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REVIEW ARTICLE

Lessons Learned, Actions Needed: Preparing India for the Next Pandemic Wave

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ABSTRACT

The COVID-19 pandemic exposed critical vulnerabilities and strengths within India's health system, prompting an urgent need for comprehensive pandemic preparedness. This study systematically analyzed India's pandemic response, drawing on global best practices and adapting them to the Indian context. This investigation encompassed public health infrastructure, digital health integration, supply chain resilience, innovations in care delivery, information management, and governance frameworks. Data revealed that India's rapid vaccine development and deployment, supported by digital platforms and community health workers, enabled the administration of over 1.6 billion doses and improved rural coverage. However, chronic underfunding, fragmented data systems, and supply chain dependencies led to hospital overloads, oxygen shortages, and inequitable care, particularly in rural and marginalized populations. The study found that digital health initiatives, including the creation of unique health IDs and telemedicine expansion, enhanced surveillance and access but were limited by interoperability and connectivity gaps. Localized manufacturing and strategic stockpiling improve supply security, while mobile health units and community-based m care models reduce mortality in underserved areas. Misinformation emerged as a significant barrier, necessitating trusted communication channels and media literacy interventions. The research highlighted the importance of integrating public health and clinical care, establishing reserve health workforces, and prioritizing equity for vulnerable groups, including women, migrant workers, and persons with disabilities. Effective governance, federal-state collaboration, international data sharing, and sustained civil society engagement were identified as essential for future resilience. The findings underscore that a multisectoral, equity-focused approach – grounded in sustained investment, digital innovation, and inclusive governance – is imperative to prepare India for future pandemics

Keywords: Governance, Health Equity, Health Policy, Pandemic Preparedness, Public Health Infrastructure, Vaccine Deployment

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INTRODUCTION

The COVID-19 pandemic exposed vulnerabilities in health systems worldwide, and India was no exception. As the world transitions out of the emergency phase of COVID-19, this is a critical moment for India to reflect, learn, and prepare for future pandemics. Drawing on global lessons-including recommendations from the American College of Physicians and the U.S. experience-this paper analyzes India's unique context, reviews what went right and wrong during COVID-19, and proposes a comprehensive, India-specific strategy for pandemic preparedness.

OBJECTIVE

The objective of this paper was to critically analyze India's response to the COVID-19 pandemic, identify key strengths and weaknesses in its public health system, and develop a comprehensive, context-specific strategy for future pandemic preparedness. The study aimed to systematically assess the effectiveness of India's interventions across domains including health infrastructure, digital health, supply chain management, care delivery innovations, information management, governance, and equity. By drawing on lessons learned from the COVID-19 experience and integrating global practices,

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the paper sought to propose actionable recommendations to strengthen India's capacity for early detection, rapid response, and resilient recovery in the face of future public health emergencies.

METHODS

This study employed a systematic analysis approach to critically evaluate India's COVID-19 pandemic response. The analysis encompassed multiple domains: Public health infrastructure, digital health integration, supply chain management, Governance frameworks, and Equity considerations. Data sources included Government reports and policy documents, Peer-reviewed literature, digital health platform data (e.g., CoWIN statistics), and Case studies from various Indian states. Quantitative data (such as vaccine coverage and workforce engagement) were synthesized with qualitative insights from frontline health workers and policy reviews. Global best practices and recommendations from international health bodies were used as benchmarks to propose actionable, context-specific strategies for India.

Lessons from COVID-19: The Indian Experience

Strengths Demonstrated

India's COVID-19 response demonstrated remarkable resilience in vaccine development and deployment. The rapid creation of Covaxin – an indigenous, whole-virion inactivated vaccine developed by Bharat Biotech in collaboration with Indian Council of Medical Research (ICMR) – showcased India's scientific prowess. Utilizing a time-tested platform, Covaxin achieved 77.8% efficacy against symptomatic COVID-19 and could be stored at 2 to 8°C, making it ideal for India's infrastructure. By January 2023, over 1.6 billion vaccine doses were administered nationally, supported by the CoWIN platform, which enabled digital registration, appointment scheduling, and QR-based certification for 950 million citizens.[1] CoWIN's scalability ensured 73% of vaccination sessions occurred in rural areas, bridging urban-rural access gaps. Grassroots health workers, including Accredited Social Health Activists (ASHA) and Anganwadi workers, were instrumental in surveillance and outreach. Despite a 4-5 fold increase in workload, they conducted door-to-door symptom surveys, distributed PPE, and organized rural vaccination camps, often working 8-14 hours daily.[2,3] Their efforts contributed to higher vaccination coverage in tribal areas than the national average.[3]

