1.7 million COVID – 19 cases and 37,405 fatalities attributed to the virus; the country entered its third phase of easing lockdown restrictions in August. The guidelines lifted restrictions on yoga centers and gymnasiums mandating separate standard operating procedures (SOPs) for their reopening. The guidelines also removed restrictions on individuals' movement during night times, which until the last two phases were restricted till 8 PM. The vast majority of activities barring schools, colleges, international flights and metro rail services were resumed (55).

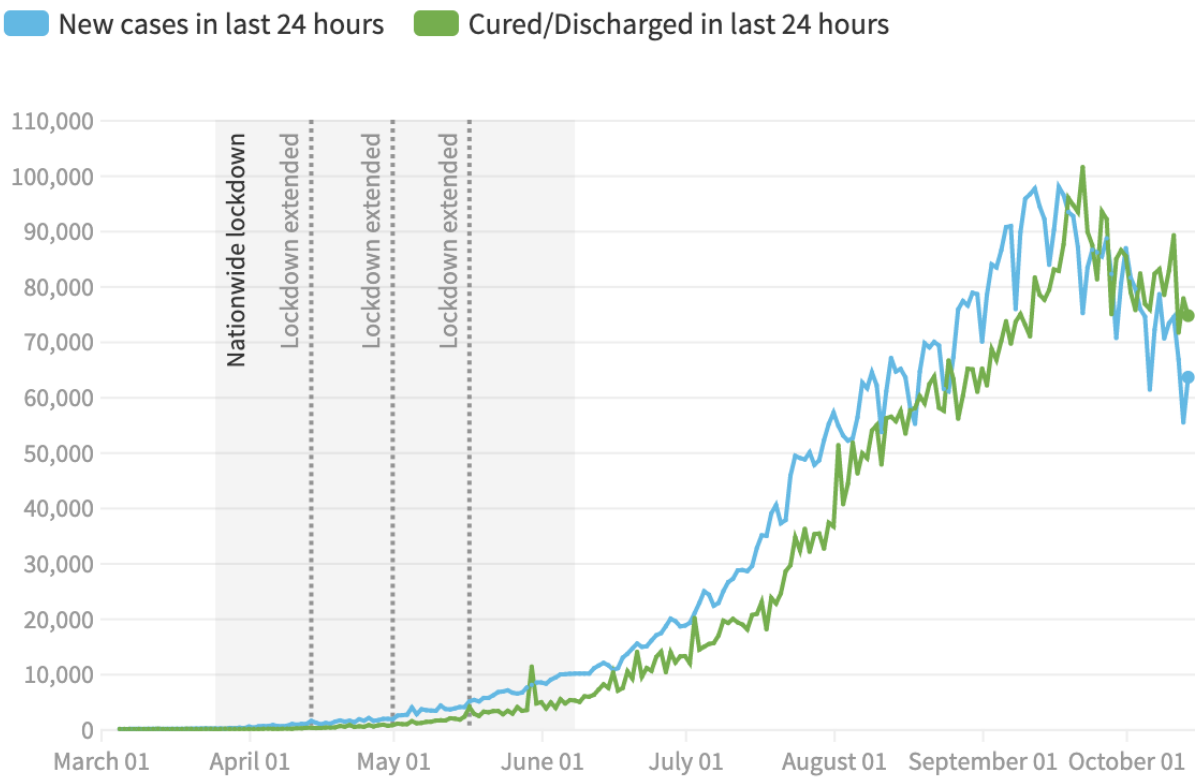

Fig 5: While the daily confirmed cases at the various stages of lockdown measures continued to increase throughout the lockdown period, the growth was slow. With the announcement of unlock measures, growth of new cases began increasing exponentially. The active case figures during the first phase of unlock 1.0 were in stark contrast to the 606 reported cases and 10 deaths before lockdown measures. Source: Ministry of Health & Family Welfare (29)

However, despite the 'unlock guidelines', several states, such as Maharashtra, West Bengal, Jharkhand, Tamil Nadu, Nagaland, Mizoram, extended state-wide lockdowns till 31st August to mitigate viral spread. In states like Karnataka, Andhra Pradesh, Uttar Pradesh, and Bihar, where emerging pockets of viral spread was observed, also issued lockdown extensions to specific activities/sectors(56).

On August 29th, the GoI issued new guidelines to further re-open the economy by September. These guidelines removed restrictions on the metro rail service from September 7th and allowed social, academic, sports, entertainment, and other congregations of up to 100 people. Education institutions were excluded from these relaxations till September 31st. Lockdowns were continued only for red zone districts(57).

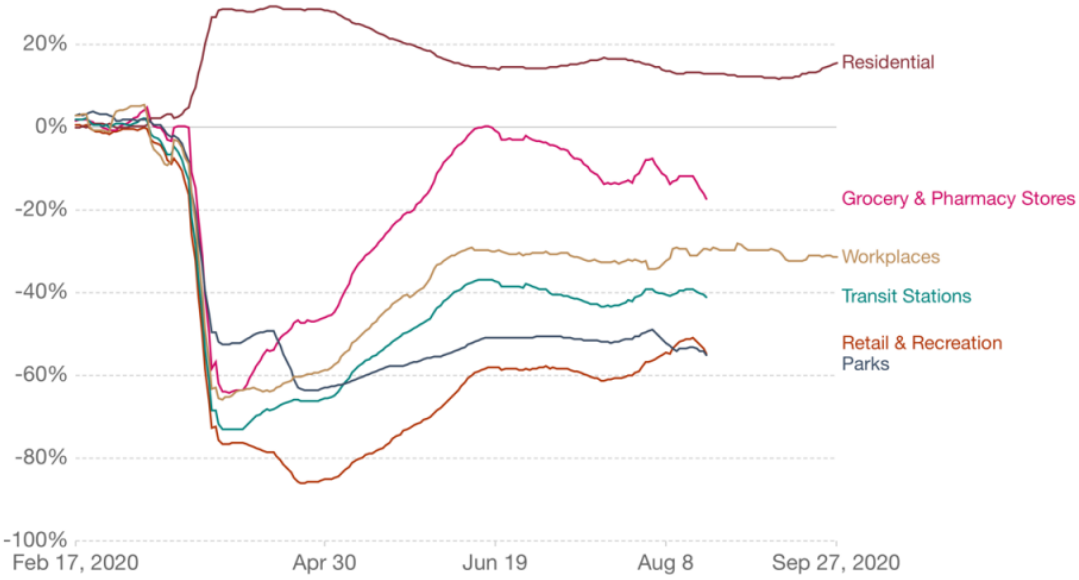

Fig 6: The change in mobility across the country since the beginning of the pandemic. The data shows how visitors changed across categorized places when compared to baseline days – The median value from the 5 – week period from "January 3rd – February 6th, 2020". The index has been smoothened to the rolling seven-day average. Changes in mobility across sectors within the country are reflective of restrictions on mobility and lockdown measures. Residential mobility saw an increase in September compared to the previous months. Parks and retail and recreation had the lowest shares that month compared to other categories at 59 and 61 percent respectively. Despite easing of restrictions since the end of May, workplaces saw an increase in mobility in June, although as of July, the numbers continue to decline. Source: Google Mobility Reports(58)

Legislative and Policy response

During the pandemic's initial days, efforts were principally directed to mitigate the outbreak's impact by containing local transmission. The countries' disaster management response was mobilized leveraging the legislative tools under the aegis of the "Disaster Management Act" (59) and the "Epidemic Disease Act of India"(60). Amendments to the Epidemic Act 1897 introducing harsh legal penalties against the harassment faced by frontline health workers were also added. Enactment of these acts in conjunction provided widespread legal power to civil authorities to implement strict pandemic control measures and ensured cooperation from the public and reporting of cases by medical professionals, regardless of their affiliation (61).

The Central government set up empowered groups, under the Disaster Management Act, for “Ensuring a comprehensive and integrated response to the COVID-19 pandemic”. Several states in India announced special financial assistance packages to provide cash transfer, food and shelter to disadvantaged groups and Below Poverty Line (BPL) families. To circumvent shortages in Personal Protective Equipment (PPE), the GoI banned the export of all kinds of PPE in mid-March 2020.(62) Further, the GoI also declared face masks and hygiene items as essential commodities to boost supply and prevent these items' hoarding across the country. The GoI also issued a notification granting all medical devices the status of ‘drugs’ and imposed tighter regulations to check on the quality of the devices and price monitoring(63).

The government earmarked USD 1.96 billion for testing centers, individual protection, seclusion beds, ICUs, ventilators, and preparing clinical and paramedical staff(64). Additionally, the “District Mineral Fund (DMF)” was diverted for “supplementing and augmenting medical testing, and screening”(65). In March, India’s finance minister announced a comprehensive economic package under the existing national scheme of ‘Pradhan Mantri Gareeb Kalyan Yojana’(66). The package included USD 21.9 billion and targeted 800 million individuals affected by the lockdown. By the end of the month, an “insurance Scheme for Health Workers Fighting COVID-19” was approved and provided a cover of USD 65,000 for ninety days to 2.2 million public healthcare providers, including community health workers. It also included “accidental loss of life on account of contracting COVID-19” (67).

A scheme for the “Promotion of Bulk Drug Parks for financing Common Infrastructure Facilities” in 3 Bulk Drug Parks was also initiated(68). Additionally, the “Production Linked Incentive (PLI) Scheme for the promotion of domestic manufacturing of critical

Key Starting Materials (KSM)/Drug Intermediates and Active Pharmaceutical Ingredients (APIs) was also mandated" (69).

Retail sale of drugs to the doorstep of consumers was also allowed by the GoI to meet the emergency requirements and expedite the distribution of drugs to the consumers(70). Registered Medical Practitioners were issued guidelines to provide healthcare using telemedicine(71). Guidelines were issued on PPE's rational use, and training was provided for frontline health workers (72). State governments also issued directives on observing COVID-19 prevention measures in the workplace before the 21- day lockdown period.

The Central Government also issued advisories to State Governments to "directly release funds into the accounts of construction workers using the cess collected by their respective Building and Other Construction Workers' Welfare Boards" (73). Advisories were issued to State Governments for making adequate arrangements for food and shelter for persons below the poverty line, including migrant laborers. Further, the advisories urged owners to grant relaxations on house rent from the laborers during the lockdown period (73).

Throughout the pandemic, the government undertook mass awareness efforts through mass media and social media channels. The country's Prime Minister addressed the citizens through the medium of national television and radio to provide updates on the pandemic and lockdown. (74) "The public charitable trust, 'Prime Minister's Citizen Assistance and Relief in Emergency Situations Fund' (PM CARES Fund)' was created to serve as a dedicated National fund to mitigate COVID – 19" (75). At the time of writing

this paper, the fund had received an estimated Rs 204.75 crore from employees' salaries in 15 government banks and institutions, including the Reserve Bank of India.

On May 12th, the Prime Minister announced a stimulus relief package of 20 lakh crore (10 percent of India's GDP) focused on "tax breaks for small businesses and incentives for domestic manufacturing"(76). According to the Oxford COVID – 19 Government Response Tracker (*Fig. 7)*, India scored high on its response to COVID – 19 (77), (78).

