Internship Training

at

IQVIA Consulting and Information Services India Private Limited, New Delhi

on

Surveillance for COVID-19 in India: A study on performance of states in testing and caseload of COVID-19 (March 25-May 31, 2020)

by

Rimjhim Mishra

PG/18/059

Under the guidance of

Dr. Nitish Dogra

Post Graduate Diploma in Hospital and Health Management

2018-20

International Institute of Health Management Research
New Delhi

IIHMR DELHI

IQVIA

IMS Health & Quintiles are now IQVIA™

June 19, 2020

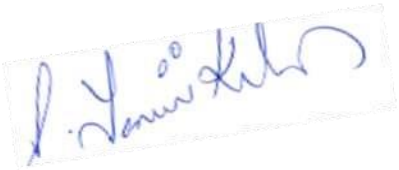
TO WHOMSOEVER IT MAY CONCERN

This is to certify that **Rimjhim Mishra** was associated with **IQVIA Consulting and Information Service India Pvt. Ltd.** as an **Intern** and the internship period was from 3rd February 2020 till 2nd June 2020**.**

This certificate is issued in recognition of successful completion of 4 months of **her Project** in the department of **Public Health.**

We wish her all the best for future endeavors.

For IQVIA Consulting and Information Service India Pvt. Ltd.



S. Yamini Krishnan

Sr. Director HR, AMESA

IQVIA Consulting And Information Services India Private Limited
Unit No. 902, 9th floor, B-Wing, Supreme Business Park,
Supreme City, Hiranandani Gardens, Powai,
Mumbai, 400076, India.
CIN : U74140MH2003PTC142482

Tel: +91 22 7109 7200
Fax: +91 22 7109 7222
iqvia.com

FEEDBACK FORM

Name of the Student: Ms. Rimjhim Mishra

Dissertation Organization: IQVIA Consulting and Information Services India Private Limited, New Delhi

Area of Dissertation:
Secondary data review and analysis for COVID-19 situation in the country with respect to testing and case detection.

Attendance: 98%

Objectives achieved:

1) Overall exposure to public health consulting; providing a platform to learn from the challenges and opportunities presented during the experience
2) Independently conduct project tasks with opportunities to learn time and task management
3) Learn and demonstrate multi-task management skills including communication, coordination with vendors service
4) Opportunities to conduct document and knowledge management, shadow primary qualitative interviews with senior stakeholders, understand how data is collated and analyzed and how data becomes information that can be converted into impactful presentations and reports.

Deliverables:

1) **Project data management**
2) **Data collation and analysis of primary qualitative interviews**
3) **Daily end-of-day updates to the team and vendor management**

She was expected to aid the Disease management and Health System Strengthening team in project coordination, primary research (interviews), report writing, documentation, data management and analysis and timely deliverables.

Strengths: I am very happy to report that after observing Rimjhim for the last several weeks, I am delighted with the progress and learning that she has demonstrated during this time. Her attitude, dedication and quality of work is commendable. She is willing to continue to work on an assignment until its near perfect. She is proactive and punctual with her work. Her service orientation and pleasant manner are a delight for all the people that she has interacted with at IQVIA. She quickly assimilates as part of a team and has demonstrated appreciable team player skills and attitude.

Suggestions for Improvement: Rimjhim needs to learn to assert herself a little more than she does currently. She also needs to pay a bit more attention to detail while finalizing deliverables. In terms of technical writing, I would encourage her to read more scientific journals and publications and attempt to start writing papers and contribute within the team for report and proposal writing. As she will grow in her role at IQVIA, she should develop the skill of completing and finalizing documents in terms of correctness, comprehensiveness and creativity and help her peers and managers with near final deliverables. Going forward, I suggest her to work upon her MS Office skills as they will be instrumental in performing well in a healthcare consulting organization.

Suggestions for Institute (course curriculum, industry interaction, placement, alumni): IIHMR is recommended to provide the students with advanced MS-Office skills which are crucial for a student to grow in their respective organizations.

Signature of the Officer-in-Charge/ Organization Mentor (Dissertation)
Ms. Kavya Sharma
Project Manager
IQVIA Consulting and Information Services India Private Limited, New Delhi

Date: 22nd June 2020
Place: New Delhi

TO WHOMSOVER IT MAY CONCERN

This is to certify that **Rimjhim Mishra** student of Post Graduate Diploma in Hospital and Health Management (PGDHM) from International Institute of Health Management Research, New Delhi has undergone internship training at **IQVIA Consulting and Information Services India Private Limited, New Delhi** from **3- Feb-2020 to 2-June-2020.**

The Candidate has successfully carried out the study designated to her during internship training and her approach to the study has been sincere, scientific and analytical.

The Internship is in fulfillment of the course requirements.

I wish her all success in all her future endeavors.

Dr Pradeep K Panda

Dean, Academics and Student Affairs

IIHMR, New Delhi

Dr. Nitish Dogra

Associate Professor

IIHMR, New Delhi

Certificate of Approval

The following dissertation titled **"Surveillance for COVID-19 in India: A study on performance of states in testing and caseload of COVID-19 (March 25-May 31, 2020)"** at **"IQVIA Consulting and Information Services India Private Limited, New Delhi "** is hereby approved as a certified study in management carried out and presented in a manner satisfactorily to warrant its acceptance as a prerequisite for the award of **Post Graduate Diploma in Health and Hospital Management** for which it has been submitted. It is understood that by this approval the undersigned do not necessarily endorse or approve any statement made, opinion expressed, or conclusion drawn therein but approve the dissertation only for the purpose it is submitted.

Dissertation Examination Committee for evaluation of dissertation.

Name	Signature
Dr. Ajay Sood	
Dr. Nitish Dogra	
Dr. B.S. Singh	
Dr. Pankaj Talreja	

Certificate from Dissertation Advisory Committee

This is to certify that **Ms. Rimjhim Mishra,** a graduate student of the **Post- Graduate Diploma in Health and Hospital Management** has worked under our guidance and supervision. She is submitting this dissertation titled **"Surveillance for COVID-19 in India: A study on performance of states in testing and caseload of COVID-19 (March 25-May 31, 2020)"** at IQVIA Consulting and Information Services India Private Limited, New Delhi in partial fulfillment of the requirements for the award of the **Post- Graduate Diploma in Health and Hospital Management.**

This dissertation has the requisite standard and to the best of our knowledge no part of it has been reproduced from any other dissertation, monograph, report or book.

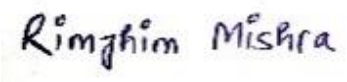
Dr. NITISH DOGRA
Associate Professor
IIHMR, New Delhi

KAVYA SHARMA
Project Manager
IQVIA

INTERNATIONAL INSTITUTE OF HEALTH MANAGEMENT RESEARCH, NEW DELHI

CERTIFICATE BY SCHOLAR

This is to certify that the dissertation titled **"Surveillance for COVID-19 in India: A study on performance of states in testing and caseload of COVID-19 (March 25-May 31, 2020)"** and submitted by **Rimjhim Mishra** Enrollment No. **PG/18/059** under the supervision of **Dr. Nitish Dogra** for award of Postgraduate Diploma in Hospital and Health Management of the Institute carried out during the period from **3-Feb-2020** to **2-June-2020** embodies my original work and has not formed the basis for the award of any degree, diploma associate ship, fellowship, titles in this or any other Institute or other similar institution of higher learning.



Signature

Acknowledgement

Above all and everyone, I thank the almighty and my parents for their love, support and everything.

Any attempt at any level, cannot be satisfactorily completed without the support and the guidance of learned people. I owe a great debt to all the professionals at IQVIA, New Delhi, for sharing generously their knowledge and time that inspired me to do my best during my dissertation period.

I express my heartfelt gratitude to Mr. Varindra, Associate HR Director, IQVIA Consulting and Information Services India Private Limited, New Delhi, for approving my internship in the organization and Mr. Kaartik Chauhan, Engagement Manager , Disease Management and Health System Strengthening team- IQVIA, New Delhi, for providing me with the valuable opportunity of working under him and his constant support given during entire project.

I am indebted to the overall support of Ms. Kavya Sharma and Ms. Vidhi Gupta, my mentors in the organization; for the guidance and support they gave to my learning in public health and for directing my thoughts, goals, and objectives towards the attitude that, one as a novice, needs to be armed with. It was a privilege to have worked under their dynamic supervision.

I am glad to acknowledge Dr. Nitish Dogra, Associate Professor, IIHMR Delhi who is my mentor for incorporating the right attitude into me towards learning and for helping and supporting whenever required.

My special words of thanks go to Col. K. Ranjit who has been a constant support since the very start of the journey. It is his motivation which has inspired me to thrive for excellence and nothing else. I extend my sincere love and thanks to his entire family and my beautiful friends, Surabhi, Saijosree and Priyansha for their moral support especially during this lockdown period. Thanks to all for being with me in this.

Table of Contents

List of tables

List of figures

Abbreviations

COVID-19	Coronavirus Disease
EIOS	Epidemic Intelligence for open source
GHS	Global Health Security
ICMR	Indian Council of Medical Research
IHR	International Health Regulations
ILI	Influenza Like Illness
MERS	Middle Eastern Respiratory Syndrome
MoHFW	Ministry of Health and Family Welfare
MoH	Ministry of Health
NCDC	National Centre for Disease Control
NICED	National Institute of Cholera and the Enteric Diseases
NRLs	National Reference Laboratories
PHEIC	Public Health Emergency of International Concern
PPM	Per Million Population
qRT- PCR	quantitative real time -reverse transcriptase polymerase chain
RT-PCR	real-time reverse transcription polymerase chain reaction
SARI	Severe Acute Respiratory Symptoms
SARS	Severe Acute Respiratory Syndrome
SARS-CoV-2	Severe Acute Respiratory Syndrome- Coronavirus 2
UTs	Union Territories
VRDL	Virus Research and Diagnostic Laboratories
WHO	World Health Organization

Chapter-1
Abstract

Surveillance for COVID-19 in India: A study on performance of states in testing and caseload of COVID-19 (March 25-May 31, 2020)

Keywords: Surveillance, testing, SARS CoV-2, COVID-19, lockdown, India

End of Lockdown 4 in India with tremendous number of COVID-19 cases and fatalities signifies that effective disease containment is a must. This can be ensured only when there is proper surveillance strategy and its implementation in place. The objective of the study is to understand the performance of Indian surveillance strategies for COVID -19, to analyze the state wise numbers of tests conducted as well as case load coming over during the four phases of lockdowns and to find association between the same. It also seeks to identify the gaps in the performance and strategies adapted. An ecological secondary research was conducted for the statistics available at official sites like ICMR, MoHFW and tracker like covid19India. In depth study of related research articles, reports and literature was done.

Results show that the aggregate number for testing may seem to grow day by day in India but there is a wide state level variation in surveillance. Every state itself is like a country with varied health system status. Sates which are less developed like Bihar, Jharkhand, West Bengal. Uttar Pradesh have conducted lesser no. of tests per million people when compared to others. Delhi, Maharashtra, Tamil Nadu, Gujarat show high number of cases per million population while those with lower number are mostly the north eastern states. However, there is no strong association between state wise tests and caseload, but removal of outliers (Delhi, Maharashtra, Andaman and Nicobar Island etc.) led to slight increase in the association but without statistical significance. Changing testing strategies add to issue of completeness in data. Scarcity of resources, unavailability of detailed information, varying sensitivity of tests also increase the challenge. India needs to strengthen the capacity of surveillance for rapid testing, identification of cases, following up and monitoring the disease progression with time. An intelligent testing strategy has to be in place with a well set up coordination and effective management right from the Centre to the community.

Chapter-2
The organization

IQVIA

IQVIA, formerly Quintiles and IMS Health, Inc. is an American multinational company serving the combined industries of health information technology and clinical research. It is a provider of biopharmaceutical development and commercial outsourcing services, focused primarily on Phase I-IV clinical trials and associated laboratory and analytical services, including consulting services. It has a network of more than 58,000 employees in more than 100 countries.

As of 2019, IQVIA was reported to be one of the world's largest contract research organizations. It is a global leader in providing healthcare advisory, consulting, research, performance management, technical assistance, technology, and data analytics services to both the public & private sector. IQVIA is a recognized leader in human data science, machine learning, predictive analysis, and healthcare technology. The company was founded in 1954, and today a Fortune 500 company with revenue of $10 billion, with over 50,000 employees operating in more than 100 countries around the world, with thousands of proprietary methodologies, including patented systems for analytics, data encryption, and forecasting. IQVIA is publicly listed at the New York Stock Exchange (NYSE). They serve more than 5,000 healthcare clients globally.

Global data and analytics capabilities of IQVIA draw on data from 100,000 suppliers and on insights from more than 45 billion healthcare transactions are processed annually. They connect knowledge across all aspects of healthcare to improve patient outcomes and operate more efficiently. In India, they have over 15+ years of experience delivering services to private and

public healthcare stakeholders across pharmaceutical sector, providers, payers, patients, doctors, academia and research institutions. IQVIA has have conducted several large-scale health care assessments, policy advocacy, impact evaluations, program implementation, formulating strong monitoring frameworks, assessing community-based model, and a strong presence in the healthcare market across data, analytics and consulting services and is the "ONLY" integrated healthcare informatics player in India, with solutions across healthcare sector value chain.

Ari Bousbib is the CEO while Mr. Lokesh Sharma is the Senior Principal & Practice Leader - Public Health, AMESA at IQVIA. The company is also working with the Government of India to support implementation of flagship programs such as Technical PMU for Ayushman Bharat, National Health Resource Repository (NHRR), National Family Health Survey, Global Youth Tobacco Survey, etc.

The range of services includes

- business strategy
- market research
- performance monitoring tools
- global market insights
- regulatory policy support
- operations improvement
- quality assurance supply chain management
- allied technology solutions

IQVIA's Public Health Practice in India works with the Ministry of Health & Family Welfare, National Health Authority, Department of Pharmaceuticals, Department of Medical Health for Uttar Pradesh, Andhra Pradesh, Karnataka & Nagaland, NITI Aayog, National Health Authority (NHA), Directorate General of

Health Services (DGHS), NPPA, UPHSSP, The World Bank, UNDP, CHAI, JSI, USAID Deliver, BMGF, DFID, PSI, Pharmexcil, Tata Trusts on significantly large mandates.

IQVIA has experience of working across various states including Uttar Pradesh, Bihar, Jharkhand, Chhattisgarh, Madhya Pradesh, Tamil Nadu, Karnataka, West Bengal, Odisha, Nagaland, Mizoram, Arunachal Pradesh, Assam, etc. IQVIA has strong presence of experienced healthcare professionals including MBBS, Health Insurance specialists, Epidemiologists, Public Health experts, Biostatisticians, Hospital Administration, Civil & Structural Engineers, Hospital experts, Health Economists, Researchers, etc. specialized in Program Management, Implementation, Monitoring & Evaluation, Supply Chain Management, Medical Education and Efficiency improvement across India.

The key marquee projects:

1. PMJAY-Programme Management and Consultant for Ayushman Bharat
2. MoHFW-National health resource Repository- First National Health Facility Registry
3. Niti Ayog-Access to affordable medicines and Healthcare and role of Pharmaceutical Industry
4. UPHSSP-Revamping of 41 district level hospital
5. Bill and Melinda Gates Foundation- Technical Assistance in private sector TB disease Burden Estimation and Surveillance for monitoring and evaluation of PPIA
6. The World Bank- Independent Verification of Disbursement Linked Indicators (DLIs) and Process Documentation of ISSNIP

Strengths of IQVIA

Largest in-house public health work force

- 1200+ Healthcare professionals
- 4500+ Technology experts
- 2500+ Advanced analytics
- data scientists
- 1400+ PHDs

Vast experience in Technology advisory, Consulting and Implementation support

- Delivered 100+ Public Health projects in last 5 years
- Worked with multilateral agencies and Central and State Governments, including BMGF

Executing projects of national importance

- Project Management Consultant to National Health Authority for implementing AB-PMJAY
- Project Management and Implementation partner for India's first health facility registry NHRR
- Implementation of NFHS - 5

Extensive experience in Healthcare software implementation

- Partner of the Dubai Health Authority for the implementation of eClaimLink
- Deployed solutions at 3,500+ healthcare providers, 70+ healthcare payers, 20,000+ clinicians

Globally acclaimed ready to deploy solutions

- Solution is deployed in more than 100 healthcare units supporting 20,000+ beds
- Performance Management Dashboard Solution Centralized MIS deployed across 70 countries

Chapter-3
Introduction

Health system of a country is based on the foundation of six pillars which include, governance, health workforce, service delivery, access to the essential medicines, health information systems and financing. All these building blocks need to be in place with quality coverage all over the nation for an efficient health system strengthening. The capacity of a health system is also assessed in the manner it faces any situation of health emergency if raised. The Emergency risk management is the process to identify, analyze, assess, treat and mitigate the risk to people, property as well as the environment of the nation. Early action and implementation of comprehensive public health measures like rapid case identification, rapid testing and isolation of cases, comprehensive contact tracing and quarantine of contacts is what is expected from the preparedness plan of countries.