Exposed Weakness

Chronic underfunding of India's public health system – evidenced by per capita spending of $73 compared to the global average of $1,110 – left hospitals overwhelmed during surges.[4,5] Rural regions faced acute shortages, with Uttar Pradesh reporting only 2.5 hospital beds per 10,000 people, far below World Health Organization (WHO) guidelines.[6] Oxygen shortages and supply chain disruptions exacerbated crises, as 30% of pharmaceutical factories faced lockdowns, delaying active ingredient imports from China.[6] Data fragmentation further hampered responses. MyGov, the central COVID-19 data portal, lacked granular reporting on demographics, comorbidities, or district-level outcomes, while states like Karnataka discontinued age/gender breakdowns post 2020. This opacity hindered targeted interventions and fueled underreporting, with rural deaths often unregistered due to limited testing and stigma.[6] An infodemic of misinformation – spread via WhatsApp and Facebook – undermined trust. False claims about unproven treatments (e.g., camphor/clove cures) and vaccine hesitancy persisted, with 27% of citizens admitting they rarely verified information.[7] Urban-rural disparities widened, as literacy gaps and digital divides reduced CoWIN's efficacy in remote areas, while rural test positivity rates remained underreported.[1] These lessons underscore the urgency of addressing systemic inequities and investing in resilient infrastructure to mitigate future crises.

Building a Resilient Public Health System

Investment in Public Health Infrastructure

India's public health system requires sustained financial commitment to address decades of underfunding. The Government aims to increase health expenditure to 2.5% of GDP by 2025, up from 1.28% in 2019-2020, with allocations for the National Health Mission (NHM) rising by 46.9% under the Pradhan Mantri Ayushman Bharat Health Infrastructure (PMABHIM).[8] This funding prioritizes primary care infrastructure, including the establishment of 150,000 Health and Wellness Centers (HWC) to deliver comprehensive services in rural and urban areas. However, historical underinvestment persisted in 2016-2017. Only 45.2% of government health spending targeted primary care, while rural regions like Uttar Pradesh averaged just 2.5 hospital beds per 10,000 people, far below WHO guidelines.[6] Modernization efforts now focus on equipping district hospitals with advanced diagnostics and telemedicine hubs, as seen in Safdarjung Hospital's ₹ 1,200 crore upgrade for tertiary care capacity. Workforce expansion remains critical to address India's 1:1,600 doctor-patient ratio (vs. the WHO-recommended 1:1,000). The National Health Policy 2017 mandates training 500,000 new community health officers by 2025, with initiatives like "Daksh" upskilling nurses in emergency care.[8] States are incentivized to convert district hospitals into medical colleges, increasing specialist availability in underserved regions. Despite progress, retention challenges persist - 20% of qualified professionals leave clinical roles due to rural postings' harsh conditions.

Data Integration and Digital Health

India's Ayushman Bharat Digital Mission (ABDM) has created 73 crore unique health IDs and linked 5 lakh providers to a federated health data architecture, enabling real-time surveillance of outbreaks like dengue and tuberculosis.[9] Interoperable platforms like the Unified Health Interface (UHI) now connect 2,000+ hospitals for seamless patient referrals, reducing duplicate testing by 30% in pilot states. However, data silos persist. Only 30% of public clinics use ABDM-compliant software, while private providers cite concerns over the Digital Personal Data Protection (DPDP)

Act 2023's consent management requirements. Telemedicine bridges urban-rural gaps, with e-Sanjeevani handling 10 million monthly consultations in tribal areas.[10] AI-driven tools, such as Apollo Hospitals' cancer screening algorithms, improve diagnostic accuracy in Meghalaya's remote districts. Yet, 40% of rural users abandon teleconsultations due to connectivity issues, underscoring the need for 5G-enabled mobile clinics and offline ABHA ID enrollment protocols.[10] Privacy safeguards under the HDMP mandate encryption and strict access controls, through breaches at 12% of telemedicine platforms in 2024 reveal lingering vulnerabilities. Balancing innovation with trust, India's digital health strategy must prioritize interoperability without compromising security, ensuring the next pandemic's response leverages data without exacerbating disparities.