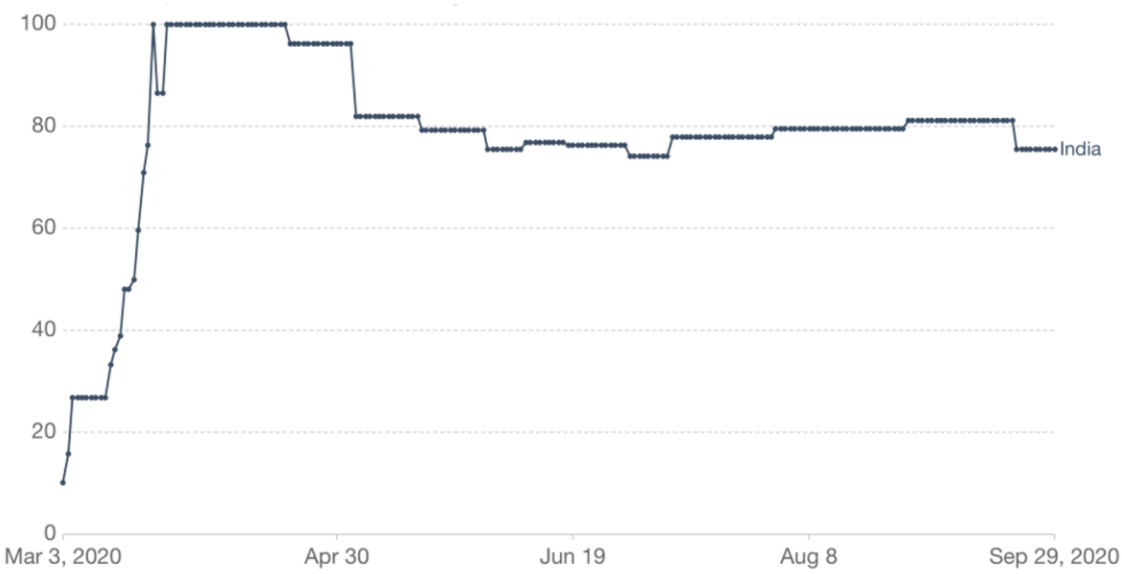

Fig 7: Policy and legislative response scores of India measured in accordance to the Oxford COVID – 19 Government Response Tracker. The country had a score of 80 as of September 1st. The score is a composite measure based on nine response indicators including school closures, workplace closures and travel bans, restricted to a value from 0 – 100 (100 being the strictest) In case of policies varying at the sub-national level, the index is shown as the response level of the strictest sub-region. Source: Oxford Stringency Index(76)

Infrastructure scale-up

In the initial weeks of February, India had only 14 Virus Research and Diagnostic Laboratories (VRDLs) capable of COVID - 19 testing. As the number of cases began to surge across the country, new laboratories were needed to meet the demand and make testing widely available. VRDLs served as platforms for capacity building and as a model for setting up new laboratories capable of conducting COVID-19 testing. The central and

state governments collaborated resources to deploy equipment and human resources to establish Molecular Virology Laboratories (MVLs)(79).

To rapidly expand testing facilities, 14 Centres of Excellence were set up in different Medical Institutes, as per the directives of the Union Ministers of Home and the "Ministry of Health & Family Welfare (MoHFW)," under the guidance of Director General, ICMR and Director, All India Institute of Medical Sciences (AIIMS), Delhi. These centers mentored government and private medical colleges in their catchment areas and eventually created a MLV network. In the initial phase, 300 medical colleges across India could upscale COVID-19 testing over a reasonably short period (79).

ICMR engaged with MoHFW laboratories, "Department of Biotechnology (DBT)," "Council of Scientific and Industrial Research (CSIR)," "Indian Council of Agricultural Research (ICAR)," "Defence Research and Development Organisation (DRDO)" and high-quality private laboratories and various medical colleges across the country to intensify testing facilities. Remote areas were mapped proactively to cover underserved populations adequately. ICMR set up Molecular Diagnostic Laboratories in remote locations such as Ladakh, Arunachal Pradesh, Sikkim, Tripura, Mizoram, Lakshadweep, and Andaman & Nicobar Islands to ensure more generous coverage. By the beginning of April, India had 106 VRDLs, which anchored COVID-19 diagnosis in the country (80).

Indigenous point of care tests like TrueNat for COVID-19 testing that required minimal training, skills, infrastructure, and biosafety measures were deployed for diagnosing COVID-19 at district facilities and primary health centers across the country. The widespread availability of customized cartridges of TrueNat and Cartridge Based Nucleic Acid Amplification Tests (CBNAAT) served pivotal for accessibility of COVID-19

testing at the level of the primary health care system. At the beginning of May 2020, the RT-PCR testing facilities became available in 360 government and 112 private facilities across the country with a daily testing capacity of 90,000 (79).

ICMR, along with MoHFW onboarded certified private laboratories in India. To ensure quality, only research centers that had picked up an endorsement by the "National Accreditation Board Testing and Calibration (NABL) (ISO15189)" were approached. A total of 1250 laboratories were registered with NABL for various scopes, of which labs with the scope of molecular virology were chosen. Virtual laboratory tours, fast-track approvals, and other measures ensured that the laboratories followed due diligence to safeguard quality testing and sample reporting. In mid-June 2020, ICMR recommended using the antigen detection test as a point-of-care diagnostic test in specific settings like hospitals and containment zones due to its minimum turnaround time of 30-minutes, including sample preparation. This provided the much-needed impetus to the government's strategy to 'Test, Track, and Treat'. By the end of July, more than 400 private sector laboratories were successfully registered for testing(81).

ICMR identified 30 quality control (QC) laboratories to verify other laboratories' results in their respective catchment areas. Testing laboratories in each state were instructed to randomly send positive and negative samples to the nearest designated QC laboratories. This enabled ascertaining the quality of diagnosis. The data entry portal was developed to provide uniform laboratories result reporting and data management(82). Validation centers were established and trained to evaluate RT-PCR kits, RNA extraction kits, Viral Transport Medium (VTM) kits, and ELISA kits by standardized scientific protocols. Various ministries supported indigenous manufacturers, and licensure procedures were fast-tracked. To ensure transparency, follow-ups, and rapid approvals, an online portal for kit validation was rolled out. By mid-August, more than 700 diagnostic kits had been

validated. By August, the number of laboratories in the country rose to more than in 1596 (79).

Setting up robust supply chain processes since the pandemic's initial phases were necessary, a live dashboard was set up to track the availability of essential testing commodities and support the forecasting of commodity requirements by the states. A web-based inventory management system was rolled out at the laboratory-level, and standard operating procedures for effective downstream supply chain management were prepared. Robust projections for commodities and timely procurement ensured adequate stock-at-hand to meet testing needs.

To guarantee that provisions arrived at each lab expeditiously while the cross-country lockdown was in place, ICMR leveraged partnerships between the Ministry of Civil Aviation's airline partners across both the private sector and the government through the aegis of 'Mission Lifeline Udan'. "Through this initiative, consignments of COVID-19 diagnostic material across the country were delivered. Close to 40 tonnes of testing material was transported in more than 150 flight operations, reaching out to the nation's remotest corners during the months of the nationwide lockdown. Several courier companies also played a pivotal role in coordinating doorstep deliveries"(83) As the laboratory network expanded, the countrywide operations of 'India Post' were engaged to streamline and enable seamless delivery of supplies to the last mile.

"Technology landscaping, leveraging resources, and optimizing the processes to increase the efficiency of operations were undertaken by ICMR, MoHFW, and the GoI to expand the scale of testing". (29) As per the latest reports, the country had scaled its capacity to an estimated 1,818 laboratories – 1,084 in the government sector and 734 private labs. At

the time of writing this paper, these included 923 RT PCR based testing labs, 769 TrueNat based testing labs, and 126 CBNAAT based testing labs (29).

Discussion

While India was proactive in cultivating a robust response system for COVID – 19 before viral onset, a few lapses hampered the uncontrolled viral transmission across different parts of the country. Notably, when the GoI issued its first travel advisory to thermal scan passengers, it was done only in the case of passengers reporting illness on flights originating from China and disembarking in India. This translated to the GoI focusing on the quarantine of passengers having symptoms of COVID-19 but excluding the quarantine of all other international passengers. This was a lapse, as infected passengers may not have had symptoms due to the viral incubation period but may have become ill later within their community. Moreover, the GoI was initially focused only on self-quarantine as opposed to compulsory quarantine under doctors' supervision, and many people were reluctant to comply.

While the announcement of a complete lockdown on the 24th March 2020 was a welcome move and was warranted to prevent community transmission of the disease, it was sudden, without adequate planning, and without a full understanding of its implications on all sections of the society including daily wage workers. There was a need for strict directives from state and local governments to ensure that poor people received at least minimum necessities free of cost if they could not afford to buy them. There was also a need to complete preliminary information about the relief camps so that migrants could access places of refuge. The lacuna on all central, state, and local Governments' actions led to a mass exodus of an estimated 600,000 migrant low and daily wage workers with their family members(84). Mass shifting of migrant daily wage workers from cities increased the risk of COVID-19 transmission in several rural areas of the country, which

lacked even the most basic health facilities(85). The purpose of the lockdown – to prevent the community transmission of infection was hampered significantly(86).

Another lapse in containing the virus in India stemmed from a lack of strict implementation of rules (81). Despite government mandates urging individuals to practice social distancing and avoid gatherings including religious congregations – more than two thousand individuals, including people from most COVID-19 affected states, were found in a religious institution at the National Capital Region, 50 meters away from the local police station. Later, many people from this congregation were found positive for COVID-19 in different parts of the country due to their migration, which significantly increased the risk of disease transmission (87). Several other similar incidences contributed to rapid viral transmission across the country.

While India was exhibiting a steady recovery rate: 48.26%in June to 59.46% in July to 65.46% in August to 81.5% in September (29), numerous factors such as the massive movement of people (88), insufficient primary level health infrastructure(89), and paucity in administrative preparedness(90) continued to hamper mitigation efforts. On the upside, the case study of the country's capital New Delhi that had been able to mitigate the active COVID – 19 cases exemplifies the importance of critical Standard Operating Procedures (SOPs) for district surveillance, home isolation, and rapid testing. Moreover, the advent of plasma therapy showed promise in the context of the New Delhi response model (91).

The country has also reported success in the containment of the virus in Dharavi, Asia's largest slum(92). The rapid recovery rate in the area is mainly attributable to the 4Ts (Tracing, Tracking, Testing, Treating) strategy. Maharashtra's government leveraged aid from NGOs, local doctors, volunteers, and utilized more than 50 mobile clinics to conduct

door to door testing in this area. Although India is doing better than some of the other worst-hit countries in terms of the recovery rate and deaths per million population, the importance of mass testing and a strong focus on preventing the virus's spread cannot be understated.

4.2 The United States of America

"As of 30th September 2020, there were a total of 7.19 million COVID – 19 cases in the United States of America. With an estimated 205,998 deaths and a case fatality rate of 2.9 percent"(93).

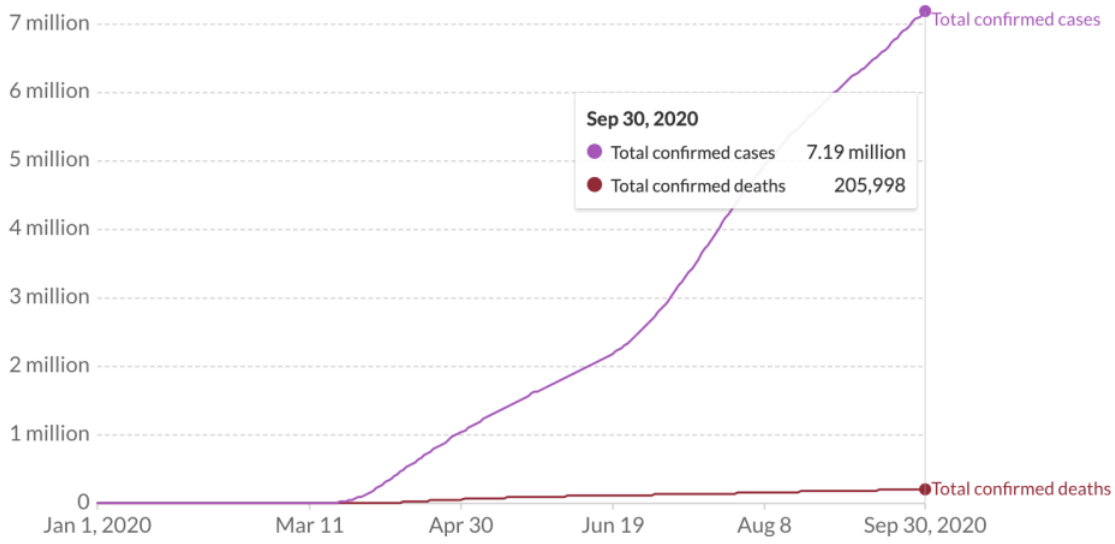

Fig 8: Total confirmed COVID – 19 cases and total number of recorded deaths in the United States of America onward of January 2020 to September 2020 (Source: OurWorldinData)(30)

Diagnosis and testing

After receiving reports of confirmed COVID – 19 cases from Japan and Thailand, the Centres for Disease Control (CDC) began screening of incoming passengers into the United States at air terminals across Los Angeles, San Francisco, and New York. (94) The index COVID – 19 case in the United States was reported on 20th January, a man returning to the country on the five days prior after having visited family in Wuhan. (95). The following week, a woman residing in Chicago, who had returned from Wuhan,

transmitted the virus to her husband, who tested for COVID – 19 by the end of the month. This was the first sign of local transmission in the country (96).