There have been many epidemics in last 20 years like those of Acute Respiratory Syndrome during 2002-2003, H1N1 influenza during 2009. According to WHO, coronaviruses are the family of virus which include Severe Acute Respiratory Syndrome (SARS), and Middle Eastern Respiratory Syndrome (MERS). The one being the current matter of our concern is Coronavirus which is also known as COVID-19, now a pandemic, and which has never been encountered before. The disease initiated in the Hubei Province of Wuhan; China has now spread across the globe. The cases are increasing day by day. Death rate associated with COVID-19 is also very high. Countries in the world are at different stages of national and subnational outbreak. They are being encouraged to make their capacities strengthened for this health emergency and disaster risk management by incorporating measures for prevention, mitigation, preparedness, response and recovery. For understanding the context of the study, an overview of the current situation is discussed as outlined below.

Public Health Emergency of International Concern (PHEIC):

International health regulations (IHR 2005) determine a serious health events to be Public health Emergency of International Concern (PHEIC) if it is the extraordinary event which is determined to constitute a public health risk to the other states through the spread of disease and potentially requires a coordinated response internationally. This signifies that the event is serious, unusual and unexpected which can carry the implications for public health beyond national borders and may require immediate international actions.

COVID-19:

The COVID-19 is an ongoing pandemic of the coronavirus disease 2019 which is caused by Severe Acute Respiratory Syndrome Coronavirus (SARS-CoV-2). First identified in Wuhan,

China in December 2019, the outbreak was declared as the PHEIC by WHO on 30 January 2020 and as a pandemic on 11 March 2020. As towards the end of May 2020, more than 5.59 million cases have been reported in more than 188 countries and territories which have resulted in more than 350000 deaths and more than 2.28 million recoveries as well

The virus primarily spreads through close contact among people through droplets which are produced by coughing, sneezing and talking. these droplets fall to the ground or on surfaces instead of travelling through air and people may get infected by touching such contaminated surface and then their faces. It is very contagious during the first three days after the onset of symptoms although the spread may happen before symptoms appear, and from those who are asymptomatic also

The symptoms of COVID-19 include fever, fatigue, cough, loss of sense of smell, shortness of breath etc., while the complications may include pneumonia, and acute respiratory distress syndrome. The time from the exposure to virus and onset of symptoms is typically around five days but it can range from two to fourteen days. Recommended preventive measures include maintaining hygiene, hand washing, covering mouth while coughing, maintaining distance from other people, wearing the face masks in public places, monitoring and self-isolation if suspected of infection There has been implementation of travel restrictions, lockdowns, control of workplace hazards by various authorities worldwide. Many places have worked towards increasing the testing capacity and tracing the contacts.

WHO Technical Guidance on COVID-19 Surveillance:

As per WHO, there has been a rapid spread of COVID-19 around the world and it has affected every community directly or indirectly. Therefor stringent and effective surveillance is to be in place that include:

1. Enabling rapid detection, isolation, testing and management of suspected cases
2. Identifying and following up the contacts
3. Guiding the implementation of control measures
4. Detecting and containing outbreaks among vulnerable populations
5. Evaluating the impact of pandemic on health care systems and society
6. Monitoring the long-term epidemiological trends and the evolution of COVID-19 virus
7. Understanding the co-circulation of COVID 19 virus, influenza and other respiratory viruses.

All these can be done when we have the comprehensive methods of detecting and testing the cases at the first place. This is the first objective of any health surveillance by WHO. Proper testing would help in identification of correct number of cases and would display the real picture of the prevailing situation which can further be followed by the other steps of implementing measures. Identification and follow-ups of contacts can be done if the countries are testing and

reporting. They need to strengthen surveillance capacities to identify the cases rapidly, and hence to monitor the trends with time. Adaption and reinforcement of the existing national systems with scaled up capacities of surveillance is what is needed. Testing methods, digital technologies for reporting, data management, and analysis is sought for better handling of pandemics like COVID-19. Robust comprehensive surveillance should be maintained in the areas where are even no cases. It is very essential to detect new cases and clusters of COVID 19 rapidly. This ensures prevention of widespread disease transmission.

As there is a potential of rapid exponential growth of COVID-19 cases amongst the populations, new cases are needed to be identified, reported and data to be included in the epidemiological analysis within 24 hours It must be a mandatory notifiable disease which requires immediate reporting. While surveillance system captures the number of cases of COVID, information collection from the laboratories conducting the tests is equally important. Knowing this would help in the understanding of the level of surveillance activity, while the number of cases would help in understanding of the level of the transmission among individuals who are symptomatic. Polymerase Chain Reaction (PCR) test is the most common diagnostic method to be used for now.

COVID-19 and India

Although India is not the worst hit countries from this pandemic, yet WHO has declared the risk assessment for COVID-19 to be high. Towards the end of May, the number of cases and the fatalities in the country being 181859 and 5185 respectively it is but understood that effective disease containment is a must. This can be ensured only when there is proper surveillance strategy and its implementation in place. It is known that one of the most effective ways to control the spread of the virus is comprehensive testing and case detection. One of the major components of the emergency preparedness and response is the management of Information and Knowledge which includes risk assessment, surveillance, early warning, technical guidance and research

ICMR has been making strategies for testing and detecting COVID-19 cases. States follow the same for tests being conducted and report the cases accordingly. Different states have been performing at a varying pace as far as the number of testing conducted is concerned. According to the Health Ministry, Standard confirmation test for COVID- 19 is RT-PCR (Reverse Transcription- Polymerase Chain Reaction) and for epidemiological and surveillance purpose is Rapid Antibody Testing is to be conducted.

In order to have knowledge about the performance of country in terms of management of public health emergency, it is needed to know what the level of surveillance is conducted by the country. This study is about creating an understanding about how states performed in conduction of tests for COVID detection and the scenario of cases which came up during the stages of lockdown that were announced in the country by the Honorable Prime Minister to tackle the severity of the pandemic.

Chapter-4

Rationale and Research Question

Rationale

"The systematic collection, analysis and dissemination of health-related data is epidemiological surveillance in most common terms. This practice if done effectively and efficiently helps in better planning, implementation and evaluation of public health programmes and an in depth understanding of any health-related event, COVID -19 being the current topic of concern. Although India is not the worst hit countries from this pandemic, but WHO has declared the risk assessment for COVID-19 to be high. Therefore, effective disease containment is a must. This can be ensured only when there is proper surveillance strategy and its implementation in place. It is being the testing and aggressive quarantine measures due to which although China which was the first to hit the most cases at the start yet has presently flattened the curve. South Korea also had the most significant initial outbreak but has also managed to slow down the spread of the disease and flattened the curve without even imposing any lockdown in the country. The only method used by them due to which they were able to significantly slowdown and contain the COVID-19 curve was the mass diagnostic testing and then following the quarantine measures/ ICMR has been making strategies for testing and detecting COVID-19 cases.

While CDC advocates timely availability of data for test and cases reported for monitoring the spread and intensity of disease, we know that testing is a window to understand how a pandemic is spreading and the risk it may possess onto the population

As the total number of patients of COVID-19, the deaths and the recovered persons is seen to be increasing continuously at the globe as well as within the India at a varying pace, knowing the trends of the tests being conducted all through the states and the cases which have been reported would help in the in- depth understanding of how the states are performing and what may be the possible gaps and lacunae in the testing strategies which can be improved The state wise performance based on surveillance and case load which have been emerging through the four stages of lockdown taking end dates as the reference cross sections is the backdrop of the study.

Research Question-

1. What has been the progression of tests conducted and confirmed cases in India (state wise) between the time period of four lockdowns?
2. Is there any association between the tests conducted with cases in various states/ UTs?
3. What have been the gaps in the testing strategies of India and what is the way forward

Chapter-5
Review of Literature

Overview

Past 20 years have seen several epidemics like those of acute respiratory syndrome coronavirus during 2002-2003 and H1N1 influenza during 2009.[i] According to the World Health Organization (WHO), coronaviruses are the family of viruses that include Severe Acute Respiratory Syndrome (SARS) and Middle Eastern respiratory syndrome (MERS). The current novel coronavirus known as COVID 19, is a pandemic. It has never been encountered before. It's a disease which initiated in Hubei province of Wuhan, in China and now spread like fire all over the globe. The first confirmed death was reported in Wuhan on 9 January 2020. The first death which occurred outside of China was in Philippines on 1 February. The COVID 19 cases are increasing day by day . It is being the testing and aggressive quarantine measures due to which although China which was the first to hit the most cases at the start, yet has presently flattened the curve. South Korea also had the most significant initial outbreak but has also managed to slow down the spread of the disease without even imposing any lockdown in the country. The only method used by them due to which they were able to significantly slowdown and contain the pandemic curve was the mass diagnostic testing and then following the quarantine measures. Some countries across the globe which have managed to control the fatalities from COVID-19, such as Germany and South Korea surely have one thing in common: they tested a lot.

Need of surveillance

As already known, surveillance is the systematic collection, analysis and dissemination of health-related data. This practice if done effectively and efficiently helps in better planning, implementation and evaluation of public health programmes and an in depth understanding of any health-related event, COVID -19 being the current topic of concern.

According to the WHO, for surveillance of COVID-19, considering the potential for the rapid growth cases in the populations, new cases should be identified, reported and the data should be included in the epidemiological analysis within 24 hours. The national authorities should include COVID-19 as a mandatory notifiable disease with the requirements of immediate reporting[ii]

The following figure shows that how at the various levels surveillance systems can be combined across different sites so that the data can be collected comprehensively.

Type of Surveillance	Individuals in the Community	Primary Care Sites (non-sentinel ILI/SARI)	Hospitals (non-sentinel ILI/SARI)	Sentinel ILI/SARI Site	Residential Facilities and Vulnerable Groups	Vital Statistics Offices
Immediate Case notification system	X	X	X	X	X	
Contact Tracing System	X					
Sentinel virus surveillance			X	X		
Sentinel case surveillance			X	X		
Cluster investigations	X	X	X	X	X	
Special settings			X		X	
Mortality	X		X	X	X	X

Figure 1: WHO representation of using various levels of surveillance systems in a combined manner

Centre for Disease Prevention and Control states that there is a need for the public health surveillance for COVID-19 data with certain goals which are to be accomplished with timely availability of data of people being tested and reported. It would help in the monitoring the spread and intensity of the COVID disease in the country and help in understanding the severity and spectrum of illness along with the risk factors associated for the transmission of COVID-19. The testing and cases data would help in the estimating of disease burden and forecasting the further spread and impact. It would help in the estimation of the health system capacity for surveillance (availability and shortages of the (key resources)[iii]

Scenario of surveillance in India

The novel COVID-19 infection which leads to Coronavirus disease 2019 had spread rapidly from China to all across the world including India[iv]. The first case of COVID 19 was reported in India when one of the students of medical science returned from Wuhan University and was tested positive in Kerala on 30 January, 2020.[v]

Globally, India ranked at 57th position in list of 195 countries in terms of preparedness of a pandemic, according to the Global Health Security (GHS) Index (GHS, 2019)[vi]. According to Michael Ryan, the chief executive director of WHO 's Health Emergencies Programmes, India has the tremendous capacity to deal with the coronavirus outbreak and being the second most populous country in the world, it will have an enormous impact over world's ability to deal with the same.

India's testing rate is one of the lowest amongst those countries which have had more than thousand confirmed cases till date (as on April 11, 2020). The biggest constrictions for increased testing capacity are the lack of testing kits and lack of skilled healthcare individuals administering these tests.[vii]

Revision of Testing Strategies of ICMR[viii]

The infrastructure for the testing of COVID-19 cases included ICMR institutes along with the partners through Virus Research and Diagnostic Laboratories (VRDL) Network of the Department of Health Research, Ministry of Health and Family Welfare (MoHFW). The network was established to enhance the India's capacity for diagnosing and detecting viruses of public importance. [ix]

The ICMR has been the official leading organization for India's laboratory surveillance testing for the COVID-19. Initially the testing of the SARS-CoV-19. Initially testing for the SARS-CoV was being conducted through 78 selected national Reference Laboratories (NRLs) (ICMR Press Release) also, in starting the labs tested samples only from those with a travel history to 12 countries designated as the high risk or those who have come in the contact with anyone testing positive or showing symptoms as per government guidelines.

Being constrained by the International Shortage of the testing reagents. ICMR testing strategy incorporated the risk-based approach along with the clinical symptoms which balanced the need of the immediate deployment of the nationwide surveillance and the correct use of the resources available in an optimum manner. As on February, 15,2020 sentinel surveillance of the Severe Acute Respiratory Symptoms (SARI) started Then on March 20, government decided to include the all of the pneumonia cases irrespective of the travel or contact history and made the first and the second confirmatory tests for the virus free.

MoH also stated that it has been using 10% of the test capacity per day by 15th March, hence in mid-March the government had authorized the accredited private labs to do the testing.

Testing for community transmission started by 15th March. On 17th March, the Union Ministry of Health decided to allow the private pathology labs to test for the COVID-19, the government has also issued the guidelines to cap the cost of sample testing by private labs at the 4500 INR. On March 24, Pune based molecular diagnostic company became the first Indian company to have received the validation for RT-PCR tests from National Institute of Virology and ICMR.

On April 9th, testing strategy was further revised which allowed testing of people showing symptoms for one week in any hotspot area of the country irrespective of his travel or contact history in April, a low-cost paper strip test that could detect COVID-19 within an hour was developed by Institute of Genomics and Integrative Biology, New Delhi. it would cost 500INR and could fulfill India's rapid need of testing. As on April 13 ICMR advised about the pool testing for low infection areas.

The expansion of the testing capacity was done when ICMR led the use of its existing laboratory network and developed the standard protocols as well as launched an online portal for reporting too[x]. ICMR's surveillance network of laboratory generates valuable data with key variables of interest which can be proved useful to inform the future course of action. Therefore, the surveillance data was used to describe the testing performance and the caseload of COVID-19 cases by time and place.

Population under surveillance:

The Government of India has 428 public testing laboratories designated along with the 182 private ones across the nation to combat the COVID-19 as on May 24, 2020 (during the period sample collection centers were being set up for facilitating the detection of the outbreak cases in the country of analysis)[xi]

Case definitions as per the NCDC (National Centre of Disease Control)[xii] (NCDC)

Suspect Case: suspect case can be two types-

- He/ She is a patient with acute respiratory illness (fever, breathing difficulty, cough) AND with no other etiology which fully explains the clinical presentation AND at least one of the following mentioned:
    - He/ She has a history of travel to or residence in China in the 14 days prior to the symptom onset, or
    - He/she is a health worker who has been working in an environment where Severe Acute Respiratory Infections of an unknown etiology are being taken care of
    - He/she has either worked or has attended a health care Centre/facility where a confirmed case of COVID-19 is admitted in the last 14 days.
    - He /she had a close contact with a confirmed case of 2019-nCoV in the 14 days prior to the illness onset or
- B type: he/she is a suspect case for whom testing -nCoV has been inconclusive

Confirmed Case: A person being a case with laboratory confirmation of 2019-nCoV infection, irrespective of his clinical signs and symptoms.