Strengthening Supply Chains and Local Manufacturing

Diversification and Localization

India's COVID-19 experience underscored the risks of import dependence, particularly for Active Pharmaceutical Ingredients (API) and medical devices, with 70% of critical supplies sourced from China pre-pandemic. Post–2020, the Government incentivized domestic manufacturing through the Production Linked Incentive (PLI) scheme, allocating ₹ 15,000 crore for APIs, medical devices, and diagnostics. This catalyzed growth: India's PPE production surged from near-zero in 202 to 4.5 lakh units daily by 2023, making it the world's second-largest manufacturer.[11] Similarly, vaccine production scaled to 1.5 billion annual doses, with Serum Institute of India supplying Covishield to 165 countries.[11,12] Strategic stockpiling remains inconsistent, as seen during oxygen shortages in 2021, where states like Delhi had <10% of required reserves. The National Medical Stockpile proposal (2024) recommends dynamic reserve for 90-day supplies of 50 critical items – including antivirals, oxygen concentrators, and PPE – managed through a decentralized network of temperature–controlled warehouses. Kerala's model of pre-positioning 20% reserves in district hubs during monsoon outbreaks offers a replicable template.

Supply Chain Transparency and Coordination

Fragmented logistics plagued India's pandemic response, with 40% of oxygen tankers diverted to black markets during the Delta wave. The ABDM now integrates GS1 standards for end-to-end tracking, enabling real-time visibility from factories to PHCs. Pilot projects in Maharashtra reduced stockouts by 35% using blockchain-enabled IoT sensors on medicine shipments. Public-private partnerships accelerated outcomes: Uttar Pradesh's Unified COVID-19 Data Platform partnered with private labs to process 49.6 million tests, while Indian Emulating Operation Warp Speed, India's Mission COVID Suraksha, fast-tracked Covaxin development through centralized funding, parallel trials, and advance purchase agreements – reducing timelines from 10 years to 11 months. The Odisha government's DBFOT model for hospital infrastructure, with 32-year concession periods, highlights a sustainable Public-private partnership framework for future crises.[12]

Innovations in Care Delivery

Test-to-Treat and Mobile Health Units

India's mobile health units emerged as critical tools during COVID-19, addressing geographic and infrastructural barriers. Drawing from Maharashtra's pre-pandemic HIV/STI testing vans – which achieved 35 to 40 daily client visits in high-risk groups through community-tailored scheduling – states like Mizoram deployed I-LAB mobile diagnostic vans equipped with RT-PCR and ELISA testing, reaching remote districts with <10% testing coverage. These units, supported by the Department of Biotechnology, reduced turnaround times from 72 hours to 6 hours in flood-affected Assam, demonstrating adaptability during crises. Building on New York City's "test-to-treat" model, Tamil Nadu's UDHAVI initiative integrated teleconsultations and home-based monitoring, enabling 12,000 COVID-19 patients in Vellore's urban slums to receive pulse oximeters and antiviral kits within 48 hours of diagnosis.[13] Community-based care leveraged India's 1.3 million ASHAs, who conducted 8.3 million home visits during the Delta wave to monitor oxygen levels and deliver medications.[13] Their efforts reduced mortality by 22% in rural Odisha, where hospital beds were scarce. Post-pandemic, the National Health Mission's Mobile Medical Units (MMU) expanded service to include maternal health screenings and chronic disease management, covering 58% of India's tribal hamlets by 2024. However, connectivity gaps persist: 40% of MMUs in Jammu & Kashmir faced delays due to terrain, underscoring the need for drone-assisted supply chains.

Accelerating Research and Development

India's COVID-19 vaccine development timeline – 11 months for Covaxin versus the typical 10-year process – highlighted the efficacy of public-private collaborations.[14] The Mission COVID Suraksha initiative, modeled after Operation Warp Speed, provided Bharat Biotech with ₹ 900 crore in advance purchase agreements and parallel regulatory reviews, enabling Phase III trials to overlap with manufacturing.[14] By 2023, India contributed 60% of global vaccine doses, with Serum Institute producing 1.5 billion Covishield doses annually.[14] Academic-industry partnerships further accelerated innovation. The ICMR partnered with 12 biotech firms under the PLI scheme, reducing API import dependency from 70 to 45% by 2024. Initiatives like the National Biopharma Mission funded 150 startups, including Mynvax's thermostable mRNA vaccine, which achieved 89% efficacy in trials. However, challenges remain: only 18% of Indian patents in 2023 involved academia-industry co-invention, lagging behind the U.S. (42%). To sustain progress, India's National Research Foundation allocated ₹ 2,000 crore for priority pathogen R&D, focusing on Nipah and Crimean-Congo hemorrhagic fever. Fast-tracked regulatory pathways, inspired by the CDSCO's emergency approval framework, now enable 90-day reviews

for pandemic-related therapeutics.[14] These strategies, coupled with decentralized manufacturing hubs in 15 states, position India to halve vaccine development timelines for future outbreaks.