In Santa Clara, California, the earliest reported death of COVID – 19 occurred on 6th February, though the CDC did not report the death till the penultimate weeks of April. Subsequent investigations determined that COVID – 19 had been circulating in the state of California as early as January (97). Across the county, the CDC began investigating opportunities to mitigate viral transmission. Initially, "sentinel surveillance" was implemented in Honolulu, New York, Chicago, Los Angeles, Seattle, and San Francisco. The CDC began shipping coronavirus testing kits to labs, but early tests were contaminated, handicapping the response(98). As a result, only a minuscule portion of tests were administered during the initial months. Results from limited initial testing indicated community transmission as COVID – 19 was spreading among individuals independently of travel history(99).

During mid-February, people who tested positive for COVID - 19 aboard the Diamond Princess cruise in Japan were flown back to the country despite CDC's discouragement. In the subsequent weeks, out of the 21 confirmed COVID-19 cases in the US among repatriated individuals, 18 were traced to individuals from the Diamond Princess cruise (100). At the time, merely three laboratories in the state of Nebraska, California, and Illinois had diagnostic capabilities to detect COVID – 19 (101). On February 25, the CDC issued the first official public warning to prepare for a local outbreak(98). Following delays in re-issuing validated CDC test kits, the Food and Drug Administration (FDA) sought to improve access to testing by issuing an allowance to certified laboratories capable of performing high-complexity testing to “develop and use validated COVID-19

diagnostics before completing a review of their Emergency Use Authorization (EUA) requests"(102). The announcement was made on February 29th.

Although RT-PCR based assays remained the predominant mode of diagnostic testing across the country, several novel and complementary diagnostic strategies also came into consideration. In March, the FDA mandated allowance of developing serological tests (103) in the hopes of their administration, following the establishment of their accuracy and reliability (102). The FDA also broadened authorization of a saliva-based COVID – 19 tests through an EUA(104). The test enabled diagnosing individuals who could not access a collection center to get tested or individuals at a high risk of contracting COVID – 19 due to their age or comorbidities.

By the first weeks of March, EUAs had been granted to more than 20 diagnostic tests. The testing capacity of the country scaled – up from 32 to 44000. More than forty-five states were performing tests without a doctor's approval in the subsequent weeks for either commercial or CDC labs. Despite these figures, there continued to be shortages in testing kits. As a consequence, the actual burden of COVID – 19 could not be correctly estimated. Public health and administrative officials alike began to anticipate a steep increase in the number of cases as the testing capacity across the county scaled up to 50,000 – 69,000 tests per day(105). By the end of March, "the United States had the highest number of confirmed COVID – 19 cases in the world and had surpassed both Italy and China" (93). It is estimated that as many as 80 percent of Americans that presented with flu-like symptoms in March were infected with COVID – 19 instead. A third of these individuals testing positive for COVID – 19 would have amounted to an estimated 8.7 million infections (106).

In the last week of March, with an exponential number of increasing cases, the city of Chicago began renting a large number of unoccupied hotel rooms to transfer coronavirus patients in need of isolation(107). Care facilities and isolation centers were extended to include two hospital ships belonging to the U.S Navy. The first of which arrived in Los Angeles, USNS Mercy, on the 27th of March (108) and the other, which arrived in New York City, USNS Comfort, towards the end of the month.(109). Sports and entertainment buildings were repurposed to field hospitals. Among others, the Fairgrounds, for instance, was repurposed to a medical facility(110). States like California began procuring vacant hotel rooms, motels, and inns to serve as COVID – 19 emergency spaces, quarantine centers, and temporary homes for homeless individuals. EUAs were granted to more than 50 COVID – 19 tests, and the country's testing capacity increased to more than an estimated 230,000 tests per day (111).

By the final weeks of April, the U.S. had >900,000 cases of COVID – 19 and a death toll greater than 50,000 translating to a fatality rate of 5.68%. In April, many deaths were being reported from nursing homes that did not have access to test kits. Several states, including Maryland and New Jersey, recorded a 20 – 50 percent of total deaths from nursing homes(112). Less than four months after the pandemic, in the final week of May, 100,000 Americans had died of COVID-19, and by June, two million COVID – 19 cases had been reported (93).

One of the first states to declare a crisis standard of care was Arizona in July. This allowed legal provisions for medical care centers to provide substandard treatment to certain patients, prioritizing others in greater need of these services instead (113). In July, the U.S. reached the grim milestone of three million COVID – 19 cases with an estimated 150,000 COVID – 19 related deaths. This number expanded to four million by the end of

the month, to five million at the start of August, and then to six million by August 31st (93).

The virus was exhibiting signs of progressively uncontrollable community spread(114). Consequently, medical facilities began out – of – state transfers of new patients or refusing the admission of new patients, entirely. This occurred across several states, including Michigan through April and March, Washington and New York in June, and in Idaho, Louisiana, and Texas in July. Dozens of hospitals across Florida were also severely affected. Multiple hospitals across the state of Mississippi began transferring patients out of state in August (115). In the penultimate weeks of August, CDC modified its earlier recommendation that "testing was recommended for anyone who has come into contact with someone who had COVID-19" to an updated message informing the public that they did not need to be tested if they were not exhibiting symptoms (116). This was distressing, as by this time, asymptomatic patients were widely recognized as transmitters of the virus. Moreover, universal testing had been deemed as an essential step to curtail COVID – 19 transmission.

The guidelines were reverted to the original recommendation in September when it was discovered that the coronavirus taskforce operating through the aegis of the "Department of Health and Human Services (DHHS)" had updated the guideline on the CDC website despite several objections raised by CDC scientists (117). By September 30th, and at the time of writing this paper, the number of cases had reached 7.19 million (93) with an estimated 205,998 deaths (*Fig. 9).*

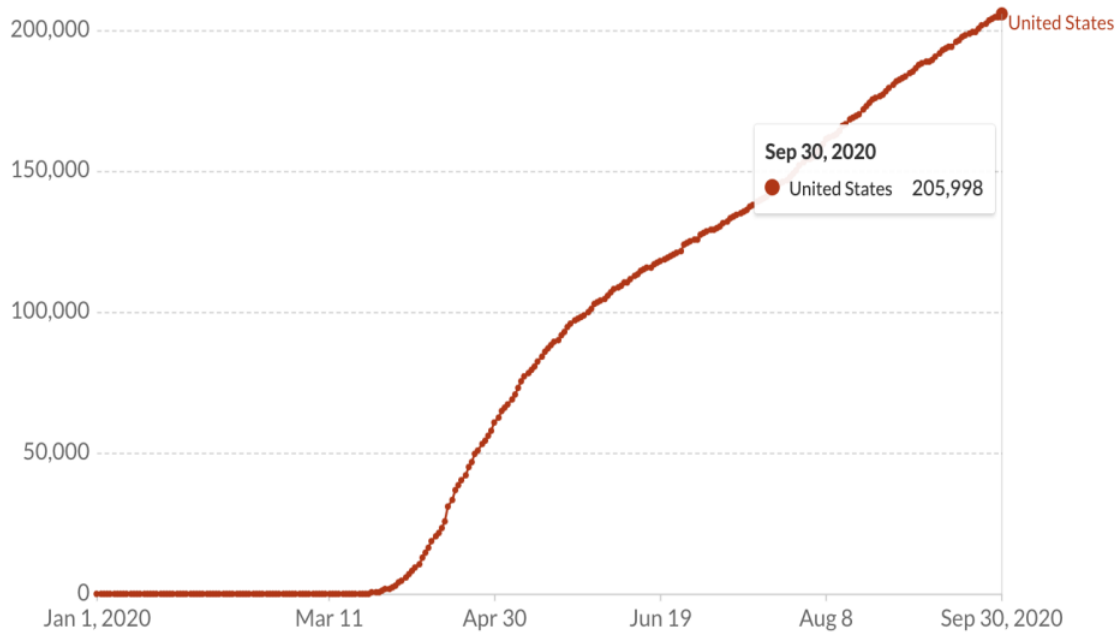

Fig 9: Total number of recorded deaths in the United States of America onward of January 2020 to September 2020 (Source: OurWorldinData)(30)

Mobility Restrictions

On the 31st of January, United, American, and Delta airlines put forward a suspension of their flights between the USA and China commencing early February(118). The Federal Government announced that travel restrictions would come into effect in the subsequent weeks. The restrictions prevented the entry of foreign nationals into the country from China. The Government also mandated a "14 – day quarantine" for individuals coming from the Hubei province. In January, an estimated 375,000 flew into the country from China, of which 4,000 were from Wuhan. This number reduced to 40,000 in February and March following travel restrictions (119). By the end of February, restrictions similar to those on China were extended to "foreign nationals who had visited/come from Iran in the last 14 days"(120).

On 12th March, the CDC issued a recommendation against any non-essential travel to China, several states within and across Europe, Iran, Malaysia, and the Republic of Korea. The Department of State, in the subsequent weeks, issued advisories to its citizens not to

“engage in international travel and urged those abroad to arrange for an immediate return to the United States” (121). Suspensions of routine visa benefits at all American international embassies worldwide were declared soon after the release of these advisories (122).

On March 16th, "15 Days to Slow the Spread"—a series of CDC recommended guidelines on self-isolation, adherence to maintaining distance, and protection of high-risk individuals were released by the Federal Government (123). Additionally, recommendations for school closures and avoiding gatherings of more than ten people were put forward. Travel restrictions on European countries belonging to the Schengen Area were also put into effect (*Fig. 10*), and State Departments began issuing advisories to citizens for avoiding all forms of international travel (124), (125), (126).

Fig 10: By the penultimate weeks of March, the U.S. extended restrictions on entry to foreign nationals who had traveled to/returned from 28 European countries within the past 14 days.(124) Conditional entry of American citizens, permanent residents, and their immediate families was granted. However, those returning from any of high-risk countries were mandated to undertake health screenings and submit to quarantines and monitoring for up to 14 days. Flights from all restricted countries were required to land at one of 13 airports where the United States Department of Homeland Security (DHS) conducted "enhanced" screenings(125). An estimated 241 foreigners, who had recently traveled in China and Iran, were denied entry to the United States between the moths of February and March(126). Source: BBC

On March 28, the Federal Government backtracked on an earlier claim of enacting a lockdown of three states *viz.*, Connecticut, New York, and New Jersey (127) opting instead "to issue a travel advisory and voluntary travel limitations within these states"(128).

Lockdown measures

With initial signs of community transmission of the virus, the state of California, in March began issuing lockdown measures urging residents to "stay at home" barring essentials. The order also instructed prioritizing services to individuals already presenting with sickness across multiple levels of health systems. In the weeks following, similar orders, in varying degrees of severity, were issued by multiple states across the country.

By the 21st of March, governors in California and New York had announced almost all types of businesses' closures and urged individuals to stay indoors. (129). "At the height of the March/April lockdown, 42 states had stay-at-home orders in place."(130) (131) (132) (133). In the month of April however, protests across the country hampered state mandated lockdown measures (*Fig. 11*).