Criteria for tests and cases

Testing is the central and the important aspect of the surveillance because it leads to the early detection, aids in minimization of further spread, and with quick detection of cases. Several countries are suffering from this severe community spread because of their delays in testing

ICMR has also developed the standard specimen collection, specimen transport and a laboratory testing process that includes the criteria for the classification of the results that are available publicly; the reported testing results are to be based on the (qRT-PCR) quantitative real time -reverse transcriptase polymerase chain reaction tests

Testing Strategies of ICMR: (as on 18th may, 2020) is as follows: all testing for the same is to be done by RT-PCR testing only,

- All individuals who are symptomatic (ILI symptoms) with history of an international travel within last 14 days.
- All individuals who are symptomatic (ILI symptoms)
- All health workers/ frontline workers/involved in the containment and mitigation of COVID-19 and are symptomatic
- All individuals having symptomatic ILI within the hotspots/containment zones
- All hospitalized patients developing ILI symptoms
- All symptomatic ILI among the migrants and returnees within the 7 days of illness.
- All individuals who are patients of Severe Acute Respiratory Infection (SARI)
- All individuals who are asymptomatic having a direct and high-risk contact of a confirmed case is to be tested once between 5th-10th day of coming in contact.

No emergency procedure is to be delayed for the lack of test; however, samples can be sent for testing if indicated as above.

The following is the flowchart as recommended by the advisories of ICMR while it suggests the Rapid Antibody test Kits to be used surveillance of COVID-19 Cases.

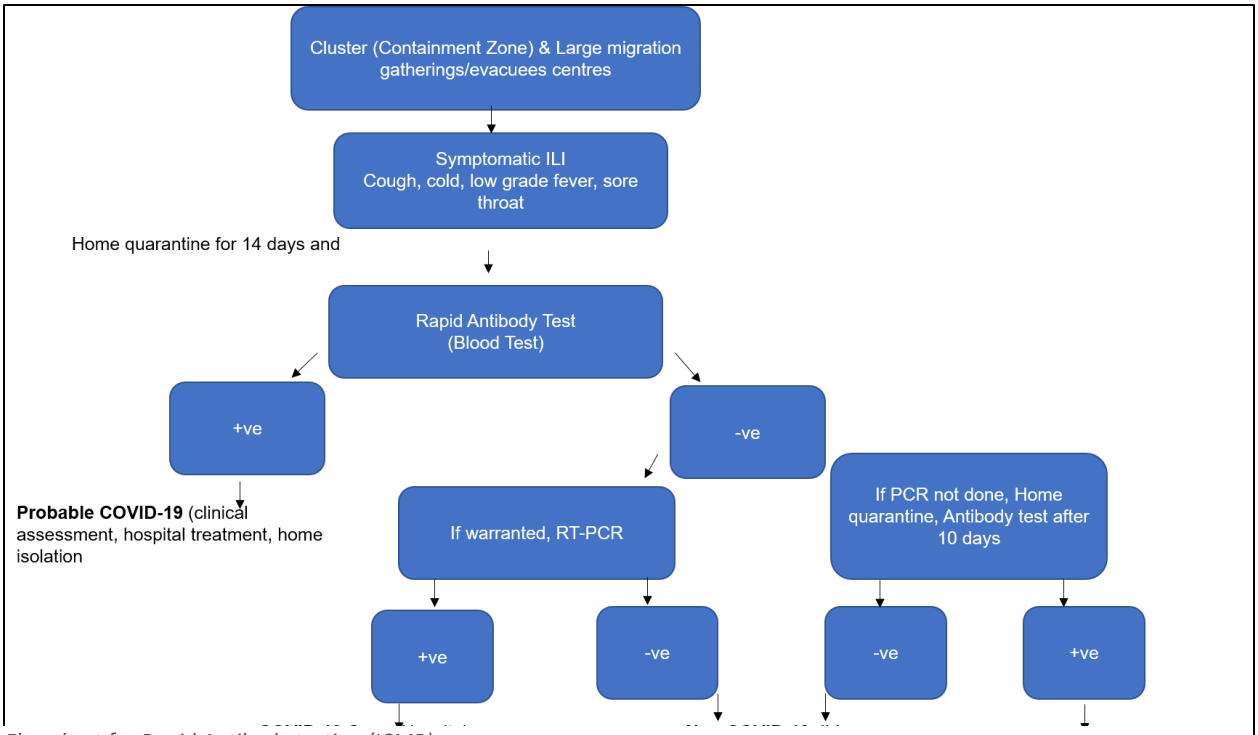


Figure 2- Flowchart for Rapid Antibody testing (ICMR)

As we all know India is a vast country having a geographic area of 3,287,240 km2.and a total population of about 1.3 billion. Most of the Indian states are quite large in geographical area and population. Analyzing the data taking entire India to be on the same page may not provide us the real picture. This is so because the measures taken by the state government for COVID surveillance, the case load coming over, progression with time are different over states. [xiii](Ghosh)

In order to have knowledge about the performance of country in terms of management of public health emergency, it is needed to know what the level of surveillance is conducted by the country. This study is about creating an understanding about how states performed in conduction of tests for COVID detection and the scenario of cases which came up during the stages of lockdown that were announced in the country by the Honorable Prime Minister to tackle the severity of the pandemic. The first lockdown which was announced on March 24th. 2020 to break the chain of transmission of the disease, followed by extending it to May 3, 2020. This was then further continued till May 17th and then to May 31st as Lockdown 3 and Lockdown 4 respectively.

Chapter-6
Objective of Study

The objective of the study is to form an understanding of performance of India in terms of surveillance strategies adopted for management of COVID -19 through analyzing the numbers of tests conducted and the case load coming over.

Although India is not the worst hit countries from this pandemic, but WHO has declared the risk assessment for COVID-19 to be high. Therefore, effective disease containment is a must. This can be ensured only when there is proper surveillance strategy and its implementation in place. ICMR has been making strategies for testing and detecting COVID-19 cases. States follow the same for tests being conducted and report the cases accordingly. Different states have been performing at a varying pace as far as the number of testing conducted is concerned.

This study was conducted to create an understanding about how states performed in conduction of tests for COVID detection and the scenario of cases which came up during the stages of lockdown that were announced in the country by the Honorable Prime Minister in four phases.

The specific objectives are as mentioned below:

1. To describe the progression of tests conducted and confirmed cases coming up in India between the time period of four lockdowns.
2. To find if there is any association between the tests conducted per million population per day with cases per million population per day in various states/ UTs?
3. To quantitatively and qualitatively describe the outliers.
4. To identify the gaps in the testing strategies and recommend areas of improvement.

Chapter-7
Methodology

The study is a secondary research to understand the India's way of Information and Knowledge management for COVID 19 so far. It is based on the ecological approach for understanding the state wise performance on testing for COVID cases. This paper compiled data on COVID-19 from different sources. For India, the database for no. of confirmed cases, deaths, recoveries and tests conducted state wise for the four days of every lockdown was taken from the covid19india.org (COVID-19India), a data-sharing portal which provides the most updated information on the daily and total confirmed cases, deaths, recovered cases, and deaths for each of the affected states. This portal data matches with data that is provided by the government official sites like MoHFW of India and also with ICMR on testing statistics for the country.

An ecological study for the cases, tests, recoveries and deaths among all states of India was conducted. An exploratory research was conducted to bring out the scenario of state wise tests conducted per million population per day and the confirmed cases per million population per day which were reported during the Four phases of lockdown. The cross-section dates of the lockdown taken are as mentioned:

1. End of lockdown-1 i.e. 14th April 2020
2. End of Lockdown-2 i.e. 3rd May 2020
3. End of Lockdown-3 i.e. 17th May 2020
4. End of Lockdown 4 i.e. 31st May 2020

Analysis to find out any kind of association (if any) between the tests being conducted and cases reported during these days was conducted with the help pf MS- Excel. Correlation analysis with an attempt to find the relation between the confirmed cases and tests being conducted on these days was done for the same.

Results of the analysis were represented and explained through Graphical representations, scatterplots and interpretation was explained further on an overall aspect. Discussion along with the gaps on testing pattern and strategy of the country as reported in different literary articles and recommendations was followed with the same.

Data collection:

This paper compiled data on COVID-19 from different sources. For India, the database for no. of confirmed cases, deaths, recoveries and tests conducted state wise for the four days of every lockdown was taken from the covid19india.org (COVID-19India), a data-sharing portal which provides the most updated information on the daily and total confirmed cases, deaths, recovered cases, and deaths for each of the affected states. This portal data matches with the data that is provided by the MoHFW, Government of India and with ICMR on testing statistics for the country.

An ecological study for the cases, tests, deaths and recoveries among all states of India was conducted. An exploratory research was conducted to bring out the scenario of state wise tests conducted and the cases which were reported during the Four phases of lockdown. The cross-section dates of the lockdown taken are as mentioned:

1. End of lockdown-1 i.e. 14th April 2020
2. End of Lockdown-2 i.e. 3rd May 2020
3. End of Lockdown-3 i.e. 17th May 2020
4. End of Lockdown 4 i.e. 31st May 2020

Data analysis and representation:

The cumulative values of state wise tests conducted, and the confirmed cases was taken on the specified four dates. Then the values for tests conducted per million population per day during the specified period of lockdown was taken. Similar was done to find out the cases per million population per day. The specific values for the period of lockdowns were calculated by subtracting the cumulative value of earlier one from the same. The variables then taken were

1. Tests conducted per million population per day
2. Confirmed cases per million population per day

A scatterplot and, graphical representations were made to understand the state wise scenario for the above-mentioned variables for the all four lockdowns. Tables were represented for the number of cases, deaths, recoveries, and tests conducted in each period of lockdown separately.

MS Excel was used for the data analysis and the graphical representations. Correlational analysis was run and the outlier states were identified and discussion over the same was done separately. Further the gaps in the testing strategies adapted by the country and the areas of improvement were discussed towards the end.

Chapter-8
Findings

State wise description of testing (per million population per day) and cases (per million population per day):

Lockdown 1:

Table 1-Statewise no. of confirmed cases, deaths, recoveries and tests during lockdown 1

States	Confirmed Cases	Recoveries	Deaths	Tests conducted	Cases pm pop. per day	Tests pm pop. per day
Maharashtra	2680	259	177	41071	1.14	17.40
Tamil Nadu	1204	81	12	19255	0.79	12.71
Gujarat	650	59	28	14980	0.51	11.81
Delhi	1561	31	30	16282	4.44	46.28
Rajasthan	1005	147	11	34928	0.70	24.24
Madhya Pradesh	741	64	54	8105	0.49	5.32
Uttar Pradesh	660	50	8	15914	0.16	3.80
West Bengal	190	36	7	3081	0.10	1.61
Andhra Pradesh	1128	126	29	25467	0.63	14.32
Bihar	66	29	1	7727	0.03	3.54
Karnataka	260	71	10	11107	0.20	8.65
Punjab	184	27	13	4844	0.32	8.33
Jammu Kashmir	278	30	4	4619	1.05	17.53
Odisha	60	18	1	4734	0.07	5.37
Haryana	198	54	3	5210	0.37	9.79
Kerala	387	211	3	16235	0.55	23.16
Assam	33	0	1	3491	0.05	5.33
Jharkhand	27	0	2	2334	0.04	3.37
Uttarakhand	37	9	0	2147	0.17	10.11
Chattisgarh	33	13	0	4812	0.06	8.97
Chandigarh	21	7	0	309	0.95	13.95
Himanchal Pradesh	33	14	2	1311	0.23	9.11
Tripura	2	0	0	738	0.03	9.57
Goa	7	5	0	479	0.23	15.65
Puducherry	7	1	0	1207	0.27	46.19
Manipur	2	1	0	276	0.03	4.83
Andaman and Nicobar Islands	11	10	0	1403	1.38	175.84
Megahalaya	1	0	0	617	0.02	9.91
Nagaland	0	0	0	174	0.00	4.18

Dadra and Nagar Haveli/ Daman and Diu	0	0	0	356	0.00	28.94
Arunanchal Pradesh	1	1	0	439	0.03	15.12
Sikkim	0	0	0	NA	0.00	NA
Mizoram	1	0	0	91	0.04	3.97

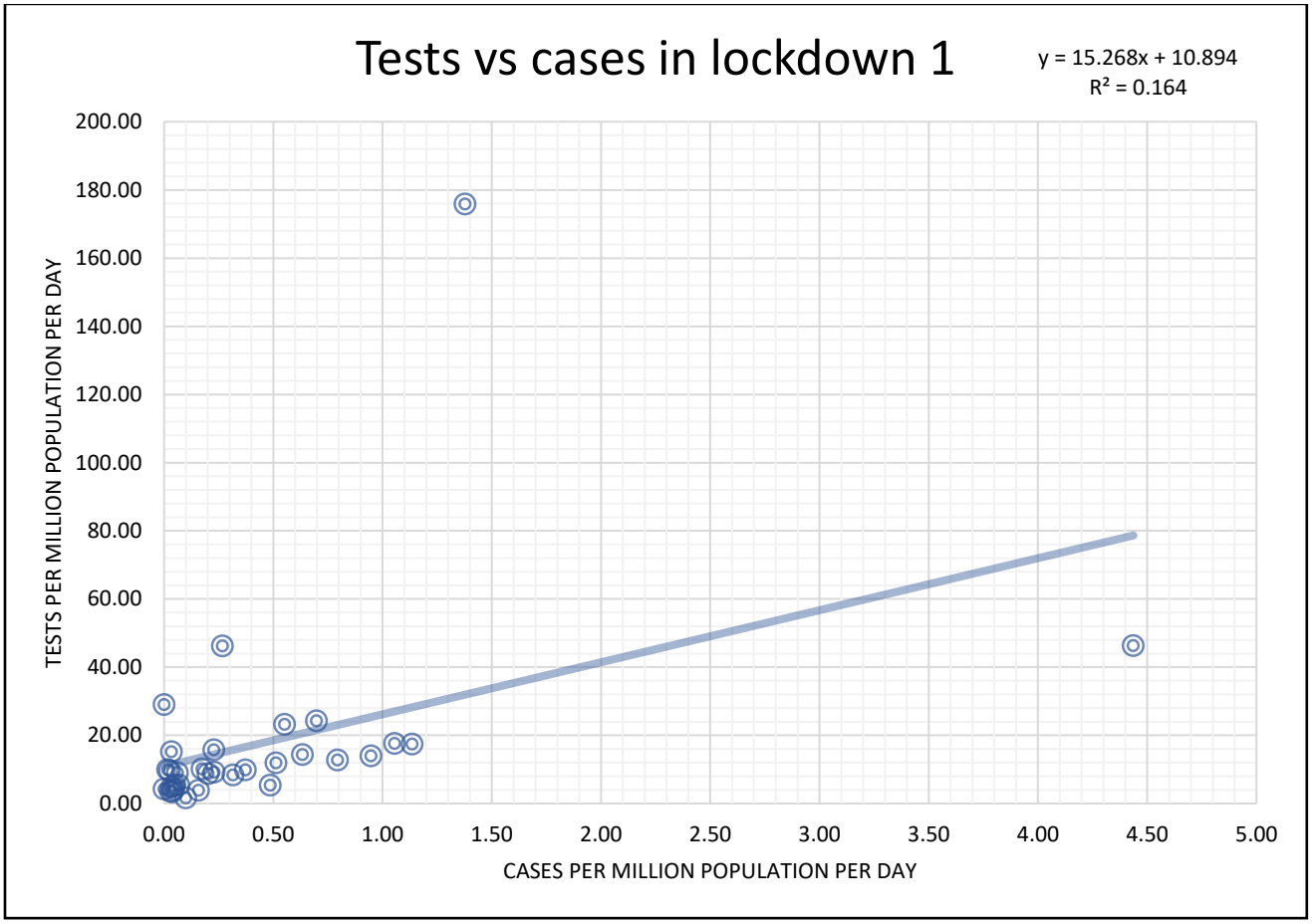


Figure 3 Scatterplot for tests vs cases per million population per day in Lockdown 1

On removing the outliers (Delhi – highest cases pm pop. per day And Andaman and Nicobar – Highest tests pm pop. per day)