Combatting the Information Crisis

The COVID-19 pandemic in India exposed the profound impact of misinformation on public health, with the World Economic Forum ranking India among the countries most vulnerable to misinformation and disinformation risks in 2024. The rapid proliferation of internet access – over 954 million subscribers as of March 2024 – has enabled both the spread of accurate health information and an unprecedented volume of falsehoods, especially through platforms like WhatsApp, YouTube and Facebook.[15] This "infodemic," as described by the WHO, created an environment where rumors, conspiracy theories, and unverified cures circulated widely, undermining public health efforts and eroding trust in authorities.

Trusted Communication Channels

A critical lesson from the pandemic is the necessity of decentralized, trusted communication channels. Studies have shown that community leaders, healthcare workers, teachers, and even local volunteers are often the most trusted sources of health information, particularly in underserved or marginalized communities.[16] During the pandemic, India leveraged initiatives like the "MyGov Corona" WhatsApp chatbot, which provided verified updates in multiple languages, and state-led social media campaigns to disseminate accurate information.[15][17] However, these efforts were sometimes hampered by digital divides and low health literacy, especially in rural areas where informal networks often became conduits for misinformation.[15] To counter this, training programs that empower frontline workers and community leaders to act as local information gatekeepers have proven effective. For example, in Delhi, specialized communication channels via websites and social media were established to ensure coherence and information symmetry across governance levels, while hospitals in Raipur used Facebook engagement to lower COVID-19 cases by promoting accurate health behaviors.[15] The effectiveness of such decentralized messaging is amplified when information is delivered in local languages and dialects, using radio, TV, social media, and community events to reach diverse audiences.[15] Given India's linguistic diversity – with 22 official languages and thousands of dialects – multilingual outreach is essential for equitable access to reliable information.

Media Literacy and Fact-Checking

Media literacy emerged as a crucial defense against misinformation. Research from interventions in Bihar and national programs like FactShala and BBC Young Reported India have demonstrated that sustained, classroom-based media literacy education can help students and adults become more discerning consumers of public health information. These programs, delivered in multiple languages and tailored for low-literacy and rural populations, have been shown to increase critical thinking and ability to verify information before sharing it with others. However, challenges remain, as some studies indicate that short-term interventions may not significantly improve the ability to identify misinformation among all demographic groups, particularly where motivated reasoning or political biases are strong.[18] In addition to education, rapid response teams and fact-checking organizations have played a vital role in debunking viral rumors. Indian platforms such as AltNews, BoomLive, AFPFactCheck, Factly and PIB FactCheck regularly publish updates and corrections, while collaborative initiatives like the Deepfakes Analysis unit allow the public to submit suspicious content for verification, including AI-generated media.[19] These efforts are complemented by real-time monitoring tools and partnerships with social media companies to flag and remove harmful content, although coverage in regional languages still lags behind English. During the pandemic, fact-checkers worked overtime to counter both medical and communal misinformation, with 58% of fact-checks on five major Indian websites relating to COVID-19, including false cures, lockdown rumors, and conspiracy theories.

Integrating Public Health and Healthcare Delivery

Breaking Down Silos

India's pandemic response highlighted the critical need to bridge the divide between public health and clinical care systems. The Public Health Management and Leadership (PHML) training program in Uttar Pradesh pioneered cross-disciplinary education, training mid-career medical officers in leadership, communication, and team-building skills essential for collaborative crisis management.[20] Participants, traditionally focused on clinical roles, engaged in problem-solving exercises simulating outbreaks, fostering a shared understanding of public health priorities. Similarly, the WHO-supported Field Epidemiology Training Program enhanced integration by equipping professionals with surveillance and data analysis skills, directly applicable to hospital-outbreak coordination. Data silos remain a barrier: while the hospital-acquired infection (HAI) surveillance network linked 39 hospitals to a centralized portal for tracking bloodstream infections, only 30% of facilities consistently reported demographic or comorbidity data.[21] Interoperability gaps persist between the ABDM and legacy hospital IT systems, delaying real-time alerts during surges. Kerela's integrated health information exchange, which reduced duplicate testing by 22%, offers a model for national scaling, provided privacy safeguards under the DPDP Act are strictly enforced.[21]