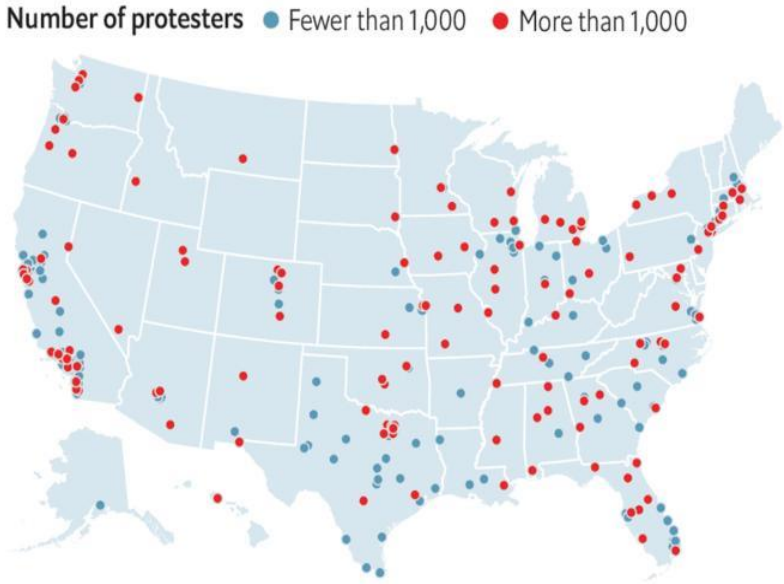

Fig 11: By the middle of April, large scale protests in several U.S. states against government-imposed lockdowns began. They ranged in size from a few hundred people to several thousand and were widely shared on social media with encouragement from the U.S. president.(132) The protests, mostly organized by conservative groups(130) denounced the economic and social impact stay-at-home orders, business closures, and restricted personal movement and association were having, and demanded that the "re-opening" of their states(131). The protests were internationally condemned for being unsafe and ill-advised.

By May 1, there had been large -scale demonstrations in more than half of the states across the country. Considering the political pressure and increasing demands, several governors of state began to take steps to lift the restrictions. Starting in late May, another series of large-scale protests ensued in at least 200 U.S. cities in response to police brutality killing of George Floyd. These raised concerns of a resurgence of the virus due to the proximity of and high population density of people across protests.(133) Source: BLM protests, social distancing and COVID – 19 by D.M Dave, A.I Friedson, K Matsuzawa, J.J. Sabia and S.Safford, June 2020, NEBR Working Paper, CDC

As a consequence of the protests, southern states were prematurely reopened and later went on to become new hotspots, reporting higher mortality rates among younger populations (134). "An estimated 5.35 million individuals lost their employer-sponsored health insurance between February and May with many southern states being the hardest hit by coverage losses" (135). In July, the U.S. Public Interest Research Group and numerous independent academics and professionals drafted a joint letter requesting the Federal Government to "shut it down now and start over". Requests multiplied in the months of July onwards until August, with many experts requesting for lockdown extensions for "six to eight weeks."

In response to the requests and in light of the recent surges in cases, several states shelved plans to reopen. “As of early August, as many as seventeen states had imposed new restrictions, and among them, seven had paused reopening. The surge in cases and growing evidence on aerosol transmission led to stricter mask wearing policies (136). At the time of writing this paper, more than 30 states had a universal mask policy, and while school reopening was underway, majority of the largest school districts had switched to telelearning/online teaching” (58), (128).

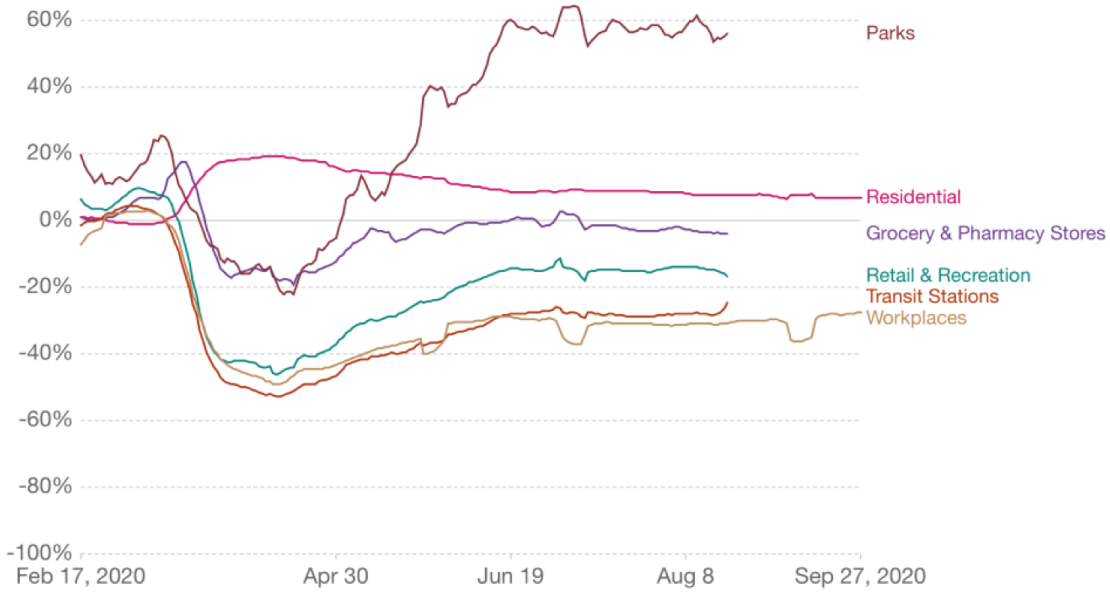

Fig 12: The change in mobility across the country since the beginning of the pandemic. The data shows how visitors changed across categorized places when compared to baseline days – The median value from the 5 – week period from January 3rd – February 6th, 2020. The index has been smoothened to the rolling seven-day average. Movement in the parks increased onward from the months of April to August probably in consequence to the large-scale protests and public demonstrations following the killing of George Floyd. Source: Google Mobility Reports(57)

Legislative and policy response

Through its Health Alert Network (HAN), the CDC issued an official health advisory on the 8th of January. The CDC also set up an incident management structure for streamlining the coordination of public health actions across national and international levels (137).

29th January was the day when the U.S. President set up the "White House Coronavirus Task Force, to facilitate and administer endeavors to relieve the spread of COVID-19 in the United States" (138). Following CDC's official advisory to the American public, informing them to prepare for an outbreak, the President appointed the Vice President to coordinate the national pandemic response. The "Coronavirus Preparedness and Response Supplemental Appropriations Act, 2020" was passed on March 6th. The act provided $8.29 billion to stimulate the pandemic response and included "more than $3 billion for the research and development of vaccines, therapeutics, and diagnostics, $2.2 billion for the CDC and $950 million to support state and local health agencies" (139).

On March 13th, the United States government declared the COVID – 19 a national emergency. In the weeks following the announcement, the Federal Emergency Management Agency (FEMA) was tasked with procuring essential health supplies and medical equipment (140). On the 18th of March, the Federal Government approved the Families First Coronavirus Act, which provided, among other benefits, free COVID – 19 testing and emergency paid leaves to employees affected by the pandemic (141). On the 25th of March, a third stimulus package entitled the "CARES Act" amounting to $2 trillion was unanimously passed in the Senate (142).

On April 21st and 23rd, the Senate and House passed a bill of around $485 billion via the Paycheck Protection Program under the CARES Act provision(s). The bill enabled COVID – 19 tests to be administered across the United States and unlocked an estimated $74 billion for hospitals' funding. It was signed to the law on the 24th of April (78), (143). According to the Oxford COVID – 19 Government Response Tracker (*Fig. 13)*, The United States scored high on its response to COVID – 19.

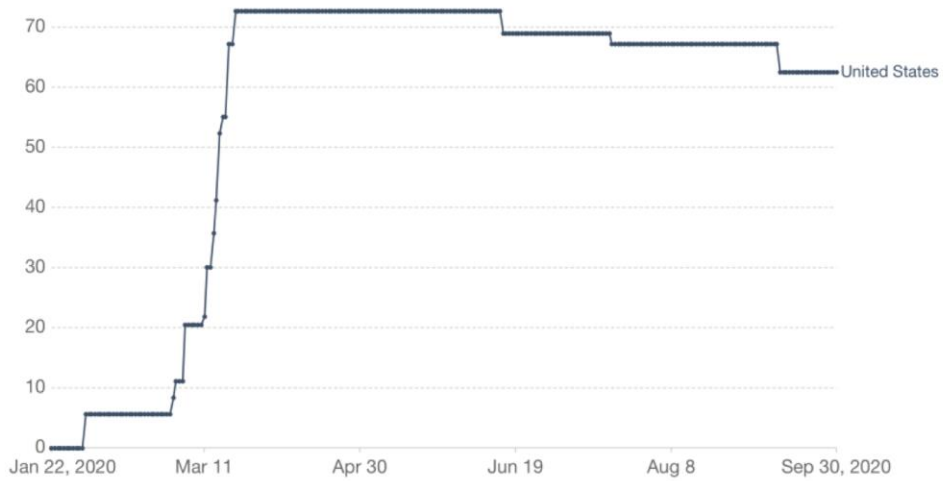

Fig 13: Policy and legislative response scores of the United States measured in accordance to the Oxford COVID – 19 Government Response Tracker. The country had a score >60 as of September 30th. The score is a composite measure based on nine response indicators including school closures, workplace closures and travel bans, restricted to a value from 0 – 100 (100 being the strictest) In case of policies varying at the sub-national level, the index is shown as the response level of the strictest sub-region. Source: Oxford Stringency Index(76)

Infrastructure scale-up

Throughout February, the U.S was slow to ramp– up manufacturing production and distribution of necessary treatment supplies, specifically, PPE (144). "While an estimated 11.5 million N95 masks and 30 million surgical masks were accounted for in the Strategic National Stockpile (SNS) in March, they represented only 1.2 percent of the requirement when compared to the anticipated need during the pandemic" (145). Notwithstanding this, essential medical supplies needed for COVID – 19 continued to be exported from the U.S. to different nations till March 17th (146).

Consequently, by the end of the month, several facilities began reporting shortages of face masks(147). 13% were out of face shields, and 25.2% were reporting shortages of gowns (148). Despite leveraging the SNS, the distribution of supplies remained uneven, with only a fraction of the states receiving the supplies they had requested(149).

On March 22nd, FEMA was directed to build eight medical stations with a high bedding capacity across California, Washington, and New York. The National Guard supported by the US Army, was leveraged for building these centers (150). In the weeks following, the Federal Government enacted the Defence Production Act (DPA) to leverage medical equipment production through industries (151). This allowed the Government to exert control on the industrial production of specific goods and equipments. Additionally, the enactment allowed the government to allocate supplies, provide industry incentives, limit export of medical equipment, and allow cooperation among companies. ‘At this time, the Federal Government also ordered General Motors to make ventilators (152). Despite these measures, supply problems continued to persist throughout August (*Fig. 14*) (153), (154), (155). 42% of nurses across the country faced shortages of PPE, with as many as 60% resorting to using single-use equipment for as long as six days (156),(157). While the DPA was effective in increasing the production of ventilators, it was not as effective in producing N95 masks.

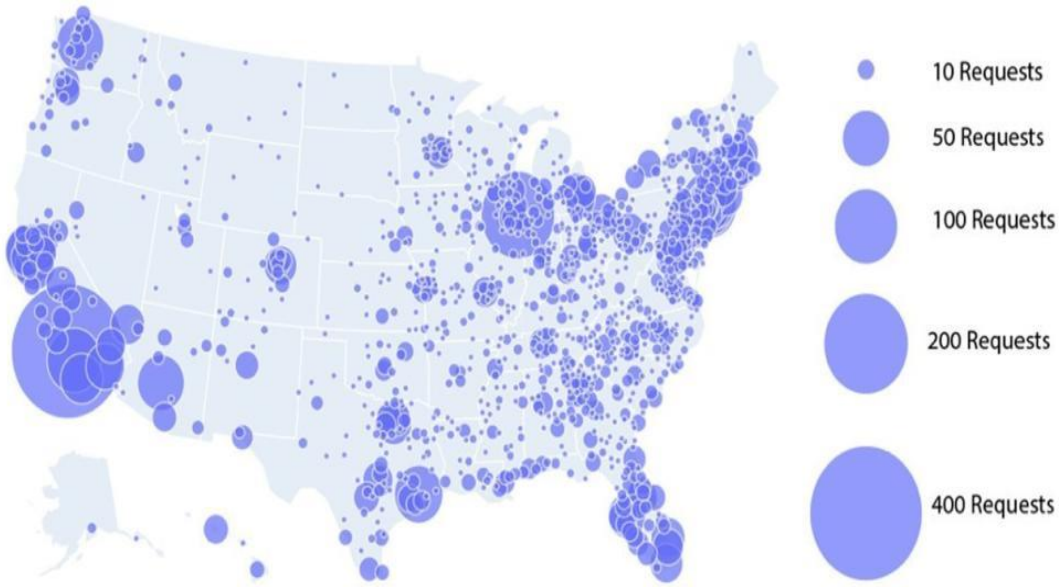

Fig 14: Map showing the number of PPE requests received by states across the USA. In March, a federal government's health inspection of 323 hospitals in late March, indicated "severe shortages" of test supplies, "widespread shortages" of PPE, and other strained resources due to extended patient stay awaiting test results.(155)

By the end of the month, several states across the country were competing with each other and the federal government for multiple medical supplies including N95 and surgical masks, ventilators, gowns, etc.(156). Meanwhile, even as states scrambled to purchase supplies at inflated prices from third party distributors (some of which later turned out to be defective), hundreds of tons of medical-grade face masks continued to be shipped by air freight to foreign buyers in China and other countries. Widespread shortage essential medical equipment across multiple states ensued onward of April.(157)

In mid-April, employees at hospitals in New York City reported not having enough dialysis machines and were being unable to cater to a high percentage (20 percent) of COVID-19 patients in the ICU in need for dialysis as a result of kidney failure. This was further compounded by a reported a shortage of dialysis nurses, since many had contracted COVID-19 due to lack of PPE.(158) Source: Cision

By September, DPA provisions exempting manufacturers from antitrust laws had not been operationalized to encourage collaboration in N95 production, and till that point, the legislation had relied on mask production primarily through major manufacturers. While the Federal Government eventually expanded the provisions of the DPA to manufacturers like Honeywell and 3M (158) for increasing N95 mask production, the supply fell hundreds of millions of units short. Supply shortages were also in part due to an exponential increase in demand that the country had witnessed with the resumption of various industrial activities. Additionally, the California wildfires also added to the already high N95 mask demands (159).