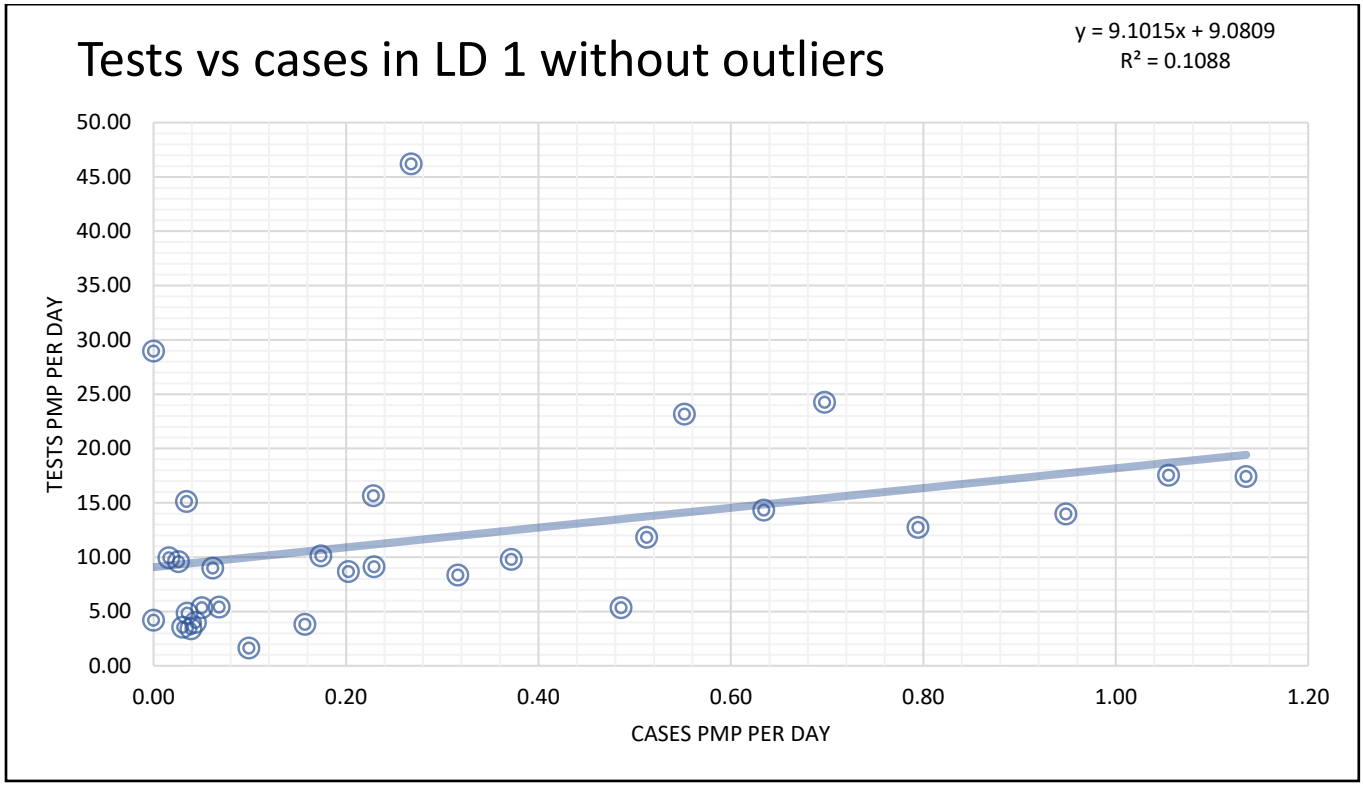


Figure 4 Scatterplot for Tests vs Cases per million population per day in Lockdown 1 (without outliers)

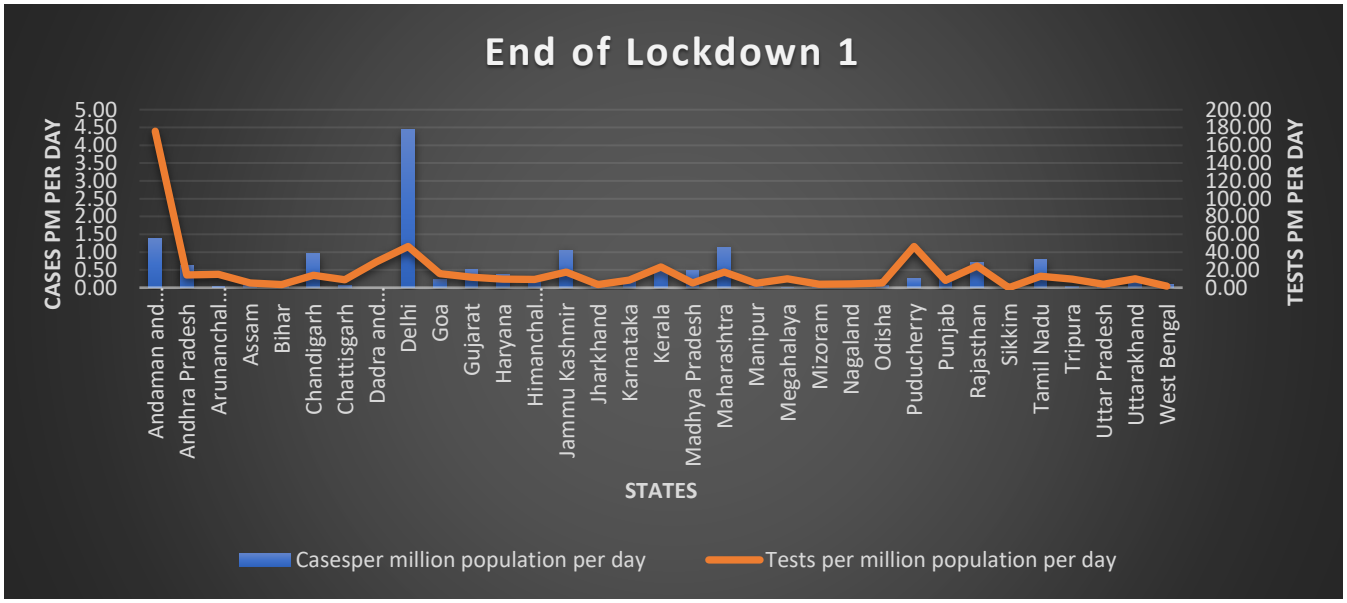


Figure 5 State wise scenario of Tests and Cases (per million pop per day) in Lockdown 1

The above graphs represent that in the lockdown 1 most of the states follow the trend line with Delhi and Andaman and Nicobar being the outliers. While in Delhi, cases PMP per day to be reported (4.4) were found to be highest of them all, the tests conducted PMP per day was 46.

However, in case of Andaman and Nicobar, tests conducted PMP per day (175) was the highest of them all. The cases per million were found to be 1.38. rest of the states/UTs performing good in tests per million were Puducherry, Dadra and Nagar haveli, Rajasthan and Kerala.

The states with overall high number of total cases were Maharashtra, Delhi, Tamil Nadu, Andhra Pradesh, Rajasthan

Lockdown 2:

Table 2 State wise no. of cases, deaths, recoveries and tests during Lockdown 2

States	Confirmed Cases	Tests	Recoveries	Deaths	Cases pm pop. per day	Tests pm pop. per day
Maharashtra	10294	118683	1856	370	4.82	55.59
Tamil Nadu	1819	130852	1298	18	1.33	95.47
Gujarat	4778	65080	983	262	4.16	56.73
Delhi	2988	43964	1331	34	9.39	138.12
Rajasthan	1881	85312	1209	60	1.44	65.43
Madhya Pradesh	2096	41081	734	103	1.52	29.78
Uttar Pradesh	1985	79927	704	35	0.52	21.08
West Bengal	1008	19834	96	115	0.58	11.43
Andhra Pradesh	1537	108748	907	33	0.96	67.60
Bihar	451	19224	95	3	0.23	9.75
Karnataka	354	63791	222	15	0.30	54.92
Punjab	918	21595	90	8	1.74	41.03
Jammu Kashmir	423	21419	257	4	1.77	89.83
Odisha	102	33924	42	0	0.13	42.56
Haryana	244	30068	190	2	0.51	62.42
Kerala	113	18373	190	1	0.18	28.96
Assam	10	9284	33	0	0.02	15.68
Jharkhand	88	10721	27	1	0.14	17.12
Uttarakhand	23	5421	30	1	0.12	28.20
Chhattisgarh	24	15090	23	0	0.05	31.10
Chandigarh	76	1307	12	1	3.79	65.22
Himanchal Pradesh	7	5874	21	0	0.05	45.09
Tripura	14	4424	2	0	0.20	63.43
Goa	0	2049	2	0	0.00	73.98
Puducherry	2	1948	5	0	0.08	82.39
Manipur	0	295	1	0	0.00	5.70
Andaman and Nicobar Islands	22	2351	22	0	3.05	325.67

Meghalaya	11	1090	10	1	0.20	19.36
Nagaland	0	510	0	0	0.00	13.55
Dadra and Nagar Haveli/ Daman and Diu	0	3972	0	0	0.00	356.89
Arunanchal Pradesh	0	371	0	0	0.00	14.12
Sikkim	0	NA	0	0	0.00	NA
Mizoram	0	92	0	0	0.00	4.44

Figure 6 Scatterplot for Tests vs Cases per million population per day in Lockdown 2

On the removal of outliers (Delhi and Maharashtra – high cases pm pop population per day And Dadra and Nagar Haveli and Andaman and Nicobar – High no. of tests pm pop per day)

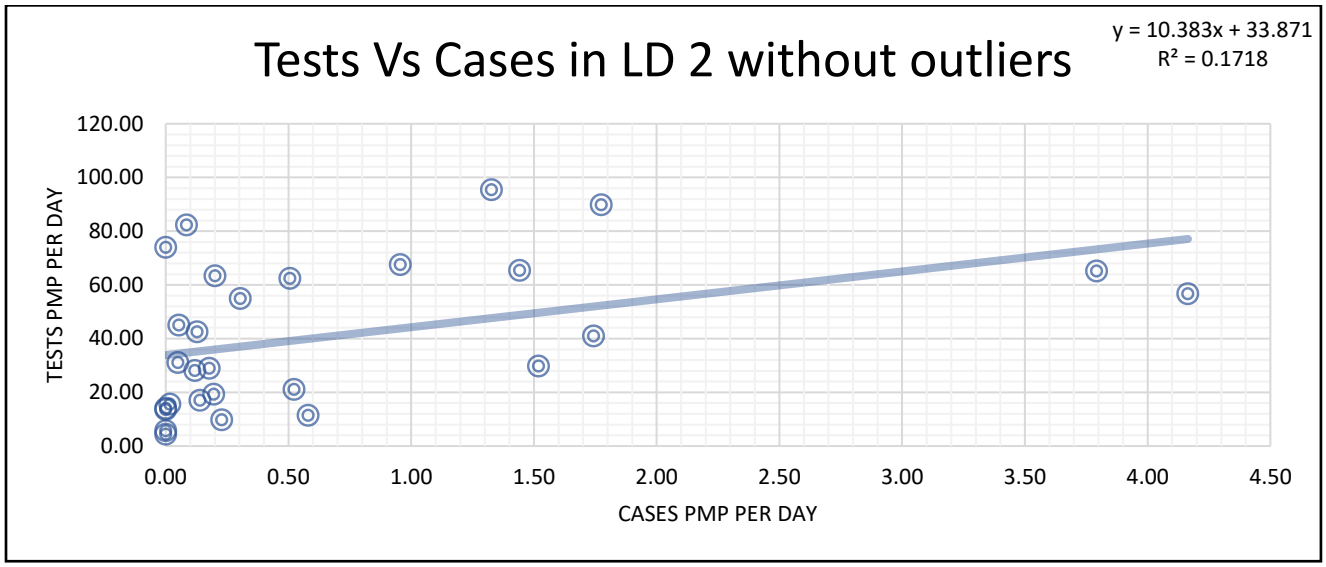


Figure 7 Scatterplot for Tests vs Cases per million population per day in Lockdown 2 (without outliers)

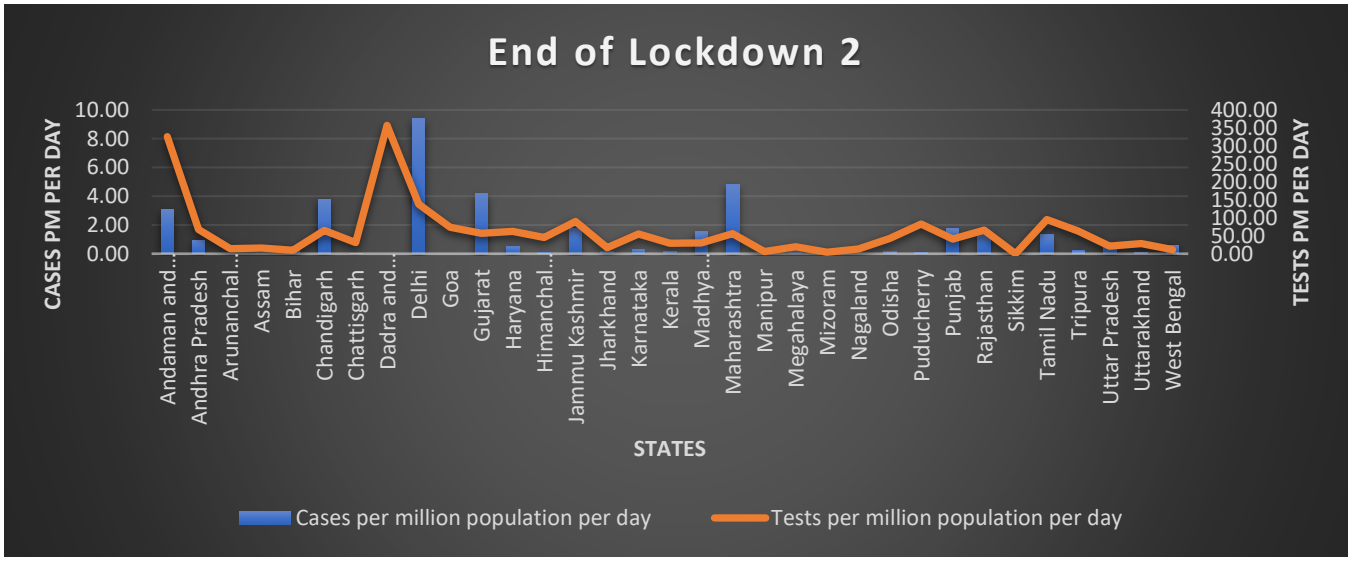


Figure 8 State wise scenario of Tests and cases (pm pop. per day) in Lockdown 2

During Lockdown 2, the outliers remain same with Delhi, Maharashtra (spike from 1.1 case pm pop. per day to 4.8 pm pop) being the state with highest cases confirmed per million population per day (9.3 and 4.8) and the tests being conducted were 138.1 and 55.5. Dadra and Nagar Haveli as well as Andaman and Nicobar perform the best in terms of tests being conducted per million population per day (356.8 and 325.6).

Other states whose number of confirmed cases per million were high were Gujarat, Chandigarh etc. North Eastern states like Nagaland, Arunanchal Pradesh, Sikkim, Mizoram had no increase in the case per million population per day

One other important finding that was noticed that Kerala which was amongst the top 8 states/UTs performing 23 tests per million population per day went below than many other states like Tamil Nadu, Andhra Pradesh, Chandigarh, Haryana, Gujarat, Karnataka, Odisha, Punjab and even Maharashtra with just an increase of 6 tests per million population in its performance.