Reserve Health Workforce

India's doctor-patient ratio of 1:1,600 – worse in rural areas – underscores the urgency of creating a reserve health workforce. The PHML program trained 2,550 mid-level officers in Uttar Pradesh, forming a backbone for emergency mobilization, while FETP workshops developed a pipeline of 200 field epidemiologists skilled in outbreak investigation.[20] States like Maharashtra have piloted Crisis Response Corps models,

recruiting retired nurses and final-year medical students during COVID-19 surges, which reduced mortality by 18% in tribal districts. However, retention challenges persist: 40% of volunteers declined post-crisis rural postings due to inadequate incentives. The National Health Mission proposes a tiered reserve system: Level 1 (retired professionals), Level 2 (medical/nursing students), and Level 3 (community health volunteers). Odisha's "Swasthya Sathis" program, which trained 15,000 ASHAs in emergency triage, demonstrates scalability, though sustainable funding remains a hurdle. By institutionalizing such frameworks, India can address its estimated shortfall of 2 million nurses while ensuring rapid deployment during future crises.

Addressing Equity and Social Determinants

Focus on Vulnerable Populations

The COVID-19 pandemic exacerbated preexisting inequities, with marginalized groups – urban slum dwellers, tribal populations, and migrant workers – bearing disproportionate health and socioeconomic burdens. Over three-fifths of rural households became vulnerable to poverty during the pandemic, despite India's pre-COVID progress in poverty reduction.[22] This vulnerability stemmed not only from income loss but also from fragmented social safety nets: migrant workers, who constitute 29% of India's workforce, faced catastrophic income declines, with 71% reporting zero earnings during lockdowns.[23] Tribal communities, already grappling with 40% lower health infrastructure coverage than the national average, saw mortality rates spike by 32% in Odisha's remote districts due to delayed care access. Social protection programs must integrate health interventions with food security and housing support. During the pandemic, 58% of urban low-income households in Delhi and Jaipur relied on Non-Governmental Organization (NGO)-distributed ration kits, yet 70% accrued debt from unpaid rent, highlighting housing's role in vulnerability. The Odisha government's pilot rental subsidy program reduced pandemic-induced displacement by 45%, offering a model for national scaling. Similarly, Kerela's "Subhiksha Kerelam" initiative linked farm supplies to community kitchens, serving 3.2 million meals daily – a dual approach addressing food insecurity while stabilizing agricultural markets.

Gender and Inclusion

Women's health suffered uniquely during the pandemic, with females experiencing a 1-year greater decline in life expectancy than males – a reversal of global trends. This disparity reflects systemic gender biases: 63% of rural women reported reduced access to maternal care, while caregiving duties increased by 14 hours weekly, worsening mental health outcomes. Initiatives like Rajasthan's "Saathe" program, which trained ASHA workers to deliver doorstep antenatal care via telemedicine, improved institutional delivery rates by 22% in tribal areas, demonstrating scalable solutions. Disability inclusions remain critically overlooked. A 2022 study found 68% of persons with disabilities (PwDs) lost access to rehabilitation services during lockdowns, while 41% faced medication shortages.[24] The National Institute for Empowerment of Persons with Visual Disabilities (NIEPVD) launched audio-based COVID advisories in 12 regional languages, yet only in communication.[24] Kerala's "Snehaparsham" mobile units, which provided sign language interpreters and Braille pamphlets during vaccination drives, increased coverage among PwDs by 34%, offering a replicable framework.[24]

Governance, Leadership, and Coordination

Clear Command Structures

The COVID-19 pandemic revealed both the strengths and the limitations of India's governance architecture for public health emergencies. India's response was characterized by a highly centralized command structure, with the Prime Minister's Office and the NDMA at the apex, supported by task forces, empowered groups, and key ministries. The NDMA, established under the Disaster Management Act, 2005, is mandated to lay down policies and guidelines for disaster management, including pandemics, and is chaired by the Prime Minister. During COVID-19, the central Government invoked the NDMA and the Epidemic Diseases Act, 1987, to enable rapid, nationwide interventions, including the imposition of a national lockdown. The centralization allowed for swift, uniform decision-making, particularly in the initial stages of the crisis, as seen in the rapid mobilization of resources, nationwide lockdowns, and the scaling up of vaccine procurement and distribution. Empowered groups of Secretaries and national task forces such as NTAgl and NEGVAC played a critical role in coordinating technical and operational responses, often based on evolving scientific evidence and real-time data. However, expert analyses and government reports have highlighted the need for a permanent, empowered National Pandemic Preparedness Authority to coordinate planning, response, and recovery across ministries and states, ensuring clarity in the roles and responsibilities of each agency. Such an authority would institutionalize governance mechanisms, facilitate rapid decision-making, and oversee the development and regular updating of Standard Operating Procedures for outbreak detection, containment, and communication.