Discussion

The United States of America has faced multiple pandemics and infectious disease outbreaks throughout its history. Dating back first to 1918 with the Spanish Flu (160), the Asian Flu outbreak of 1957 (161), the 1968 Hong Kong Flu pandemic (162) till the most recent Swine Flu pandemic of 2009(163). The country has had experience in dealing with adverse infectious disease outbreaks exemplified by the 2019 Global Health Security Index, which ranks the U.S. to be the "most prepared" nation in the entire world(17).

However, significant lapses and delays in action contributed to “a lack of effective viral containment. The slow progress and dissemination of testing throughout February delayed adoption and the use of social distancing guidelines. This resulted in exponential growth of cases in March, creating an excessive strain on an overloaded health infrastructure” (164). “It is estimated that if social distancing policies had been implemented just two weeks earlier, U.S. deaths due to COVID-19 could have been reduced by up to 90 percent”(164).

Throughout March, the President repeatedly promoted hydroxychloroquine and chloroquine as ‘game-changing’ COVID – 19 treatments in the absence of scientific backing (165). Both of these have since been proved ineffective against the virus as a therapeutic (166). Repeated promotion of the drugs by the President led to panic buying within the country and in several overseas states of Africa and South Asia, causing a shortage of these drugs (167). Even as testing capacities increased across the country, delays were noted in the reporting of tests due to glaring shortages in supply. Epicentres of the virus faced “significant shortages of hospital beds, treatment supplies, PPE, and healthcare workers.” The sharing of leadership between the many components of governments and private group(s) lacked coordination, with “exact roles, authorities, and responsibilities constantly shifting. In some instances where the Federal Government should have taken the lead (as instructed by national pandemic response plans and emergency laws), the responsibilities were shifted to the states”.

“By June-July, administrative leadership devolved almost entirely to state and local governments, with organizations like the National Governors’ Association (NGA) playing a leading role in coordinating between state governments” (128). An abundance of inconsistent messaging and misinformation flowed from the White House administration leading to confusion and an erosion of trust (168). Moreover, the “politicization of mask wearing and other public health measures contributed to the lack of collective action”(169). While testing and contact tracing capacities increased across the country, delays in test reporting continued to impede the timely implementation of contact tracing measures. A lot of these issues could have been circumvented by a (currently non – existent) national testing and tracing strategy(170). In September, allegations mounted against the DHHS meddling with COVID-19 Morbidity and Mortality Weekly Reports (MMWRs) further undermined social trust and confidence in

responding to the pandemic (171). Vital information with regards to hydroxychloroquine as an ineffective therapeutic against the virus was delayed by several months (172). This led to the condemnation of the current administration for tampering with scientific reporting at a time of crisis by physicians and public health experts alike(173).

In the current situation, despite an ongoing increase in the levels of patient volumes, "U.S. Census data illustrates that delayed medical care is at 40%"(174). From an epidemiological standpoint, "the convergence of reopened economies and uncontrolled community spread has created a new group of at-risk essential workers to monitor, e.g., teachers and barbers"(128). With the approaching flu season, public health experts have expressed concerns about an added burden on the country's diagnostic capabilities(175). In the wake of the pandemic, multiple academicians, scientists, and policy advocates have urged the United States to adopt healthcare policies that are the norm in most other wealthy nations including, universal childcare(176), paid sick leave(177), increased investments in Public Health (178) and Universal Healthcare Coverage (179). On the upside, care delivery services across the country are slowly returning to pre-pandemic levels(180). "Telehealth utilization across the U.S had greatly increased(128),(181), and several temporary flexibilities (e.g., originating site and provider eligibility) had the potential to translate themselves into permanent mandates by law"(182). "Emerging treatments (Remdesivir, Dexamethasone, Monoclonal Antibodies, and convalescent plasma) have improved care for severely ill COVID-19 patients(183). Several states have banded together to create the first multi-state testing strategy and deliver rapid antigen tests, an approach that was showing promise"(184). "Vaccine development was also making headway, with some candidates entering phase 3 clinical trials(185). The U.S. Federal Government is determined to distribute 300 million doses of the vaccine by January 2021(186). While the move would certainly play a vital role in returning to

normalcy in light of the missteps during the COVID – 19 response, key questions around vaccine safety, efficacy, prioritization, accessibility, and affordability remain"(128). Nevertheless, "if continued outbreaks and recent moves by major employers to extend work-from-home to summer of 2021 (187) are any indication, the fight against COVID-19 in the U.S. is far from over"(128).

4.3 Nigeria

As of 30th September, there were 58,647 reported COVID-19 cases in Nigeria (*Fig. 15*) In the weeks leading the 30th, 480,874 tests had been conducted and 48,569 people were estimated to have recovered from the virus with 1,111 recorded deaths(93).

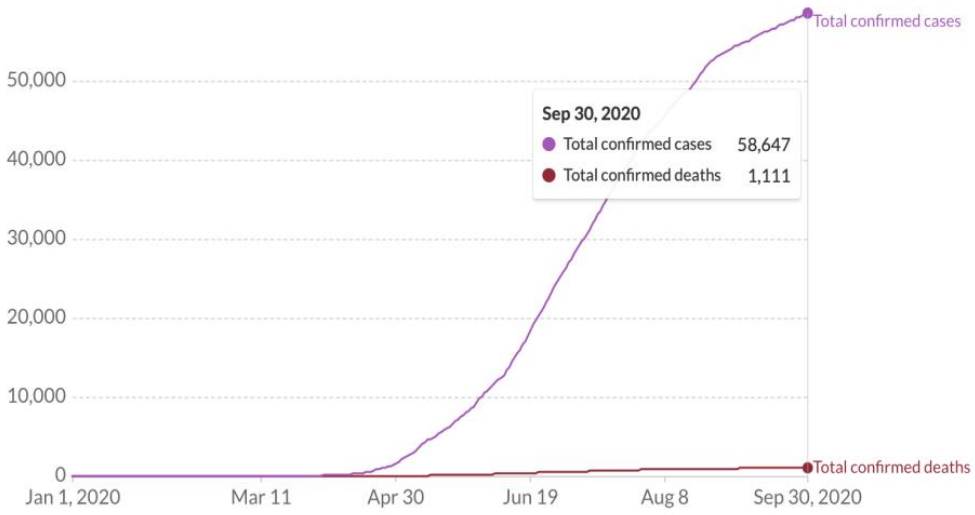

Fig 15: Total confirmed COVID – 19 cases and total number of recorded deaths in Nigeria onward of January 2020 to September 2020 (Source: OurWorldinData)(30)

Diagnosis and testing

The Federal Government strengthened surveillance at five international airports across the country during the last weeks of January. Measures such as temperature checks at the Lagos, Kano, FCT, Enugu, and the Rivers airport were initiated(188). Despite its strengthened surveillance, the first COVID – 19 case was reported in Lagos on the 27th of February. The index case, an Italian returning to the country during the final weeks of

February via the Murtala Muhammed International Airport from Milan (189), tested positive for the virus in one of the state's biosecurity isolation and testing facilities (190). The primary strategy following the identification of the index case in Nigeria was contact tracing. However, the implementation of the contact-tracing measures in the country was challenging due to a lack of support and cooperation from citizens returning to the country. They reportedly filled incorrect phone numbers and fake contact addresses in the various entry points across the country (191).

"The entirety of confirmed cases of COVID-19 in the first 30 days in the country were imported by returning travelers" (192). A month after recording its preliminary case, ten states across the country had 81 clinically confirmed cases (192). The number of positive cases began increasing exponentially by April, reaching 232 cases by the first week (193), (194).

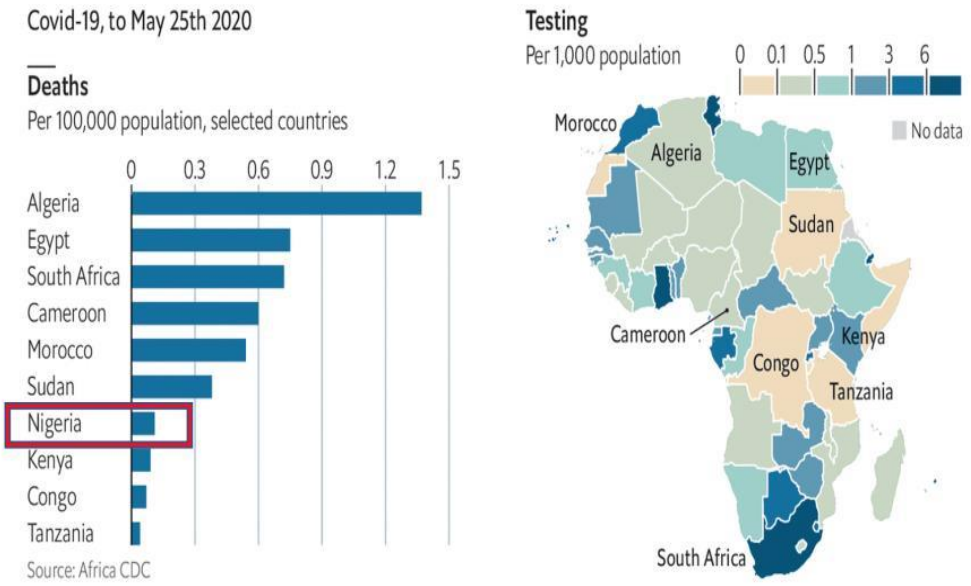

Fig 15: The African Centre for Disease Control (Africa CDC) (198) had trained experts from Nigeria and 15 other African countries on the diagnosis of COVID-19 using Polymerase chain reaction (PCR), during the early months of the pandemic and as of early June, majority of the tests (In Nigeria) were conducted using Polymerase Chain Reaction (PCR) tests in molecular laboratories. Studies to validate the integrity of the Rapid Diagnostic Test (RDT) kits continued on the side. In the weeks following, the NCDC planned to add Gene-Xpert machines to laboratory infrastructure when they became available.(199) Despite the capacity response, the number of deaths recorded across the country kept increasing as the CFR increased from 1.2% (on March 27) to 3% on April. The case fatality rate from COVID-19 in Nigeria was among the highest in West Africa (196)

On April 1, signs of community transmission were first publicized. This became more evident in the weeks following with 203 positive cases whose sources of infection remain indeterminate(199) Between February 27 and June 7, 76,802 persons had been tested in Nigeria. This was a very low number in comparison to the county's estimated 200 million population(196). Moreover, COVID-19 testing had to be conducted in 'runs'; each run taking an average of six to seven hours. Per person, diagnostic results took between 20 and 48 hours to be ready. While efforts were made to reduce the timing (to 12 h), due to limited testing and treatment resources 2020), the Federal Government targeted only those in pressing need of testing. Source: Africa CDC

From May 18 to June 7, the relative increase in COVID – 19 cases became more pronounced. 6,527 COVID – 19 cases corresponded to a 52% increase in the total number of positive cases (195).