Lockdown 3:

Table 3 state wise no. of cases, recoveries, deaths and tests during lockdown 3

States	Confirmed Cases	Tests	Recoveries	Deaths	Cases pm pop. per day	tests pm pop. per day
Maharashtra	20079	114286	5573	650	12.76	72.64
Tamil Nadu	8201	176613	2793	49	8.12	174.87
Gujarat	5952	63540	3457	369	7.04	75.16
Delhi	5206	75545	2840	84	22.20	322.09
Rajasthan	2316	111706	1699	60	2.41	116.28
Madhya Pradesh	2140	54712	1605	92	2.11	53.83
Uttar Pradesh	1999	76378	1882	69	0.72	27.34
West Bengal	1479	63041	827	116	1.16	49.29
Andhra Pradesh	1266	128171	1415	22	1.07	108.13
Bihar	803	18778	349	4	0.55	12.92
Karnataka	533	70500	216	12	0.62	82.38
Punjab	862	25373	1249	14	2.22	65.42
Jammu Kashmir	482	54896	288	5	2.74	312.47
Odisha	666	52565	160	3	1.13	89.51
Haryana	468	42751	317	9	1.32	120.44
Kerala	102	15428	96	0	0.22	33.01
Assam	58	21601	9	0	0.13	49.50
Jharkhand	108	20165	86	0	0.23	43.69
Uttarakhand	32	5644	13	0	0.23	39.85
Chhattisgarh	28	16704	23	0	0.08	46.72
Chandigarh	94	1196	32	2	6.37	81.00
Himanchal Pradesh	40	10232	6	1	0.42	106.59

Tripura	148	8588	83	0	2.88	167.10
Goa	22	6257	0	0	1.08	306.59
Puducherry	8	2464	3	0	0.46	141.43
Manipur	5	1912	0	0	0.13	50.18
Andaman and Nicobar Islands	0	2923	1	0	0.00	549.52
Meghalaya	1	1189	1	0	0.02	28.65
Nagaland	0	268	0	0	0.00	9.67
Dadra and Nagar Haveli/ Daman and Diu	1	2829	1	0	0.12	344.97
Arunanchal Pradesh	0	2539	0	0	0.00	131.17
Sikkim	0	777	0	0	0.00	91.33
Mizoram	0	99	1	0	0.00	6.48

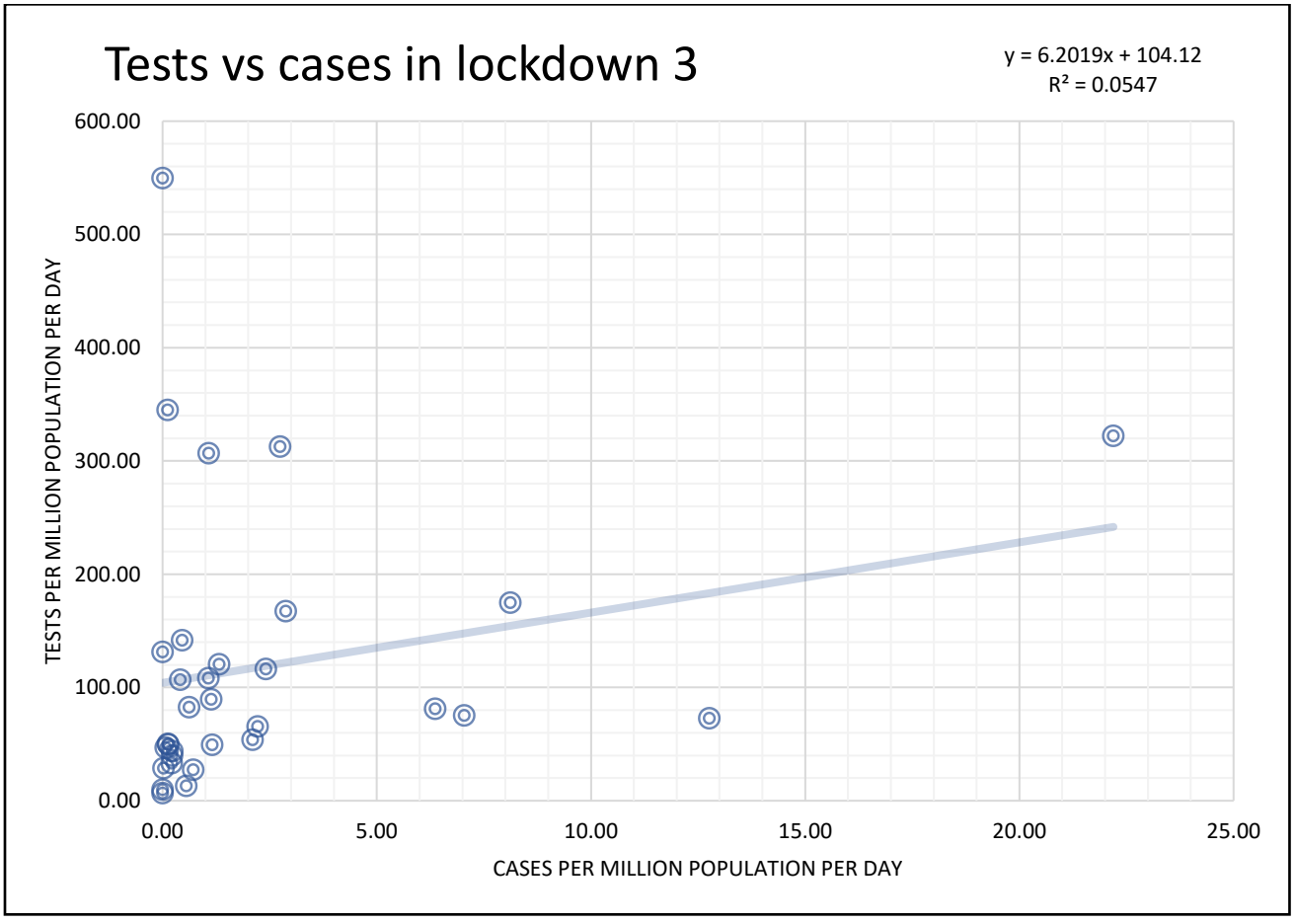


Figure 9 Scatterplot for tests vs cases per million population per day in lockdown 3

On the removal of outliers (Delhi and Maharashtra – high cases pm pop population per day And Andaman and Nicobar And Dadra and Nagar Haveli – High no. of tests pm pop per day)

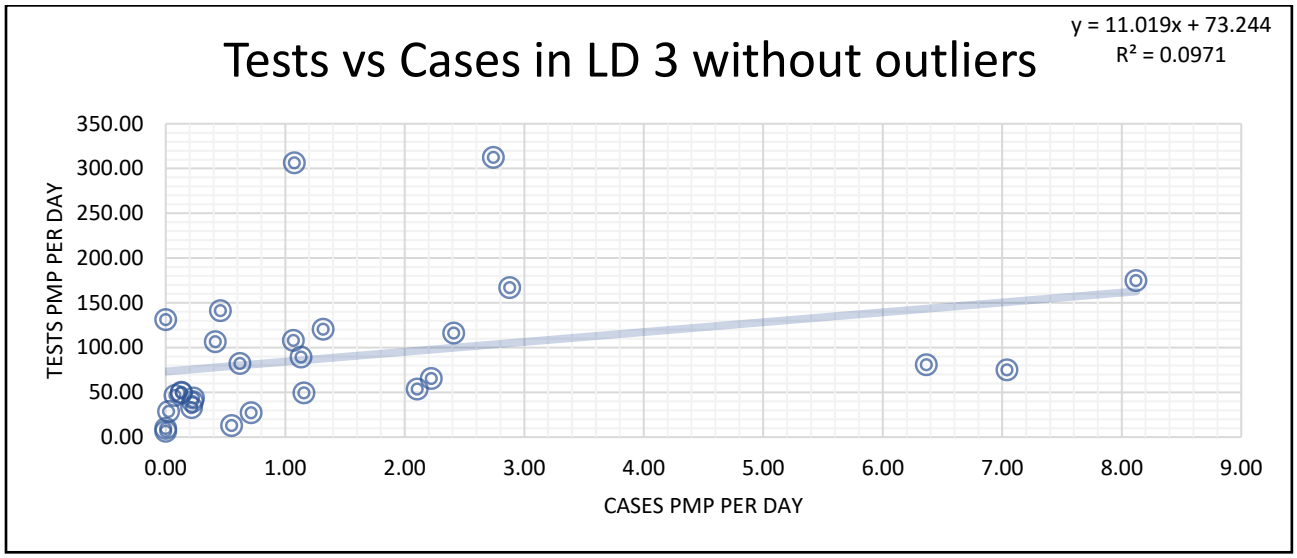


Figure 10 Scatterplot for tests vs cases per million population per day in Lockdown 3 (without outliers)

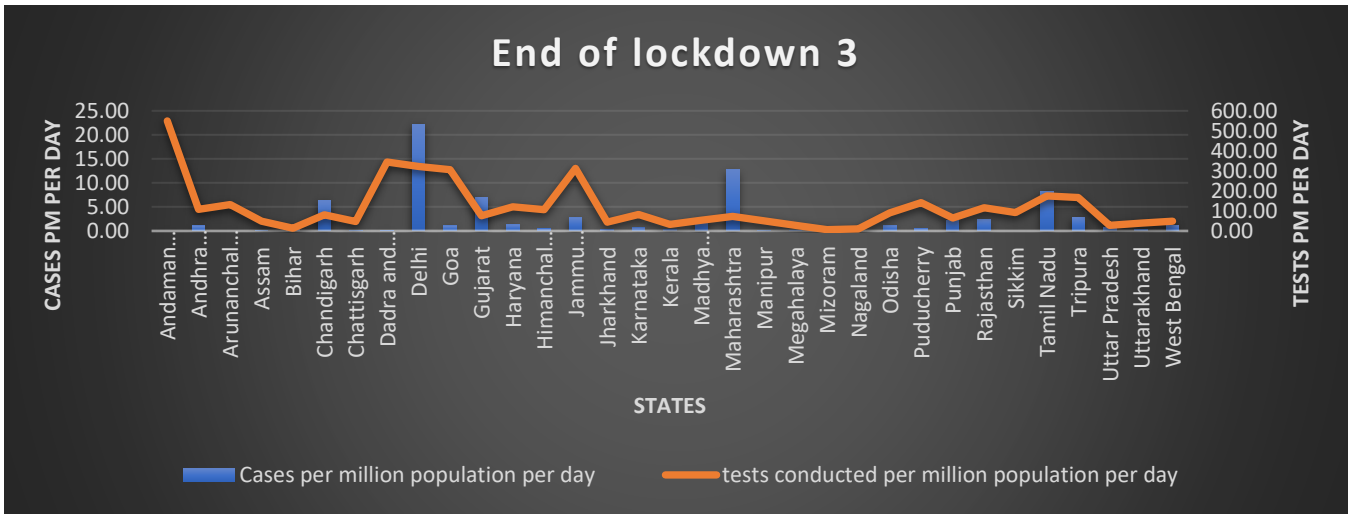


Figure 11 State wise scenario of tests and cases (pm pop. per day) in Lockdown 3

Outliers are the same in this lockdown phase also, with Delhi and Maharashtra being the states for top two highest number of cases getting confirmed per million population per day (22.2 and 12.7) and Andaman and Nicobar and Dadra and Nagar Haveli being the states with high level

of testing getting conducted (549.5 and 344,9). Kerala and West Bengal conducted lesser number of tests per million and were at lower levels. Uttar Pradesh and Bihar lag far below. Highest number of cases however were confirmed in Maharashtra, Tamil Nadu, Gujarat, Delhi, Rajasthan.

North Eastern states like Nagaland, Arunanchal Pradesh, Sikkim, Mizoram had no increase in the case per million population per day like the lockdown 2

Lockdown 4:

Table 4 state wise no. of cases, recoveries, deaths and tests during Lockdown 4

States	Confirmed Cases	Tests	Recoveries	Deaths	Cases pm pop. per day	Tests pm pop. Per day
Maharashtra	32115	174621	20393	999	20.41	111.00
Tamil Nadu	9960	152435	7828	84	9.86	150.93
Gujarat	4976	62180	4733	348	5.89	73.55
Delhi	8794	70948	3873	268	37.49	302.49
Rajasthan	3415	163544	2684	62	3.55	170.24
Madhya Pradesh	2914	57654	2041	95	2.87	56.73
Uttar Pradesh	3057	107069	2015	101	1.09	38.32
West Bengal	2453	108441	1011	71	1.92	84.79
Andhra Pradesh	2029	123935	1253	53	1.71	104.56
Bihar	2245	28200	838	13	1.54	19.40
Karnataka	1775	134819	488	12	2.07	157.53
Punjab	269	32685	601	9	0.69	84.27
Jammu Kashmir	1158	83647	333	15	6.59	476.12
Odisha	991	56267	830	5	1.69	95.81
Haryana	1013	36654	409	6	2.85	103.27
Kerala	607	27221	78	6	1.30	58.24
Assam	1116	66881	122	2	2.56	153.27
Jharkhand	371	29696	143	2	0.80	64.34
Uttarakhand	657	15221	50	4	4.64	107.47
Chhattisgarh	362	29811	43	1	1.01	83.37
Chandigarh	98	1842	148	1	6.64	124.75
Himanchal Pradesh	233	18251	67	3	2.43	190.13
Tripura	106	12626	87	0	2.06	245.67
Goa	41	9086	35	0	2.01	445.21
Puducherry	40	1545	14	0	2.30	88.68
Manipur	53	6113	4	0	1.39	160.43
Andaman and Nicobar Islands	0	586	0	0	0.00	110.17
Meghalaya	14	3657	1	0	0.34	88.13
Nagaland	36	1258	0	0	1.30	45.37
Dadra and Nagar Haveli/ Daman and Diu	1	4020	0	0	0.12	490.20

Arunanchal Pradesh	3	4668	0	0	0.15	241.16
Sikkim	1	1882	0	0	0.12	221.21
Mizoram	0	404	0	0	0.00	26.45

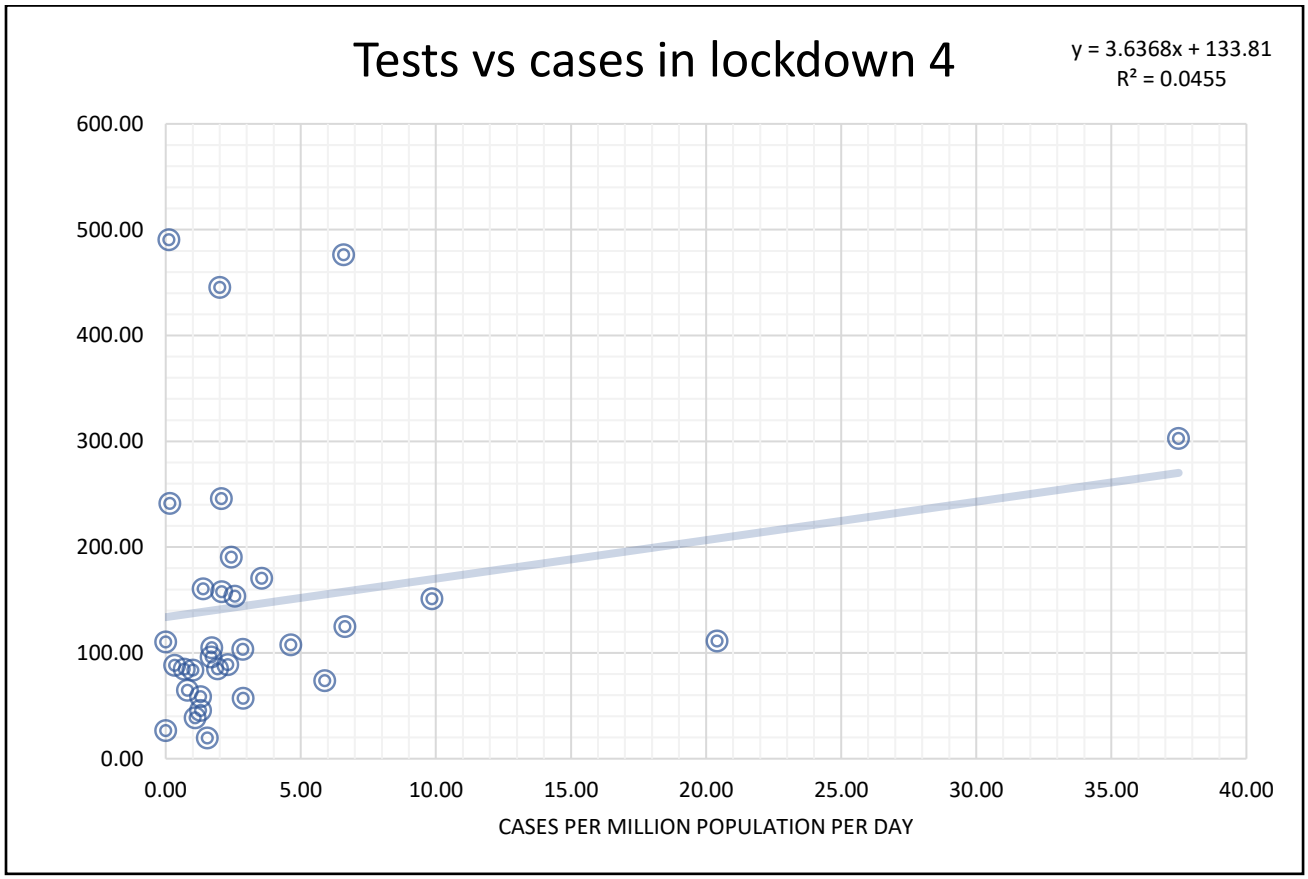


Figure 12 Scatterplot for tests vs cases per million population per day on Lockdown 4