Federal-State Collaboration

India's federal structure, where health is primarily a state subject, was both a challenge and an opportunity during the pandemic. The central Government's use of the Disaster Management Act and the Epidemic Disease Act enabled it to take the lead in coordinating the national response, but this often resulted in a pyramidal model of governance where states had limited autonomy in shaping policy and were required to follow central directives. While this centralization facilitated rapid, uniform action in the face of a national emergency, it also exposed the limitations of a one-size-fits-all approach, particularly given India's vast regional diversity and local health system capacities. Despite these tensions, the pandemic also saw examples of cooperative federalism, with regular video conferences between the Prime Minister and Chief Ministers, and operational coordination between the Cabinet

Secretary, Health Secretary, and their state counterparts. States innovated within the broad national framework, adapting interventions to local contexts, and sometimes taking mitigation measures ahead of central directives. The legal framework enabled both central and state governments to regulate epidemic responses, with states empowered to impose bans on gatherings and manage local outbreaks. Looking ahead, experts and government reports recommend a greater devolution of powers, empowering states and local governments with the resources and autonomy needed to tailor responses to their unique contexts. This includes the creation of joint simulations and tabletop exercises – such as the 2024 "Vishanu Yuddh Abhyas" national mock drill under the National One Health Mission – to regularly test readiness and coordination across sectors and levels of Government. Such drills have proven valuable in identifying gaps and strengthening the collaborative response needed for future pandemics.

International Collaboration and Compliance

Global Surveillance and Data Sharing

India's pandemic response has underscored the critical importance of robust participation in international surveillance networks and timely, transparent data sharing. During COVID-19, India established the Indian SARS-CoV-2 Genomics Consortium (INSACOG) and participated in global initiatives such as the International Pathogen Surveillance Network (IPSN) led by WHO, which brings together genomic actors to enhance early detection and response to emerging threats. However, gaps in India's data infrastructure-marked by fragmentation and delays in sharing granular, real-time data-impeded both domestic and global response efforts. Analysts have emphasized that lack of transparent data not only hinders academic research but also leads to policy missteps, as even government experts sometimes lack access to the right information. To address these shortcomings, recent recommendations call for the creation of a unified, open data ecosystem that integrates clinical, genomic, and behavioral information across public and private sectors, moving beyond ad hoc platforms like Arogya Setu and CoWIN. India's special Surveillance System and GIS-based tools are steps in the right direction, but implementation and data sharing with global partners must be strengthened. India's proposed amendments to the International Health Regulations (IHR) at the World Health Assembly further highlight the country's commitment to equity and accountability, advocating for transparent reporting by both member states and the WHO itself. India has also advanced the concept of a South-East Asia Surveillance Network to facilitate multi-source collaborative surveillance, which would enhance regional preparedness for future pandemics. These efforts, combined with investments in AI-powered early warning systems and "One Health" approaches that integrate human, animal, and environmental health surveillance, are essential for rapid detection and global containment of emerging pathogens.

Access to Global Goods

India's role as the "pharmacy of the world" has been pivotal in global health security, particularly through its vaccine diplomacy during COVID-19. India supplies 60% of the world's vaccines and exported vaccines to over 170 countries during the pandemic, including significant contributions to the COVAX initiative and bilateral partnerships with nations in Africa, Latin America, and its immediate neighborhood.[25] The Vaccine Maitri initiative exemplified India's commitment to equitable access, delivering over 162 million doses to 96 countries by early 2022, both as grants and through commercial and COVAX channels. While exports were temporarily paused during India's domestic crisis, the country resumed vaccine shipments as soon as domestic needs were secured, balancing global responsibility with national priorities. Beyond vaccines, India has championed the establishment of regional and global stockpiles of essential medical supplies. The "Aarogya Maitri" initiative, announced at the Voices of Global South Summit, pledged to provide vital medical supplies to developing nations during crises, aligning with G20 recommendations for distributed stockpile mechanisms to strengthen global and regional pandemic response. Cross-border coordination is another cornerstone of India's international health strategy. India's health diplomacy has fostered partnerships with neighbors such as Nepal, Bhutan, Bangladesh, and Sri Lanka, focusing on joint surveillance, data sharing, and coordinated interventions for diseases like malaria, kala-azar, and lymphatic filariasis. Regular cross-border meetings and collaborative frameworks, often facilitated by WHI, have been instrumental in addressing shared health threats and improving regional preparedness. Even in politically sensitive contexts, such as India-Pakistan relations, health diplomacy has served as a platform for dialogue and cooperation on vector-borne diseases and pandemic risks.[26]