By the first week of June, all of Africa had reported COVID – 19 cases, and while generalized testing was ramping up across the globe, this was not possible in Nigeria due to glaring shortcomings in laboratory and testing infrastructure (*Fig. 15*) (196). By the end of the month, a cumulative estimated 138,462 COVID – 19 diagnostic tests had been conducted in Nigeria (197). In July, the country was able to administer merely 2,500 tests a day and in the absence of universal testing, these were primarily directed toward symptomatic patients and their immediate contacts.

Mobility restrictions

"A multi-sectoral National Emergency Operations Center (NEOC) heralded by the Nigerian Centers for Disease Control (NCDC) was mobilized to manage the national response to COVID – 19"(198). One of the first mandates of the Presidential Task Force (PTF), inaugurated on the 9th of March, was to issue travel advisories to citizens across the country (199). Citizens that had either visited/traveled from 13 COVID-19 countries deemed 'high-risk', were denied entry into Nigeria (199).

While the NCDC Port Health Services began the monitoring of self – quarantine of individuals coming through the airports, many individuals that arrived before the imposition of the ban had not complied with the recommended 14 – day isolation (192). Non – compliance hampered the implementation of contact tracing, which in turn led to a delay in closures across several of Nigeria's entry points (200). To further restrict mobility, the PTF and NCDC issued interstate mobility restrictions onwards from March.

Lockdown restrictions

Lagos, Ogun, and the FCT announced 4 – week lockdowns effective onwards of 30th March in their states, with hopes for abetting COVID – 19 transmission within their communities. The lockdown was applicable across all sectors, with exceptions for essential service workers. Initial relaxations from the first week of May replaced total shutdowns with mandated curfews from 6 AM – 8 PM. While interstate bans continued, relaxed lockdowns indicated the government's intentions for gradually reopening the country's already fragile economy (201).

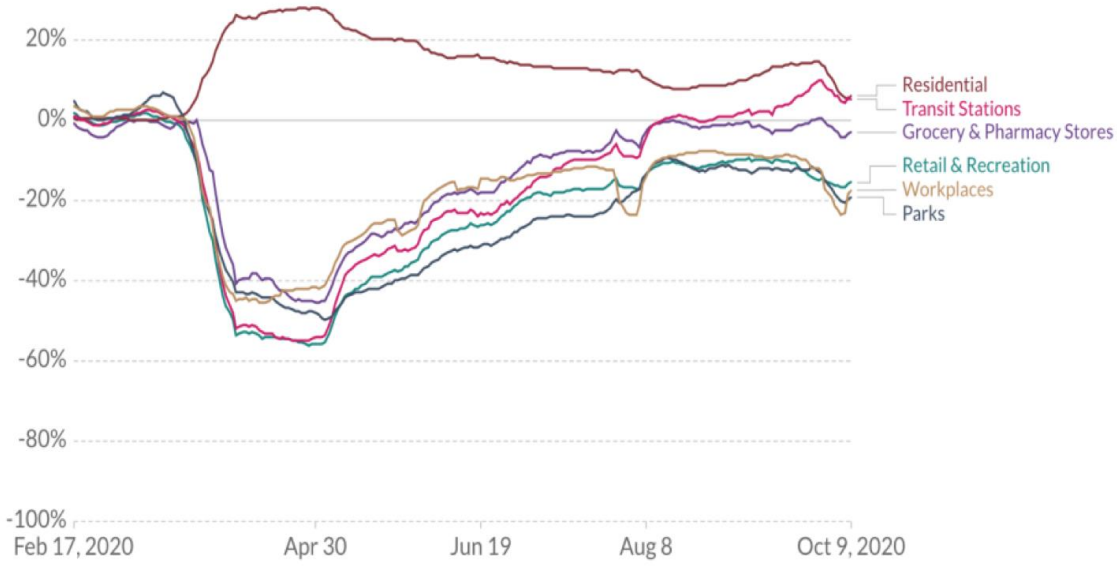

Fig16: The change in mobility across Nigeria since the beginning of the pandemic. The data shows how visitors changed across categorized places when compared to baseline days – The median value from the 5 – week period from January 3rd – February 6th, 2020. The index has been smoothened to the rolling seven-day average.

Legislative responses

For most legislative and policy decisions surrounding the COVID – 19 response, the country's presidency assumed leadership, specifically, the PTF and various Ministries, Departments, and Agencies (MDAs). The former, which included members from the Ministries of Health, Information, and Humanitarian affairs, also assumed the role of advising the president on technical decisions on lockdowns, press briefings, and procuring support from the private sector (202).

Within five days following the ban on flights from high COVID – 19 risk countries and the announcement of "a total closure of Nigeria's airspace and interstate borders" was initiated, (203) Federal Government grants were issued to fight COVID-19. The NCDC, among others, produced several guidelines aimed at mitigating the spread of the virus, including ones on wearing of non-medical face coverings, avoidance of public gatherings, social/physical distancing, and on the use of public transport (204).

The Federal Government announced an airplane to the NCDC for emergency responses along with "five billion Naira (US$ 12.5 million) special intervention funds" (205). The Epicenter of COVID – 19, Lagos mobilized an additional "ten billion Naira (US$ 25 million)"(195). The President also approved the conversion of "pilgrimage transit camps to isolation centers"(192) and issued advisories to all state governors for establishing minimum "300-bed treatment facilities, in preparation of an upcoming surge of COVID – 19 cases"(206). The responsibility for implementing palliative measures across Nigeria was primarily entrusted with the Federal Ministry of Disaster Management with support from Ministries of Social Development and Humanitarian Affairs (207). In conjunction, the ministries issued grants to low-income households across multiple states, approximating to 20,000 Naira. Food was donated to state governments, and the impetus was provided to existing primary school meal programs.

In May, the PTF was donated an isolation center with a bad capacity of 300 in order to "assist in the management of confirmed COVID-19 cases"(208). A dedicated basket fund for mobilizing resources across a range of stakeholders was also set up with help from the United Nations. Restructuring of the Treasury Single Account was also approved by

the President (209) to provide financial support to businesses, organizations, and individuals affected by the pandemic(210).

Infrastructure scale up

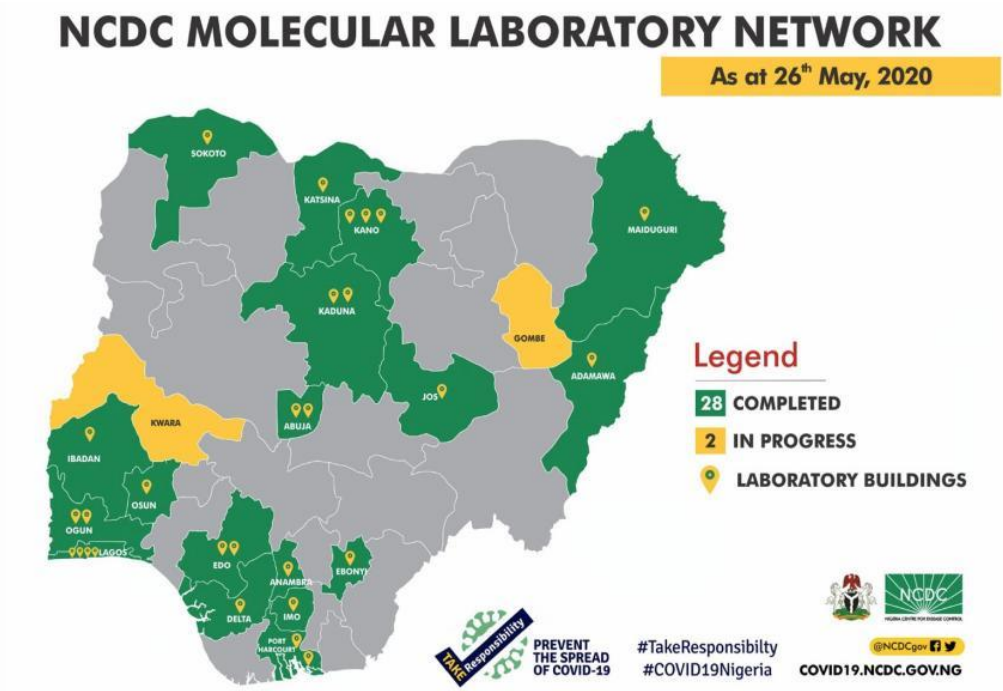

Fig 17: By June, the number of molecular laboratories with the capacity to test for COVID-19 across Nigeria increased from 5 to 23. However, private molecular laboratories were not leveraged for COVID-19 testing(196). More than one-third of the 36 states across Nigeria were without a testing laboratory. Test Samples were being exported to Abuja and other available molecular laboratories if any case was suspected from the states without testing centers.(196)

Nigeria had an estimated 350 ventilators and 350 ICU beds in July for its entire population before the outbreak. In April 2020, while the country acquired 100 ventilators, the government and public health experts expressed concern in light of the increasing caseload(216). By the end of the month, there had been a continuous rise in the number of cases and deaths across the country. Source: NCDC

The NCDC scaled up several molecular diagnosis labs across the country (*Fig. 17*). "The infection of healthcare personnel in Nigeria created apprehensions on overwhelming the already strained COVID-19 control efforts in the country. The Lagos State Government initiated the, Eko Telemedicine platform, to cater to COVID-19-unrelated health problems in the state" (211) to lessen patient burden on hospitals and to overcome the problems arising from infected healthcare personnel.

Discussion

The health system response to the coronavirus outbreak in Nigeria may be viewed as reactionary. By setting up isolation centers only after the confirmation of active cases in

the country, the Federal and State Governments exhibited a delayed response. Ogan state, where the first case was identified, did not have a molecular diagnostic laboratory. The patient had to be transferred to Lagos. A similar situation was observed across several states across the country, including Oyo, Abia, Sokoto, and Akwa Ibom) where medical equipment was procured by governments only after the identification of positive cases. Inadequacies in proactive preparedness across governments and communities partly accounted for the initial wave of panic and misinformation across the country (212). Glaring shortcomings in health infrastructure were exposed anew as a consequence of the pandemic – a significant contributor to the increasing trend of medical tourism observed among the Nigerian elite (213). As a whole, the country needs to reduce dependencies on foreign countries to overcome lacuna in its health infrastructure.

"The country's existing health facilities and equipment, including PPE, ICUs and ventilators, were grossly inadequate for an infectious disease outbreak like the COVID – 19" (192,197,214). While an attempt to scale up the country's infrastructure was undertaken, inadequacies across several states highlighted Nigeria's constant struggle to keep up with the increasing caseloads. Many countries have rapidly aggregated multisource data to spatially track cases and develop predictive modeling for infection by using a combination of smartphones, GPS, credit card transactions, and satellite technologies to track infection rates and potential hotspots. Currently, vital data is not mainstreamed into Nigeria's public policy and decision making(215). Moreover, the recently released "National Digital Economy Policy and Strategy 2020-2030" does not articulate a policy framework for creating either a (national) data infrastructure to leverage data in providing more efficient and responsive public services or for regulations on the ethical and responsible use of data by government and its agencies (78),(216).

According to the Oxford COVID – 19 Government Response Tracker (*Fig. 18)*, Nigeria has exhibited an inconsistent score on its response to COVID – 19.