On the removal of outliers (Delhi and Maharashtra – high cases pm pop population per day And Dadra and Nagar Haveli and Goa – High no. of tests pm pop per day)

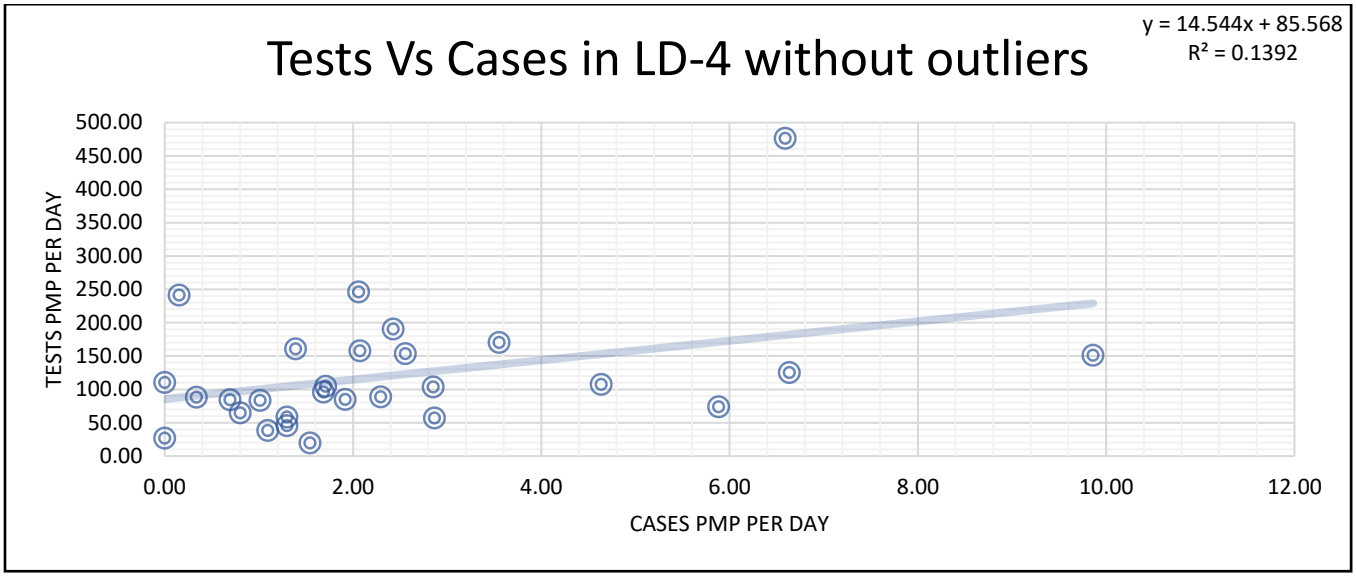


Figure 13 Scatterplot for tests vs cases per million population per day in Lockdown 4 (without outliers)

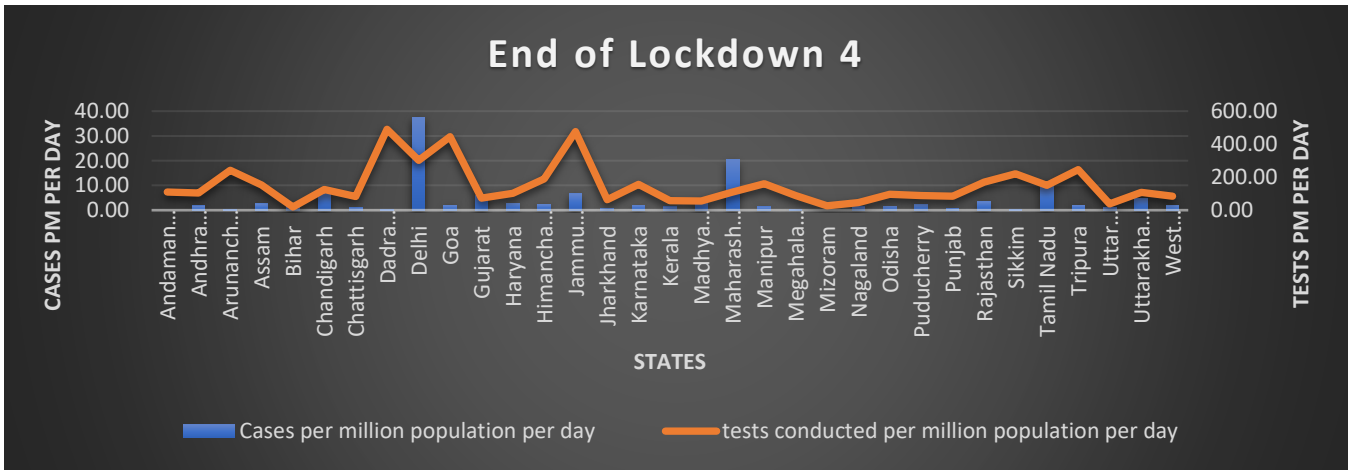


Figure 14 State wise scenario of tests and cases (pm pop. per day) in Lockdown 4

Outliers are the same in this lockdown phase also, with Delhi and Maharashtra again being the states with highest number of cases getting confirmed per million population per day (37.4 and 20.4) and Dadra and Nagar Haveli, Goa being the states and UTs with high level of testing getting conducted (490.2 and 445.2)

Kerala and West Bengal still conducted lesser number of tests per million and were at lower levels. Uttar Pradesh and Bihar lag far below. Highest number of cases however were confirmed in Maharashtra, Tamil Nadu, Gujarat, Delhi, Rajasthan.

North Eastern states like Nagaland, Arunanchal Pradesh, Sikkim, Mizoram had no increase in the case per million population per day similar to the lockdown 3

Many states have started testing fewer people each day than they were doing a month ago. When the analysis for people being tested per million population per day was run, it was found that in Delhi, Andhra Pradesh, Haryana, Gujarat. Tamil Nadu, Puducherry and Andaman and Nicobar; the number of people tested per million per day was reduced in Lockdown 4. However, the cases per million per day had increased for the same states except for Gujarat and Andaman and Nicobar

Situation at the end of Lockdown 4 (cumulative):

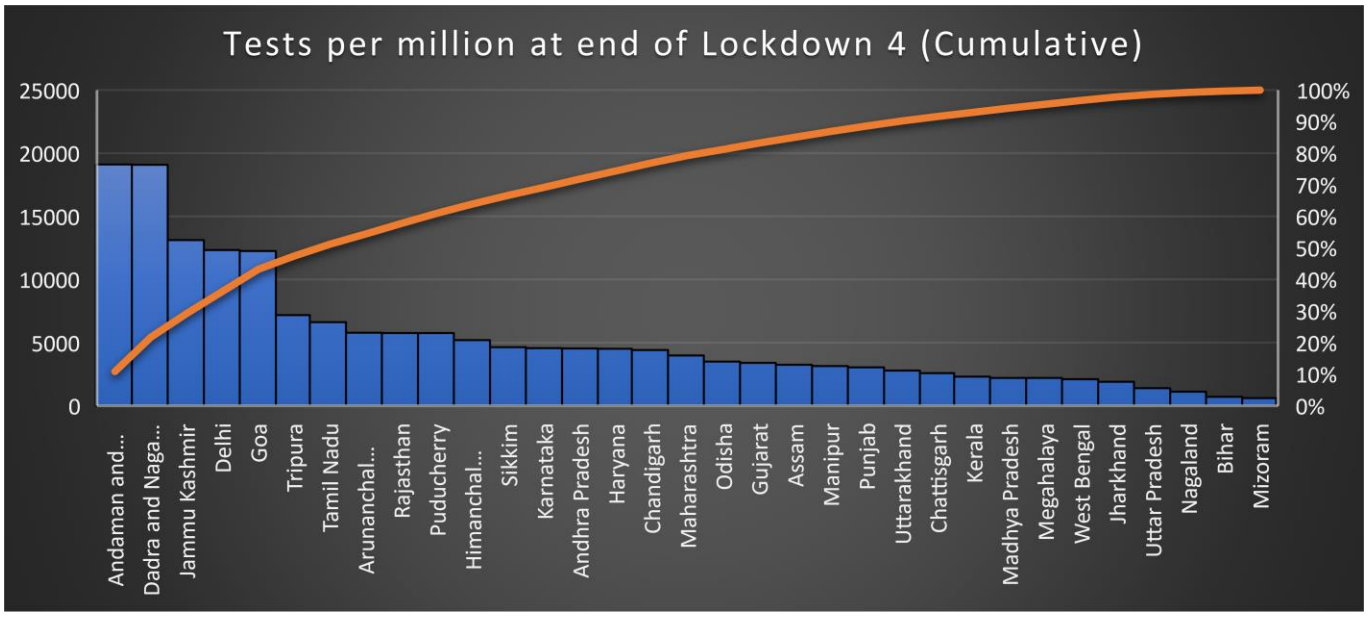


Figure 16 Tests per million population at the end of Lockdown 4(cumulative)

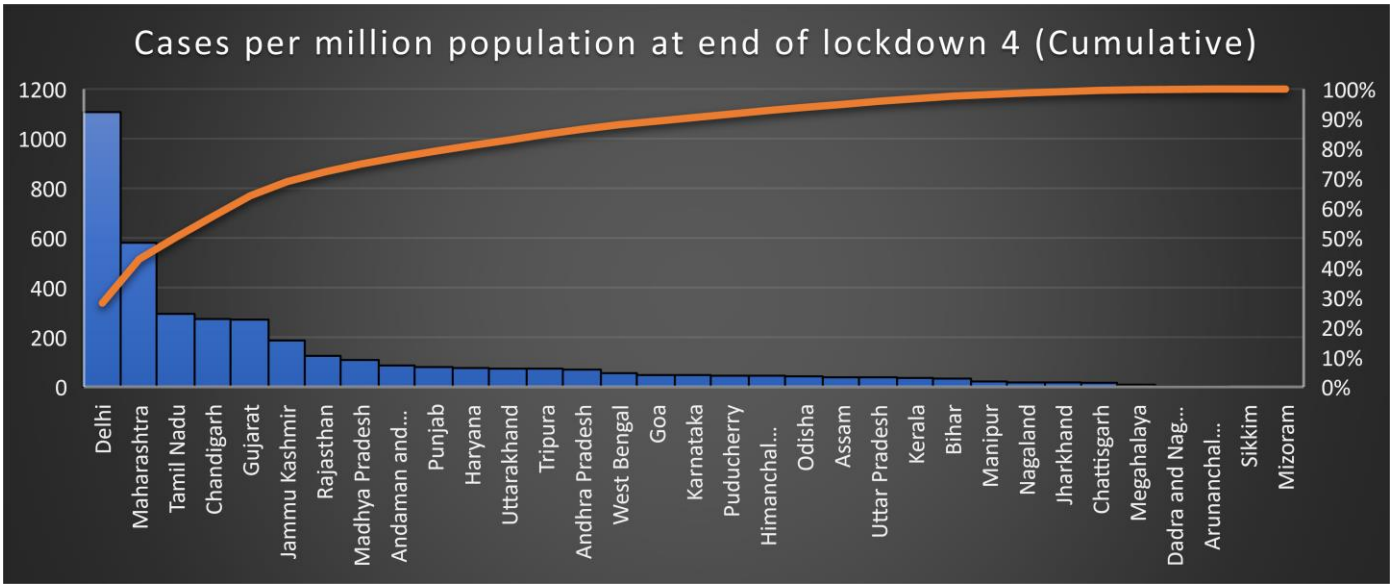


Figure 17 Cases per million population at the end of Lockdown 4 (cumulative)

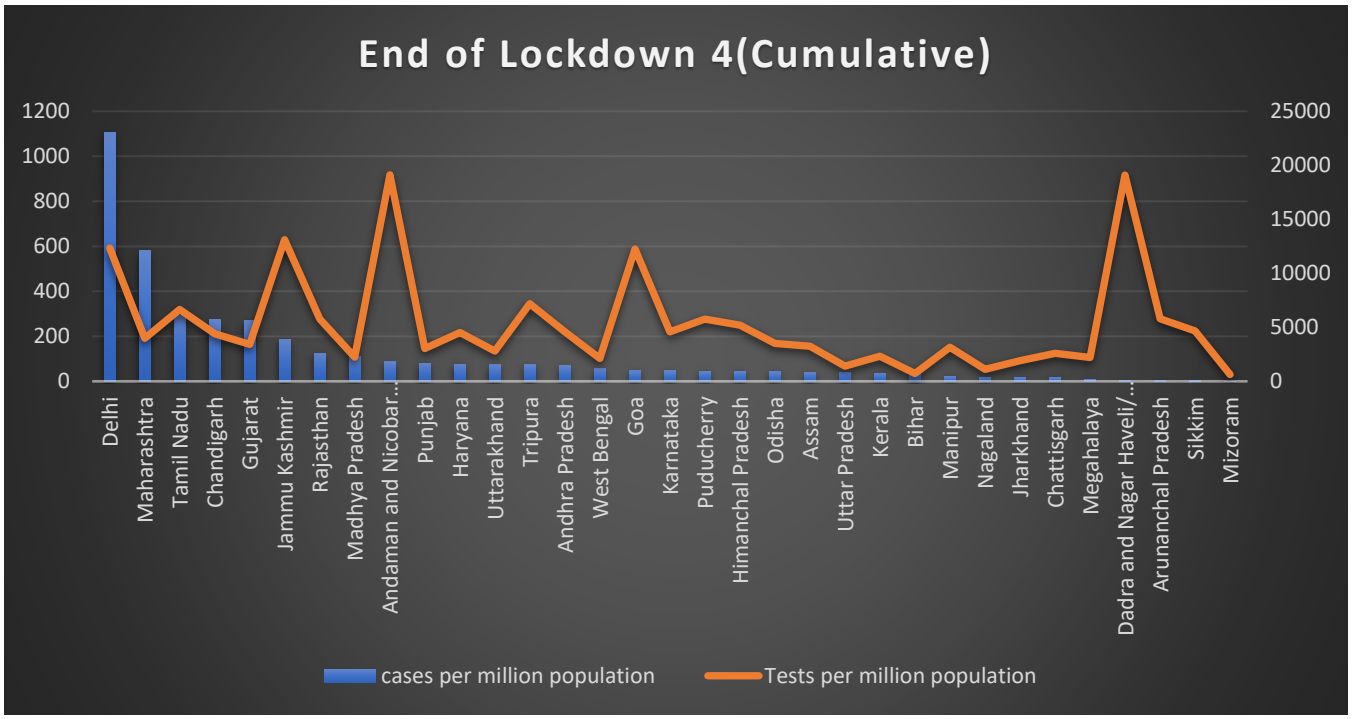


Figure 18Statewise scenario of tests and cases (pm pop. per day) at the end of Lockdown 4 (cumulative)

Overall Interpretation

Description of tests performed:

Amidst the period of four lockdowns, a total of 3586455 individuals were tested for SARS-CoV-2 . Testing has increased from 25144 individuals as on March 25, 2020 to 3611599 individuals towards the end of lockdown 4. There has been an increase from 21 people per million population getting tested at the start of phase 1 of lockdown to 29``84 individuals per million population tested towards the end of phase 4 of Lockdown. This shows a tremendous increase of people being surveillance and tested over the period of around 9 weeks with 44 individuals per million population being tested per day (taking population of India as on Census 2011)

Description of confirmed cases reported:

Amidst the period of four lockdowns, a total of 181202 individuals were reported as confirmed cases for SARS-CoV-2. the number has increased from 657 individuals as on March 25, 2020 to 181859 individuals towards the end of lockdown 4. There has been an increase from 0-1 people per million population reported confirmed case at the start of phase 1 of lockdown to 150 individuals per million population as confirmed case towards the end of phase 4 of Lockdown. This shows a tremendous increase in cases over the period of around 9 weeks with 2 individuals per million population being detected as confirmed case of COVID-19 per day (taking population of India as on Census 2011)

Correlation:

A weak and moderate positive correlation can be seen between the tests per million population conducted per day along with the cases per million population confirmed per day during the four phases of lockdowns. The states where the number of tests conducted are higher are having higher number of cases and vice versa. Although the association is not very strong subject to health care facilities. However, the pattern is not regular. there is a huge state wise variation that comes up when tests and cases are to be analyzed. This further depends upon the health system infrastructures well as the surveillance performance state wise that varies greatly across the national geographies.