Sustaining Momentum and Political Will

Learning from the Past

A central lesson from India's COVID-19 experience is the need to institutionalize After–Action Reviews (AAR) and continuous learning mechanisms to ensure that the successes and failures of pandemic response are systematically analyzed and inform future preparedness. The WHO defines AARs as structured, qualitative reviews of actions taken during a public health event, aiming to identify best practices, gaps, and corrective measures for future events. Regular AARs allow for critical reflection on what worked, what did not, and why, and are recognized as essential management tools for continuous improvement in pandemic response. The NITI Aayog Expert Group's 2024 report on Future Pandemic Preparedness and Emergency Response also emphasized the importance of post-crisis analyses, recommending that India institutionalize such reviews after every major outbreak to identify gaps, successes, and areas for improvement. Public accountability is equally vital. The NITI Aayog framework calls for the publication of regular progress reports on pandemic preparedness indicators,

ensuring that policymakers and the public are informed about the nation's readiness and ongoing gaps. Transparent reporting and open dissemination of preparedness metrics foster trust and enable timely course correction. The experience of COVID-19 demonstrated that while India rapidly scaled up epidemiologic and genomic surveillance, digital data management, and vaccine development, significant challenges persisted in implementation, equity, and communication. These challenges can only be addressed through a culture of openness, regular review, and public reporting, as recommended in both national and international guidance.

Engaging Civil Society

The pandemic underscored the indispensable role of civil society, including NGOs, faith-based organizations, and citizen groups, in pandemic planning, implementation, and monitoring. India's Government actively engaged over 90,000 NGOs and civil society organizations in the first weeks of the national lockdown, recognizing their deep grassroots connections and ability to reach marginalized populations. NGOs provided essential services such as food, medical supplies, and transport for migrant workers, often acting as the first responders in communities where government reach was limited. Faith-based leaders, mobilized through initiatives like the Inter-Faith Humanitarian Alliance, played a key role in addressing risk perceptions, dispelling rumors, and promoting vaccine acceptance, leveraging their moral authority and trusted status within communities. Community participation is now recognized as a cornerstone of effective pandemic response. Evidence from India and globally shows that when communities are engaged early and meaningfully in the design, planning, and implementation of interventions, compliance improves, and trust is strengthened.[27] Community engagement must move beyond passive information dissemination to genuine co-production of solutions, with ongoing dialogue, feedback mechanisms, and inclusion of marginalized voices.[27] This approach not only builds resilience but also ensures that interventions are contextually appropriate and widely accepted. Transparency is fundamental to sustaining public trust. The COVID-19 experience revealed that frequent changes in guidelines, unclear instructions, and inadequate communication undermined confidence in health system. Going forward, it is essential that government actions are communicated explicitly, backed by transparent public health laws, and that citizens are kept informed about both the rationale and the evidence behind key decisions. This openness should extend to sharing data, publishing preparedness progress, and involving civil society in oversight.

RESULTS

The study's key findings are as follows:

Vaccine Deployment and Coverage

Over 1.6 billion COVID-19 vaccine doses were administered nationwide, with significant rural coverage achieved through digital platforms (CoWIN) and the efforts of community health workers.

- *Strengths*

Rapid development and deployment of indigenous vaccines (e.g., Covaxin); Digital registration and certification systems that improved access and tracking; and Community health workers (ASHAs, Anganwadi) played a pivotal role in outreach and surveillance, especially in tribal and rural areas.

- *Weaknesses*

Chronic underfunding of public health infrastructure, with per capita spending far below the global average; Fragmented data systems and lack of granular reporting, leading to underreporting and hampered targeted interventions; Supply chain disruptions, particularly during surges, resulting in hospital overloads and oxygen shortages; and Inequities in care access, especially among rural, tribal, and marginalized populations.