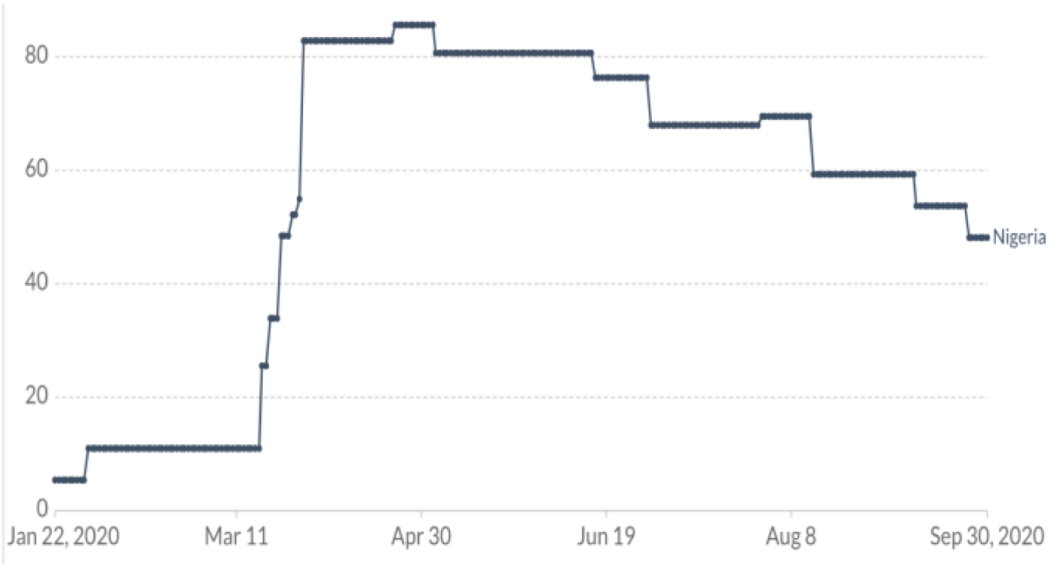

Fig 18: Policy and legislative response scores of Nigeria measured in accordance to the Oxford COVID – 19 Government Response Tracker. The country had a score 48.9 as of September 30th. Source: Oxford Stringency Index(76)

5. Conclusions

In the absence of well-proven therapeutic interventions and a vaccine, the response to mitigating COVID – 19 was primarily undergirded by non-pharmaceutical measures of social distancing, mask wearing, ramping up testing capacities, and emphasizing the importance of hygiene. However, analysis of country-specific responses to COVID -19 showcase the range and breadth of country-specific strategies that were adopted in line with several unique, contextual factors such as health care infrastructure, politics, and population dynamics. The common shortcoming that most countries faced stemmed primarily from a delay in the implementation of measures to mitigate the spread of the virus. Case study analysis of these countries demonstrated how prevention efforts, even with isolation and quarantine, were hampered by an ongoing shortage of reliable tests, making it arduous for health officials to warrant judgments regarding the duration and extent of isolation strategies. The global response has also highlighted the importance of

investments in and scale-up of global public health infrastructure, especially primary healthcare investments. In conjunction with improved disease surveillance systems with the ability to integrate data on new outbreaks and an indigenous technological capacity to scale up and manufacture essential health supplies, these investments would improve a country's epidemic preparedness and response capacity. In complex population dynamics, inequity, and poverty, measures of contact tracing, quarantine, and hygiene are not always feasible. Widespread adherence to policy occurs through community engagement, which requires enormous amounts of public cooperation and trust. A healthcare system embedded in the community, close to local governments with an active engagement with the vulnerable in the community, potentiates the cultivation of trust and social capital, both of which are key from a public health perspective. The analysis also highlights the need for additional dimensions to be included in the GHS index for predicting the response of countries to the COVID-19 pandemic and its impact on the countries themselves. A recent study in PLoS validates this by stating, "The high ranking of the US on the GHS index with regards to its preparedness against the threat of infectious agents is inconsistent with current data from the COVID-19 pandemic" (217). The US is currently among the top nations with the highest number of cases per million individuals, while Nigeria and India, ranked significantly lower on the index, are better off among a few of the study indicators. This also sets the need to establish, collect, and ascertain the accuracy of data-enabled monitoring for a realistic assessment of health systems preparedness. "Importantly, the GHS index does not directly engage authorities responsible for emergency preparedness in their respective countries and other key stakeholders"(217), its evaluations are based on information provided by individual countries. This methodology leaves the potential to overlook vital shortcomings in a nation's ability to face infectious disease outbreaks like the COVID – 19. For instance, the United States may have more COVID-19 testing capacity than any other country.

However, an over-reliance of public and private labs on automated testing equipment locked the country into supply chain bottlenecks due to limited proprietary chemical kits being produced only by a handful of manufacturers. "In contrast, countries ranking lower in the GHS index that fared relatively well during the pandemic made significant investments in scaling up infrastructure in a relatively short period and in shutting down activities associated with a heightened risk of COVID – 19 infections. The discrepancy between the GHS index ranking and the actual response of countries based on COVID-19 performance indicators likely indicates that the GHS index may have underestimated the level of preparedness of some countries while overestimating that of others."(217)

6. Study limitations

COVID – 19 is a currently ongoing pandemic, and multiple components of country responses and knowledge of the virus are constantly changing. In addition to the study analysis being limited in its timeline from January to September, the indicators are limited in their scope to analyze the entirety of health systems response, wholistic coverage of which was beyond the study's scope. While the W.H.O. has developed COVID – 19 response monitoring and evaluation frameworks, the complete picture of health system response would be comprehensive only in retrospect, after the pandemic's culmination. Moreover, it is beyond the scope of the current study to undertake a comparison between the countries that were selected for analysis. Multiple questions pertaining to the utility of death rates as a means to judge a countries' success in battling COVID-19 have been raised(218). Moreover, the issue of a high number of "excess deaths" in many countries is an essential factor to consider. A country's geography and demography also play a significant role in the ways countries have been affected by the pandemic(219). Penultimately, there continue to be wide variations in data collection across several COVID – 19 parameters "This has an impact on perceptions of a country's response to the crisis. The daily figure for COVID-19 deaths in a country might, for example, only

include those dying in hospitals while other nations include deaths in care homes in reporting their figures"(220). The exact figures of COVID-19 cases are likewise recorded diversely in numerous nations, with some including forthcoming tests and others discounting the outcomes from certain laboratories (220). There are also large contrasts in COVID – 19 testing strategies. Nigeria, for instance, "prioritized testing frontline workers and people who were ill and in need of hospitalization."(221). Other countries like India and the USA progressed to adopting blanket testing models. This embroils that one nation's information might be less finished than others, making its death rate per affirmed case higher than others. All of which suggests that, while certain broad deductions on country-specific COVID-19 response(s) can undoubtedly be gauged through an idiographic approach, caution needs to be exercised when making generalizations and direct comparisons. The study's key strength lies in its idiographic approach, which allows for independent analysis of country specific health systems responses.

7. Way forward

In the wake of the COVID – 19 pandemic, global leaders are being challenged by problems they have never experienced. Overcoming these difficulties will require future research to examine the multiple interconnected dimensions of pandemic preparedness and response. "Researching the viability of long-standing policy assumptions, just as the tragedies of the pandemic have raised questions about the efficacy of many of our current health systems to protect the communities who have been most impacted by COVID-19 would be beneficial"(220). In light of findings from this study, the dire need to assess health system performance indicators' is also underscored. Future research focused on exploring performance indicators with regards to overall health systems preparedness and responses against infectious disease outbreaks (such as the GHS index) would be tremendously important in the times to come.

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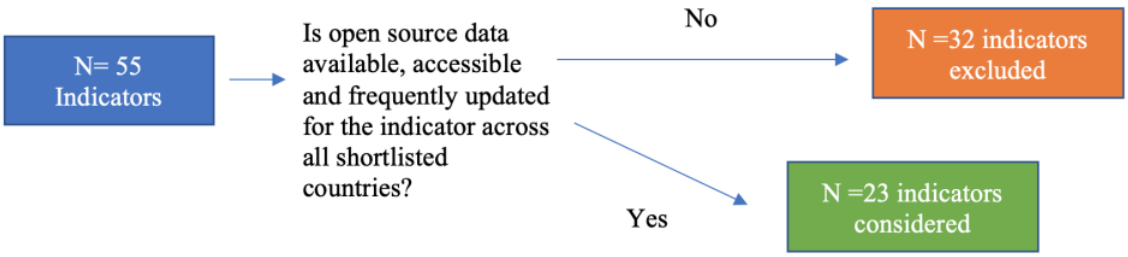
Annexure A: Indicator review

COVID – 19 health systems response indicators reviewed	
1	Restrictions on mass gathering events (Public events and events of national importance)
2	Countries having comprehensive national COVID – 19 plans
3	Number of COVID – 19 tests conducted (relative to population size)
4	Timely adoption of comprehensive contact tracing measures
5	Changes of COVID – 19 case density
6	Changes to the Case Fatality Rate (CFR)
7	Stay at home restrictions
8	Measures for school closures
9	Measures for restrictions on interstate mobility
10	Measures for Airline/International travel restrictions
11	Coordination of public information campaigns
12	Changes in mobility trends
13	Economy & employment stimulation packages
14	Scale up of protective equipment (PPE) and ventilator manufacturing
15	COVID – 19 specific policy changes
16	Setting up of isolation wards and COVID – 19 specific treatment centres
17	Increased engagement in vaccination and drug research
18	“Gross Domestic Product (GDP) expenditure on Health and Healthcare”
19	Stringency of measures adopted by government authorities

20	Weekly number of new confirmed cases nationwide, disaggregated by age and sex
21	Portion of the population wearing masks
22	Number of PCR tests vs serological tests
23	“Percentage of countries that have mechanisms in place to capture community feedback (e.g., community meetings, hotlines, health volunteer networks, social listening, surveys, etc.)”
24	Number of asymptomatic patients
25	“Percentage of countries where a RCCE coordination mechanism is active and formally implemented (e.g., multi-sectoral RCCE team, working group, task force)”
26	Weekly number of new confirmed cases in health care workers by sex
27	Percentage of countries testing for COVID-19 and reporting routinely through established sentinel or non-sentinel ILI, SARI, ARI surveillance systems such as GISRS or other WHO platforms.
28	Number of health workers trained in IPC
29	Number of ICU beds provided to priority countries through EMT or similar surge mechanism
30	Number of PPEs available for frontline health workers “Number of health workers trained in case management of COVID-19 cases”
31	Number of consultations availed through telemedicine
32	Effect on routine immunization of children in the context of COVID – 19
33	Number of surgeries postponed due to COVID – 19
34	Number of universities that transitioned to online classes
35	Number of exams conducted online/Open Book Exams (OBE) mode
36	Number of people followed through contact tracing
37	Number of psychiatric consultations availed during lockdown periods
38	% of beneficiaries of economic stimulation packages/job and enterprise support
39	% of people identified to have COVID – 19 antibodies as part of zero surveillance programs
40	% of international travellers quarantined
41	Number of autopsies for COVID – 19 performed
42	Number of recovered persons who donated convalescent plasma
43	Number of recovered persons who received convalescent plasma
44	% COVID – 19 recoveries from preliminary anti-viral therapies
45	% COVID – 19 patients admitted with comorbidities
46	% of people adhering to social distancing guidelines
47	% of people adhering to wearing masks
48	State-wise Ambulance availability
49	Restaurants and bar closures
50	Gym closures
51	Number of makeshift treatment/quarantines centres
52	Number of COVID – 19 specific IEC materials disseminated
53	Number of COVID – 19 specific insurance successfully claimed
54	Out of pocket expenditure on COVID – 19 testing and treatment
55	State-wise provisions for clean water and sanitation services

A total of 55 health systems response indicators were identified as part of the literature review. For the study, exclusion criteria of data availability, accessibility, and frequently of updating was applied and 23 indicators were shortlisted for the study. Most of the identified indicators were also used for analysing health system responses in infectious disease outbreaks of the past.