Table 5 values of correlation coefficient for four lockdowns

Days	Correlation between tests conducted and the cases reported	
Lockdown 1	0.404	p value (0.02)
Lockdown 2	0.275	p value (0.12)
Lockdown 3	0.23	p value (0.19)
Lockdown 4	0.21	p value (0.25)

However, on removing the outliers from the frame of analysis, it was found that the correlation between tests conducted pm population per day with cases confirmed per million population per day has increased slightly

Table 6values of correlation coefficient for four lockdowns (without outliers)

Days	Correlation between tests conducted and the cases reported	
Lockdown 1	0.329	p value (0.07)
Lockdown 2	0.414	p value (0.02)
Lockdown 3	0.311	p value (0.10)
Lockdown 4	0.373	p value (0.05)

with not so strong coefficient of correlation and the varying values of statistical significance (p), it can be inferred that there is not a strong association between the two variables taken that can be stated to be statistically significant.

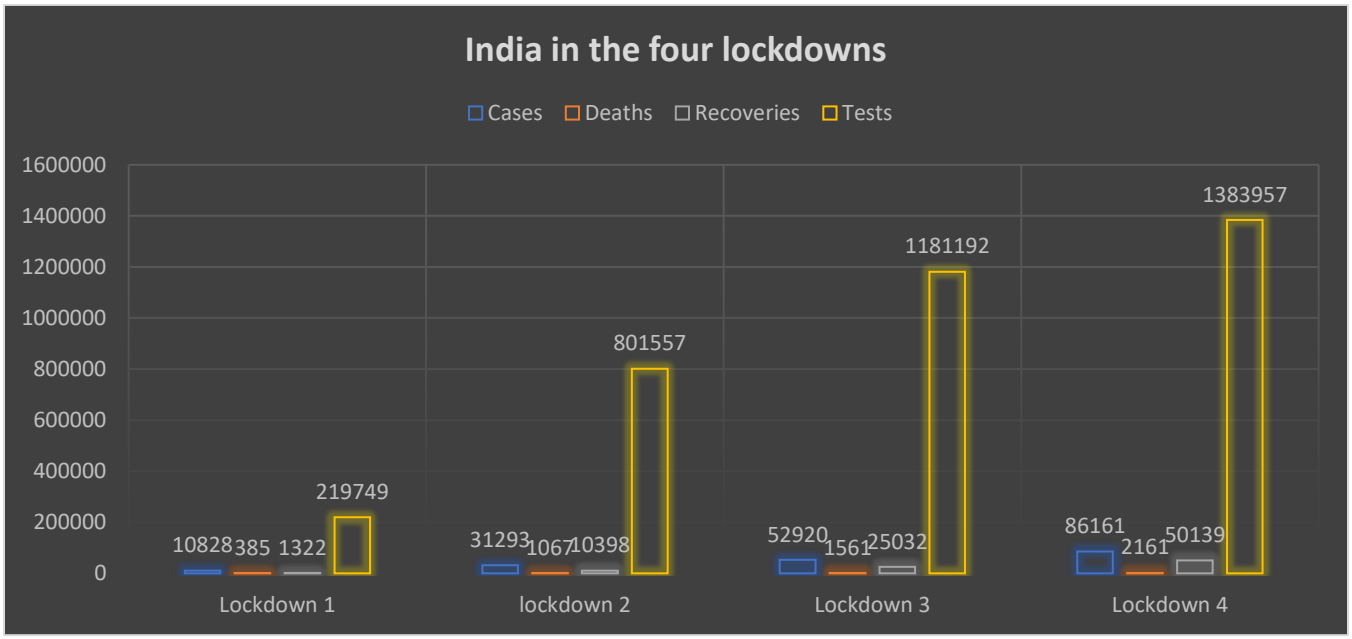


Figure 19 Trends of cases, deaths, recoveries and tests in four lockdowns (India)

Although aggregate number for testing seem to grow day by day in India if seen superficially yet the fact is that there is a wide state level variation in performance of surveillance. However, the fact that is hidden underneath is that many states have started testing fewer people each day than they were doing a month ago. When the analysis for people being tested per million population per day was run, it was found that in Delhi, Andhra Pradesh, Haryana, Gujarat. Tamil Nadu, Puducherry and Andaman and Nicobar; the number of people tested per million per day was reduced in Lockdown 4. However, the cases per million per day had increased for the same states except for Gujarat and Andaman and Nicobar (for the UT it remained near zero confirmed cases). Andaman and Nicobar Islands was the first state in the country to have started doing the pool testing that includes maximum five samples to be tested at once and the samples are tested individually only if the pool tests positive. This has possibly led to the increase in the UTs capacity of testing and saving resources. The north eastern states have constantly performed better in terms of cases being confirmed per day per million population

Table 7 States with high number of tests conducted per million population

States with high number of tests conducted per million population	
States	**Tests Per million population**
Andaman and Nicobar Islands	19116
Dadra and Nagar Haveli/ Daman and Diu	19081
Jammu Kashmir	13115
Delhi	12340
Goa	12260
Tripura	7185
Tamil Nadu	6642

Table 8 States with low number of tests conducted per million population

States with low number of tests conducted per million population	
States	**Tests Per million population**
West Bengal	2128
Jharkhand	1908
Uttar Pradesh	1399
Nagaland	1116
Bihar	712
Mizoram	629

Table 9 States with high number of confirmed cases per million population

States with high number of cases per million population	
States	**Cases per million population**

Delhi	1107
Maharashtra	580
Tamil Nadu	294
Chandigarh	274
Gujarat	271
Jammu Kashmir	187
Rajasthan	126

Table 10 States with low number of confirmed cases per million population

States with low number of cases per million population	
States	**Cases per million population**
Manipur	22
Nagaland	18
Jharkhand	18
Chhattisgarh	18
Meghalaya	9
Dadra and Nagar Haveli/ Daman and Diu	3
Arunanchal Pradesh	3
Sikkim	2
Mizoram	1

Less developed States like Bihar, Uttar Pradesh, Jharkhand, West Bengal are amongst the states which conducted lesser no. of tests per million people as compared to the other states when seen as a cumulative at the end of lockdown 4. While the places which performed better proportionate to their population were Andaman and Nicobar Islands Delhi, Jammu and Kashmir. Tripura, Tamil Nadu etc. north eastern states have performed better when it comes to comparing the tests being conducted as when compared to big states like Uttar Pradesh, West Bengal, Bihar. Even Kerala is testing lesser individuals per million when compared to National level which is 2984 per million population. This can clearly signify towards the gap in the health system infrastructure for the surveillance and judicious testing.

Mostly there has been increase in the number of cases per million per day in every lockdown. there may be a possibility that the states might have missed a cluster or two of the infections in the earlier phase of testing which resulted in the large number of cases being detected later. The states with high number of cases per million population are Delhi, Maharashtra, Tamil Nadu, Gujarat while those with lower number are mostly the north eastern states.

Chapter-9

Qualitative and Quantitative Description of Outlier states

States with high number of cases per million population (PMP)

During the four lockdowns the states of Delhi and Maharashtra have been the constant top two outliers being the states with the highest count of cases PMP per day, Delhi being at the top with 4.44, 9.39, 22.20 and 37.49 cases per million per day during the four phases of lockdown. Maharashtra has been the second largest in terms of per million cases per day with the 1.14, 4.82, 12.76 and 20.41

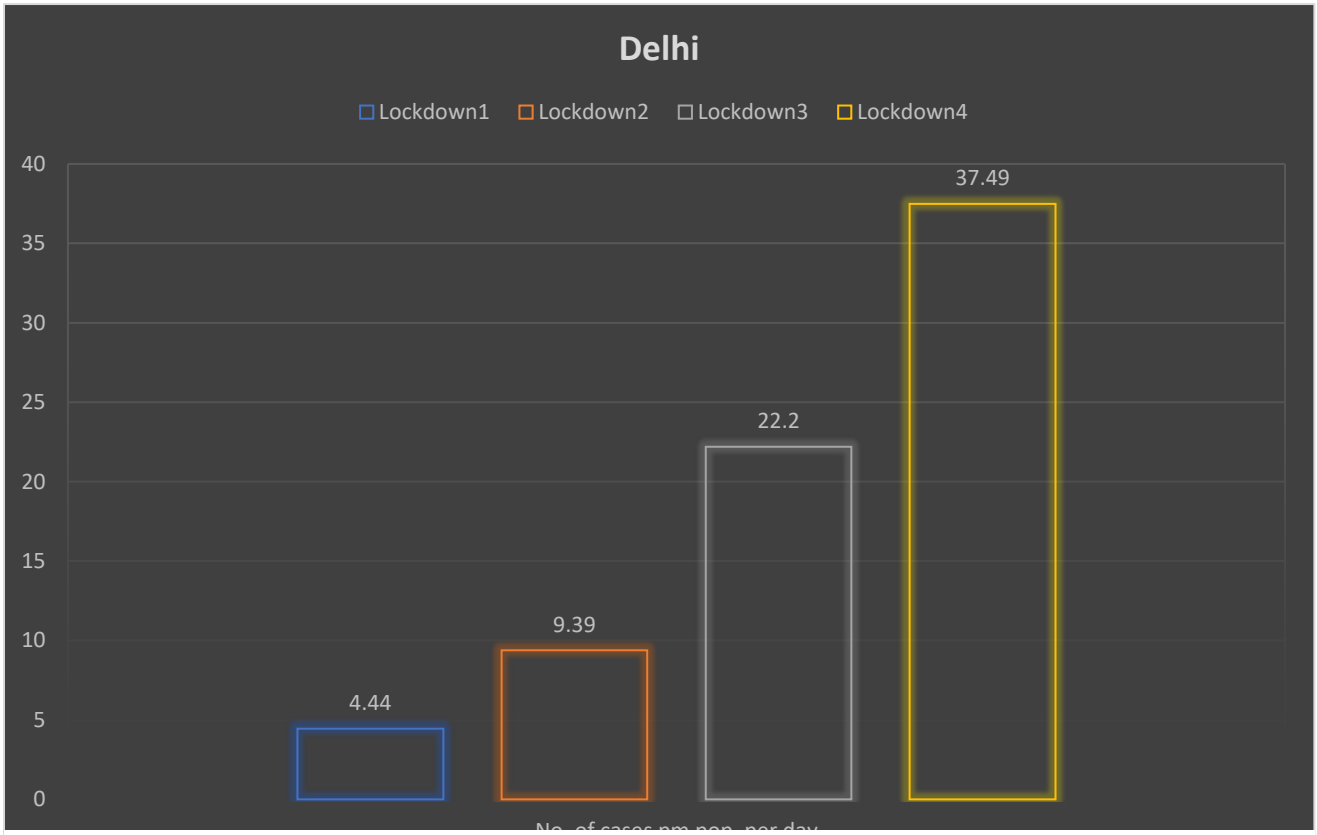


Figure 20 Trend of cases per million population per day in four lockdowns (Delhi)

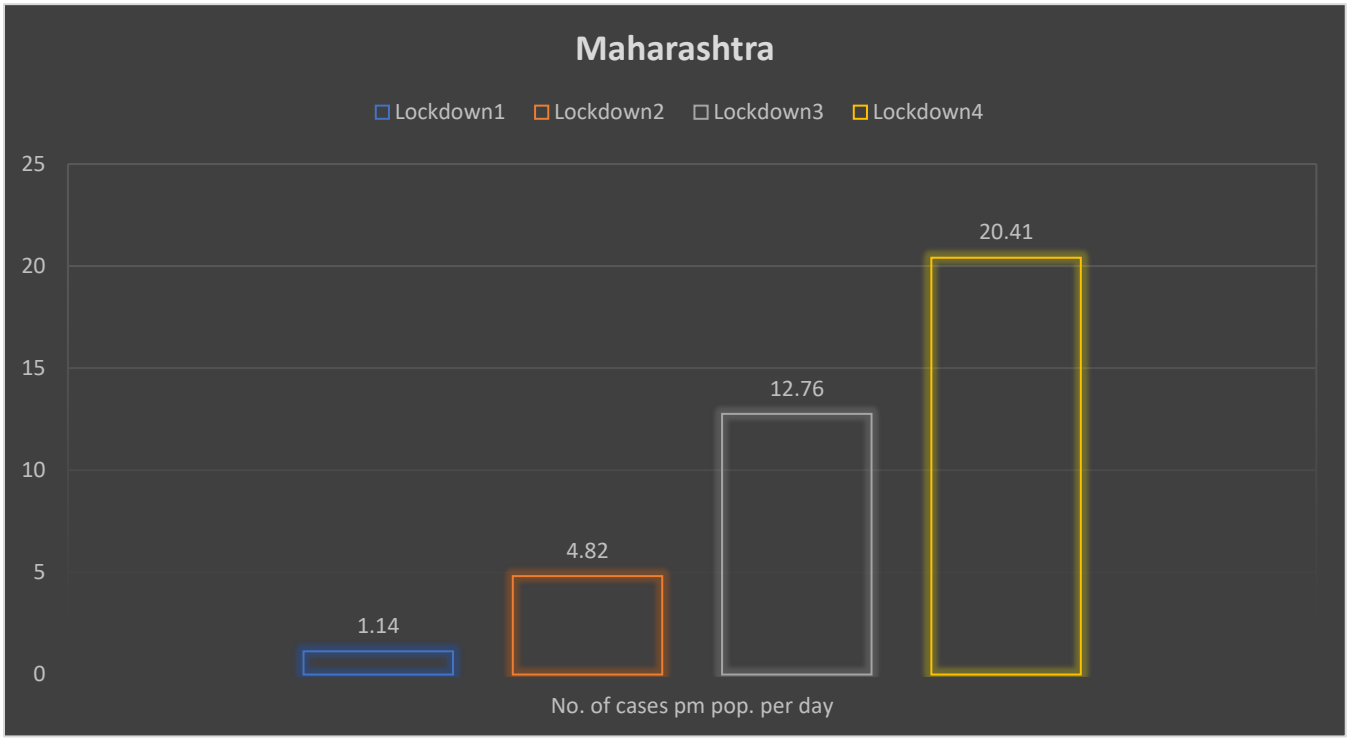


Figure 21 Trend of cases per million population per day in four lockdowns (Maharashtra)