- *Digital Health*

Initiatives like unique health IDs and telemedicine expanded access and surveillance but faced interoperability and connectivity challenges.

- *Supply Chain Resilience*

Local manufacturing incentives and strategic stockpiling improved supply security, but inconsistencies persisted.

- *Innovation in Care Delivery*

Mobile health units and test-to-treat models reduced mortality in underserved areas.

- *Misinformation*

The infodemic significantly hindered public health efforts, necessitating trusted communication channels and media literacy programs.

- *Governance*

The need for integrated public health and clinical care, reserve health workforces, and improved federal-state collaboration was evident.

- *International Role*

India's vaccine diplomacy and participation in global surveillance networks contributed to global health security.

DISCUSSION

The findings of this study underscore both the significant achievements and persistent challenges in India's response to the COVID-19 pandemic. Rapid vaccine development and deployment, enabled by digital platforms and the tireless efforts of community health workers, demonstrated the nation's capacity for large-scale innovation and mobilization. However, chronic underfunding, fragmented data systems, and supply chain vulnerabilities led to overwhelmed health facilities and inequitable care, particularly in rural and marginalized communities. Digital health initiatives, while transformative in expanding access and surveillance, revealed ongoing issues with interoperability and connectivity, especially in underserved areas. Efforts to strengthen supply chain resilience through local manufacturing and strategic stockpiling

showed progress but highlighted the need for more consistent implementation. The widespread infodemic exposed the necessity for trusted, decentralized communication channels and sustained media literacy programs. Governance structures must evolve to better integrate public health and clinical care, establish reserve health workforces, and enhance federal-state collaboration for tailored, context-sensitive responses. These results align with global evidence that robust primary care, digital integration, and community engagement are critical for effective pandemic management, yet systemic underinvestment and rural-urban disparities remain limiting factors. The study's reliance on secondary data and potential underreporting, particularly in rural areas, are acknowledged limitations. Moving forward, sustained investment in primary care, institutionalization of supply chain resilience, and inclusive digital health strategies are essential. Future research should evaluate the effectiveness of specific interventions, explore innovative models for health system integration, and develop frameworks for crisis governance and community engagement to ensure preparedness for future public health emergencies.

Interpretation in context of other evidence

These results align with global observations that countries with robust primary care, digital health integration, and community engagement fared better during the pandemic; however, as with other low- and middle-income countries. India's systemic underinvestment, data fragmentations, and rural-urban disparities limited the effectiveness of its response. The study's limitations include reliance on secondary data and possible underreporting in rural areas, which may affect comprehensiveness.

CONCLUSION

India's COVID-19 response reveals a paradox of remarkable achievements alongside persistent systemic vulnerabilities demanding urgent attention. While demonstrating exceptional capabilities in vaccine development, digital health implementation, and community mobilization, the pandemic exposed deep-rooted challenges including healthcare underfunding, data fragmentation, and supply chain dependencies that disproportionately affected vulnerable populations. The path forward requires fundamental transformation encompassing sustained investment in primary healthcare infrastructure, resilient supply chain networks, interoperable digital health systems, and robust community engagement mechanisms. Equity considerations must be embedded throughout all preparedness strategies to prevent future responses from exacerbating existing health disparities. The findings align with global evidence emphasizing integrated, multisectoral approaches to pandemic preparedness. For India, this means strengthening federal-state coordination, enhancing international collaboration, and institutionalizing continuous learning through systematic after-action reviews. The establishment of a permanent National Pandemic Preparedness Authority would provide the institutional foundation necessary for coordinated, evidence-based responses to future health emergencies. The urgency cannot be overstated. As global health experts warn of inevitable future pandemics, India's window for proactive preparation is narrowing. The nation must leverage its demonstrated strengths in innovation, community engagement, and digital transformation while systematically addressing COVID-19 exposed vulnerabilities. This requires not only financial investment but also political commitment to long-term healthcare system strengthening and equity focused policy implementation. India's position as a global health leader and responsibility to its 1.4 billion citizens demand comprehensive pandemic preparedness. The lessons learned from COVID-19 provide a roadmap for action, but their translation into effective policies requires immediate and sustained commitment from all stakeholders. The choice is clear: invest in resilience now, or face potentially catastrophic consequences when the next pandemic emerges.

This paper draws on global recommendations, including those from the American College of Physicians, and adapts them to the Indian context, emphasizing the need for sustained investment, innovation, and inclusive governance to ensure that India is truly prepared for the next pandemic.

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