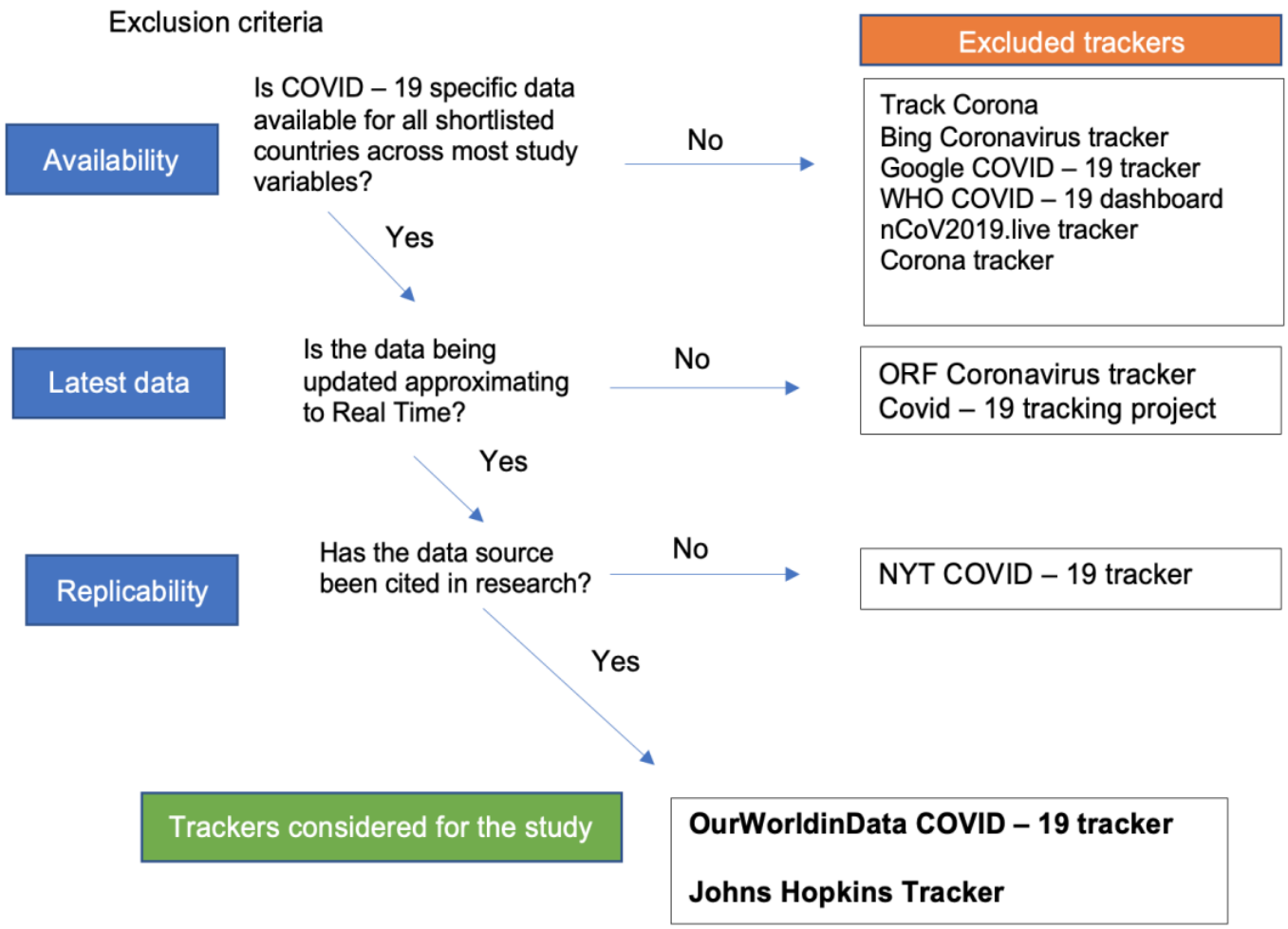
Health systems response indicator	**Used in the analysis of health systems response of previous infectious disease outbreaks**
Number of tests conducted (relative to population size)	Every major infectious disease outbreak(222) (SARS, MERS, influenza, H1N1, Ebola, etc.)
Contact tracing measures	Most new and contagious infectious disease outbreaks (Ebola, SARS, etc.)(223)
Changes in case density	Every major infectious disease outbreak(222) (SARS, MERS, Influenza, H1N1, Ebola, etc.)
Case fatality rate	Every major infectious disease outbreak(222) (SARS, MERS, Influenza, H1N1, Ebola, etc.)
Stay at home restrictions	Spanish Flu(224), SARS(225)
Restrictions imposed on national events/public gatherings	Spanish Flu(224), SARS(225)
School closures	Spanish Flu(224), SARS(225), H1N1(226)
Workplace closures	Spanish Flu(224), SARS(225)
Closures of places of worship	Spanish Flu(224), SARS(225)
Cancellation of public events	Spanish Flu(224), SARS(225)
Public transport closures	Spanish Flu(224), SARS(225)
Restrictions on interstate mobility	Spanish Flu(224), SARS(225)
International travel restrictions	SARS, Ebola,
Coordination of public health campaigns	Every major infectious disease outbreak(222) (SARS, MERS, Influenza, H1N1, Ebola, etc.)
Scale-up of protective equipment (PPE) and ventilator manufacturing	COVID – 19 specifics
Disease-specific policy changes	Every major infectious disease outbreak(222) (SARS, MERS, Influenza, H1N1, Ebola, etc.)
Setting up quarantine wards and isolation centres	Spanish Flu(224), SARS(225), Ebola(227)
Increased funding toward vaccine and drug developments	Every major infectious disease outbreak(228)

	(SARS, MERS, Influenza, H1N1, Ebola, etc.)
GDP Expenditure on health	Every major infectious disease outbreak (SARS, MERS, Influenza, H1N1, Ebola, etc.)
The stringency of measures adopted by govt. authorities	Spanish Flu(224), SARS(225)
Changes in mobility trends across sectors	COVID – 19 specific
Economy and stimulation packages	Ebola(229)
Jobs, income and enterprise support	Ebola(229)

Annexure B: COVID – 19 tracker review

Tracker	Description	Maintained by
Coronatracker	Community-based project powered by over 460 volunteers from across the globe	Independent
ORF Coronatracker	A COVID – 19 tracking project by ORF	Observer Research Foundation
Google Covid – 19 tracker	A COVID – 19 tracking project from Google	Google
OurWorldin Data Tracker	The synergistic exertion between specialists at the University of Oxford and the Global Change Data Lab	Oxford University
WHO COVID – 19 dashboard	Vital COVID – 19 statistics monitoring by the WHO	WHO
Track Corona	Made by students at Stanford, University of Virginia and Virginia Tech	Independent
Johns Hopkins Tracker	"COVID – 19 tracker developed by Johns Hopkins To provide the most up-to-date information the COVID-19 data and trends"	Johns Hopkins University
Bing Coronavirus Trackers	A COVID – 19 tracking project by Bing	Microsoft
nCov2 tracker	"A COVID – 19 case tracking project"	Worldometer

Covid tracking project	"Volunteer organization launched from The Atlantic and dedicated to collecting and publishing the data required to understand the COVID-19 outbreak"	Atlantic
NYTimes COVID – 19 tracker	New York Times COVID – 19 tracker	NYT



Annexure C: Indicators used in the study – by data source and type

Sub – index 1: Diagnosis & Testing			
Indicator	**Description**	**Source**	**Data Type**
"Number of Covid – 19 tests conducted* *Irrespective of test type"	"Total number of Covid 19 tests conducted / per 1000 people"	Our World in Data JHU tracker	Quantitative
"Total number of cases"	No. of COVID – 19 +ve cases recorded	JHU tracker	Quantitative
Timely adoption of comprehensive contact tracing measures	Classification **No tracing** **Limited tracing** – country applied exclusion criterion applied to some cases *i.e. n*ot all COVID – 19 +ve cases were traced **Comprehensive tracing** – All cases included for contact tracing measures	Our World in Data JHU Tracker	Quantitative
Changes in COVID – 19 case density	"Daily confirmed cases / total number of confirmed cases. (Plotting the data in this way enables us to see when different countries bent the curve) Moving average since the onset of the pandemic will be analyzed"	Our World in Data JHU Tracker	Quantitative
Changes in Case Fatality Rate (CFR)	COVID – 19 Deaths / COVID – 19 cases *1000 Changes in CFR would be captured from the onset of disease outbreak	Our World in Data	Quantitative

Subindex 2: Mobility Restrictions			
Measures on Public Transport closures	Classification **No measures** **Recommended closures/volume reduction** **Enforced closing or prohibition on the use**	Our World in Data	Quantitative
Measures for Restrictions on interstate mobility (Travel between cities)	Classification **No measures** **Recommendations for movement restriction** **Complete locking of national borders**	Our World in Data	Quantitative
Measures for International travel restrictions	Classification **"No measures** **Screening measures** **Quarantine arrivals from high-risk regions** **Ban on high-risk regions** **Total border closure"**	Our World in Data	Quantitative + Qualitative
Changes in mobility trends across: Retail & Recreation Supermarkets & pharmacies Parks Public transport Workplaces Residential areas	"Visitor numbers to specific categories of every location / change relative to baseline days before the pandemic outbreak. Baseline days represent a normal value for that day of the week, given as median value over the pandemic period"	Google mobility reports	Quantitative

Sub – index 3: Lockdown Measures			
Measures for stay – at – home restrictions	Classification **"No measures** **Recommended to not leave homes** **Required not to leave home except for daily exercise, grocery shopping and 'essential' trips** **Required to not leave the house with minimal exceptions (once a week allowance/only one person allowed to leave)"**	Our World in Data The OxCGRT project	Quantitative + Qualitative
Measures for school closures	Classification **No measures** **Recommended school closures** **Limited requirement** **All level requirements**	Our World in Data The OxCGRT project	Quantitative + Qualitative
Measures for workplace & commercial closures	Classification **No Measures** **Recommended closures** **Required for some workplaces** (**"**A country is coded as 'required closures' if at least some sub-national regions required closures") **All workspaces closed except for essential services**	Our World in Data The OxCGRT project	Quantitative + Qualitative
"Restrictions on public gatherings"	Classification **Restrictions on very large public gatherings (>1000 people)** **Restrictions on large gatherings (100 - 1000 people)** **Restrictions on medium sized gatherings (10 – 100 people)** **Restrictions on small gatherings (<10 people)**	Our World in Data The OxCGRT project	Quantitative + Qualitative (for specifics)

Cancellation of public events of national importance/festivals	Classification **"No measures** **Recommended cancellations:** A country is coded as 'recommended' if at least some sub-national regions required cancellations **Enforced cancellations"**	Our World in Data The OxCGRT project	Quantitative + Qualitative
Closure of places of worship	Restrictions & ban on churches, temples, religious gathering, etc.		Qualitative
Sub – index 4: Legislation			
Covid – 19 specific policy changes	Legislation/guidelines/SOPs and other policy relating explicitly to COVID – 19	International Labour Organization (ILO)	Qualitative
Public information campaigns	Classification: **No public information campaigns** **Coordinated information campaigns**: "A country is coded as having these campaigns if at least some sub-national regions have implemented them"	Our World in Data The OxCGRT project	Quantitative + Qualitative
Economy & employment stimulation packages	Classification: **No income supports** **Covered <50% of lost salary** (Avg. values) **Covered >50% of lost salary**	Our World in Data The OxCGRT project International Labour Organization (ILO)	Quantitative + Qualitative
Jobs, income & enterprise support	Classification: **No Debt relief packages** **Narrow relief packages**: some freezing on financial obligations (e.g. Loan repayments, banning evictions, etc.)	Our World in Data The OxCGRT project International Labour Organization (ILO)	Quantitative + Qualitative

	Broad relief packages		
GDP Expenditure on Health	%allocation of GDP allocation on public health/healthcare infrastructure	World Bank	Quantitative
The stringency of measures adopted by government authorities	"The OxCGRT project calculates a Government Stringency Index, a composite measure of nine of the response metrics. including school closures, workplace closures, and travel bans, rescaled to a value from 0 to 100 (100 = strictest response)"	The OxCGRT project	Quantitative
Subindex 5: Infrastructure scale-up			
Covid – 19 specific treatment units	How much non – hospital infrastructure was converted to COVID – 19 specific isolation and treatment units	PubMed, NCBI, Local Ministries of Health, Our World in Data, News, etc.	Quantitative
Supply chain	Effect on networks between companies and its suppliers to produce and distribute a specific product to the final buyer.	PubMed, NCBI, Local Ministries of Health, Our World in Data, News, etc.	Qualitative
Scale up of drugs, PPE and medical equipment	Scaling up production and scale up of PPE, ventilators, Face shields, etc.	PubMed, WHO, NCBI, Local Ministries of Health, Our World in Data, News, etc.	Qualitative
Vaccine Research and development	Clinical vaccine candidates across each country	PubMed, NCBI, WHO, Local Ministries of Health, Our World in Data, News, etc. The Global Health Network Vaccine Tracker	Qualitative