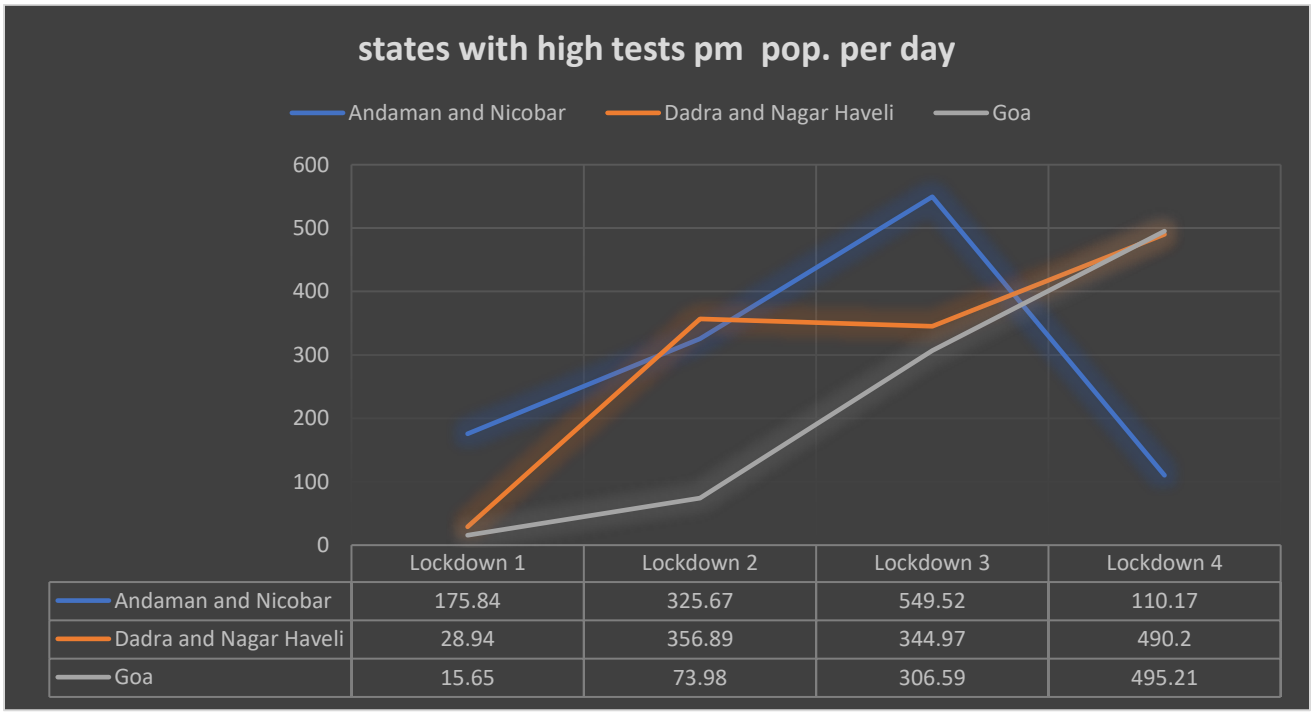
Delhi and Maharashtra being the workplace for thousands and thousands of migrants from all around the country have proven to be the outliers in terms of largest number of cases per million population each day during the four phases of lockdowns.

Many migrants from the states of Uttar Pradesh and Bihar etc. use to gather at public places like bus stations when they wanted to retreat to their native places after loss of work during the shut downs hence the protocols of social distancing were hard to be followed in these situations. In addition to that, In Delhi, the Tablighi Zamaat held a religious congregation programme in the Nizamuddin West making the city one of the India's major coronavirus hotspots

Maharashtra which accounted around 2/3rd of the total cases of the country, had cities like Mumbai (one of the worst affected cities on India) which is one of the hotspots for large number of migrant populations from various states in search of work. In order of going back to homes, they had got together, which may have led to the community transmission of the infection. In April, the cases and the death toll spiked as the infection started spreading its legs in the largest slum of Asia, Dharavi where not only hygienic conditions are poor but also the education and the awareness level is low too. Pune had also reported the largest number of cases and deaths during May within a day.

States with high number of cases per million population (PMP)

During the lockdown periods, Andaman and Nicobar, Dadra and Nagar Haveli have constantly shown the highest number of tests conducted PMP per day. Goa is also one of the outliers during the last phase of Lockdown.



	Lockdown 1	Lockdown 2	Lockdown 3	Lockdown 4
Andaman and Nicobar	175.84	325.67	549.52	110.17
Dadra and Nagar Haveli	28.94	356.89	344.97	490.2
Goa	15.65	73.98	306.59	495.21

Figure 22 Trend of tests conducted per million population per day during four lockdowns in Andaman and Nicobar, Daman and Diu and Goa

For Andaman and Nicobar, there was a drop in tests for the fourth lockdown; However, the number of confirmed cases and the deaths were zero for the same. It has also been the first state to start ICMR advised Pool testing that involves multiple swab samples taken at one time. this optimizes the availability of limited testing kits and more people can get tested at a time. There have been no active cases in Andaman and Nicobar, and Goa as well during May.

For these outliers with high testing, the confirmed cases (PMP per day have remained comparatively lower

These representations of highest number of cases conducted per million population per day may not reflect the quantum of tests as compared to whole country as the proportion of population in these UT's and States is relatively lower than the bigger states.

Chapter-10

Gaps in the strategy and performance of tests

According to the new guidelines of ICMR, the current testing strategy makes the testing of all symptomatic contacts of confirmed cases, and all patients with fever, cough, and shortness of breath, all symptomatic health workers mandatory, while for the asymptomatic individuals those with recent travel history, there are guidelines for home. All the asymptomatic direct contacts of confirmed cases are asked to get tested once between 5 and 10 days. Although the current testing method is targeted towards containing COVID-19 infection, there are some gaps

The known cases as seen, are mostly self-reported hence testing happens only amongst the symptomatic cases and there are chances of missing asymptomatic cases which usually do not report their contact with the confirmed ones. The patients being asymptomatic and having chance of getting infected through community spread may get missed most of the times. Also, the data which is being collected is vulnerable being biased towards patients with the symptoms of infections. With the missing cases not getting reported, the data becomes inappropriate to be used directly for any prediction models or forecasts of infection. Therefore, data completeness is an issue to be specific.

On one hand where data completeness is an issue, availability of limited testing resources is also a challenge to be catered. Testing people with the mild or no symptoms occupies the resources which are already limited. Also, the shortage of testing kits comes up as a problem where healthcare professionals cannot send the samples for testing even if they suspect the case on the clinical grounds. According to the official reports from Chhattisgarh. expanding of tests that too without any assurance of test kits from the central level lead to the shortage of kits at the state level. Although the health is a state subject, in these cases, states are dependent over Centre

Varying sensitivity of the tests questioning the quality of results they give is another gap to be looked into. As per one of the advisories of ICMR, certain Rapid Antibody Testing Kits like Guangzhou Wondfo Biotech, Zhuhai Livzon Diagnostics, etc. are subject to wide variation in the sensitivity and therefore lack in the performance and the surveillance purposes. During the period of second lockdown, there're instances reported where Health department of West Bengal claimed that large number of the testing kits which were supplied by ICMR-NICED (National Institute of Cholera and the Enteric Diseases) were giving the inconclusive results. The institute also admitted the fact that there was problem with the testing kits. Rajasthan also stopped using the rapid testing kits as they were of low accuracy. Therefor usage of Rapid Testing Kits was put on hold as ICMR advised all states the stop the usage, that may have created a miss in the number of cases to be detected correctly. Hence the varying sensitivity of the tests adds to the challenge

As revealed by ICMR, the screening measures as those of temperature checks at airport are not sometimes sufficient to test for the symptoms. It has been reported that around 46% of the passengers have missed the screening as they did not show symptoms

Despite being amongst the handful of country testing over millions of people, India has one of the lowest testing rates proportionate to its population. Towards the end of lockdown 4, India had tested 2984.31 people per million population. Besides, having a huge variation amongst states performance, the condition varies across the country. With north eastern states and UTs performing constantly better, less developed States like Bihar, Uttar Pradesh, Jharkhand, West Bengal are amongst the states which conducted lesser no. of tests per million people as compared to the other states when seen as a cumulative at the end of lockdown 4. This attributes to different health system infrastructure and capacity for different states. Underinvestment in the public health care system poses a threat to an efficient disease containment.

Another gap that can be interpreted from the overall increasing aggregate of testing in the country may be attributed to the futile testing wherein people out of fear want to get tested again and again. This further adds to the scarcity of resources which are already less.

Places where under reporting is an issue, health-seeking behavior of people and their ability to access services and the social stigma of the pandemic that varies across and within the subnational settings may be a cause for the same.

Official sites also do not clearly express that to what is the scope of the sampling efforts. how and when the individuals being tested are originally selected, what tests are being specifically used in each state and so on. The disease spread can be better estimated if these bifurcated details are provided.

ICMR lately announced the new advisory that there has to be introduction of tests for asymptomatic people having direct and high-risk contact of a confirmed cases, but provided the tremendous void in testing for community spread so far, there must have been clusters who were missed. Henceforth there is a need for large scale random testing of both symptomatic and asymptomatic cases for better understanding of the spread

Chapter-11
Recommendations to Way forward

As far as surveillance of COVID-19 cases is concerned, it is the number of tests conducted by the country which can actually tip the scale in our battle against coronavirus. Testing would give Indian authorities sense of the trajectory for transmission which will better inform the models and allow to make predictions regarding where is the actual need to be emphasize stronger responses

The availability of more detailed data will allow a better understanding and tracking of the size and scope of outbreak and also would help in strengthening the prevention and response efforts. Knowing the correct and accurate testing denominator indicates the level of the surveillance capacity.

To achieve the best results and lowering down of the curve. what is needed is to focus the surveillance system towards finding every single case and not to miss any behind. Each state is like a different country in India with different level of preparedness and the varied response. Benchmarks for adequate testing rates can be set for states to follow. District level task forces and active testing should be formed to plan and improve the surveillance and testing and step up preparedness

A syndromic approach can also be taken up in which the health care professionals initiate all necessary measures like isolation if they see a flu-like illness. They can record and report the numbers as ‘likely covid-19 case’. This can be a better measure so as to confront the shortage of supplies and equipment.

ICMR has suggested the pool sampling which includes performance of real time PCR for testing COVID-19 by pooling of 5 samples. This would cater the problem of limited testing resources but it is feasible when the prevalence rate is low for the infection. If sample is found positive, people are tested individually otherwise all individual in a pool which came out to be negative are to be regarded as negative. A community transmission can be screened through this technique. Andaman and Nicobar is the first of all states and UTs in the country to use this technique. Uttar Pradesh has also accepted the same. States can use this strategy for fast and ramped up testing.

The number of tests to be conducted can also be controlled as per the disease progression in a balanced approach to see in what way, the disease is progressing in a particular population and then strategize accordingly.

Door-to-door screening in the semi urban areas and rural areas, setting up kiosks and covid-19 control rooms, introduction of mobile sample collection centers and home care delivery mechanism can assist in the surveillance of COVID-19 cases as well.

Ongoing national and the local level analysis ongoing national and local analysis of the testing data can be enhanced by supplementing laboratory surveillance with additional intelligence from population based and sentinel site strategies as also recommended by WHO.

Individuals at the community can also aid in surveillance of COVID-19. Individuals having signs and symptoms of the disease should be able enough for accessing the testing at the primary level. If at some places, primary level is not possible, community base surveillance where community participates reports health events to local authorities, may be helpful in identifying the cases. Participation in cluster investigation and contact tracing are other ways in which individuals can contribute to the testing being done comprehensively. Contact tracing can be combined with the door to door case finding or the systematic testing in closed settings.

Self-reporting is also one of the initiatives that can be taken so that the case is not missed. This can be a participatory surveillance which enables public to self-report sign or symptoms that too without the laboratory testing or assessment from a health care professional, it's based on the voluntary reporting mostly through the smart phone applications, it shows the health seeking behavior is important for interpreting facility based surveillance data. Awareness and advocacy are required to be done at the community level that would remove the stigma associated with the COVID.

At primary level, surveillance is needed for the detection of the cases and clusters in community. Wherever possible, there should be established and dedicated COVID-19 community testing practices in place such as drive thorough sites or some fixed sites in the community establishments. Daily zero reporting is also crucial to verify that the testing system and the surveillance methods are functioning continuously.

In the hospital settings along with the mandatory procedures and testing, all clusters must be investigated. Mortality surveillance should be in place regularly. Laboratory testing data should be available from all the relevant laboratories. As kits are not available all the time, a quick screening can be ramped up be Computed Tomography and Chest Radiography. Chest Radiography being an easily available option is being used frequently worldwide. Usage can be increased in India.

Event based surveillance mechanisms can be used to strengthen the capacity of detecting the overall COVID-19 situation which captures unstructured information from the online content, radio broadcasts, print media to complement the public surveillance mechanism. Numerous web systems have been developed which converge with WHO led EIOS (Epidemic Intelligence for open source). EIOS is a unique initiative made up with collaboration amongst public health stakeholders around all over the world. This brings new and already existing initiatives, networks and systems together to create a One Health approach that enhances the capacities of early detection, verification as well as assessment of public health risks and threats all through open source of information.

Coordination of Centre and state level administration is the utmost important thing required now. A well-coordinated and interoperable system is needed to maintain the transparency and authenticity of resources being utilized, and to track the status of tests being performed and cases being reported. Moving from states to district based surveillance and indicators can aid to the enhancement of performance in surveillance. However, a strong political will and commitment is needed for the same. Capacity building of the whole system goes without saying.

Chapter-12
Conclusion

COVID-19 is a global pandemic which has emerged as the most complex viral infection to be handled by the human race. The objective of the surveillance of COVID-19 is limiting the spread of the disease , enabling the authorities of public health to manage the risk in an efficient and effective way, understanding the disease burden so that required and judicious steps can be taken for the same and henceforth the economic and the social activities can resume to maximum extent possible. It is required to monitor the trends of the COVID transmission as well as changes in the virus that keeps on mutating for longer terms

The study documents improved coverage and frequency of testing for SARS-CoV-2 infection across the country through four lockdowns. However, the statistics vary across states. The national COVID-19 testing strategy formulated and implemented by the ICMR has also evolved with the logistics and phases of the pandemic in India. The coverage as well as testing frequency has improved since launch. but since the testing criteria, require exposure to a positive case, there remains uncertainty about the transmission among unlinked individuals in the community. States also demonstrated wide variations in tests conducted and cases confirmed per million population per day during the four lockdowns. The surveillance data has provided insights on the epidemiology of COVID-19 in India. The change in the trend could be attributed to various health measures implemented on a wider scale. As the human resource capacity varies across the country, this may also affect the quality, timeliness and the coverage of surveillance in terms of tests being conducted, cases being reported etc.

The data in the study has limitations in terms of all case-based data, where trends are influenced by changes in case detection strategy and volume as well as various individual-level and overall health system-level variations. Health-seeking behavior and access to these services are also subject to variation across and within several subnational settings. The possibility of under-reporting of the cases as well as misreporting of comorbidity are also possible in the India which is needed to be monitored by health providers

The analysis trends over time and correlations with variables taken at broader geographical level may have potential bias typically associated with ecological analysis. Implementing other methods of surveillance, such as population-based and sentinel site based, will help to understand the trends in a better manner. Since the data of specific dates was used in the analysis, the number of cases and tests indicated might change with updating of records in the database.

Variation across the States in terms of cases can be further investigated to evaluate and improve the quality of isolation and quarantine measures to reduce transmission. While exposure to different contacts could vary per case, the reason for this variation needs to be further explored

to improve tracing and testing strategies. Analysis of the same with the density of states across the countries can be further done to understand the differences.

India needs to strengthen the capacity of surveillance for rapid testing, identification of cases, following up and monitoring the disease progression with time. Every state in India represents a different country with varying health system infrastructure. Therefore, being a health subject a strong political will right from the Centre at the highest level to the well planned and dedicated community level administration is what is the need of the hour for this pandemic to overcome. A high-level advocacy from various health institutions, technical partners, and government officials can also help in making the state health systems to understand that at current situation, surveillance system needs be comprehensive geographically and should include every person and the communities which are at the risk.

India, being the largest democracy and the second most populated country, always impacts the world and sets an example through its long term and thoughtful actions. This time also, it needs to set a good one.

References

1. Cascella, M., Rajnik, M., Cuomo, A., Dulebohn, S. C., & Di Napoli, R. (2020). Features, evaluation and treatment coronavirus (COVID-19). In Statpearls [internet]. StatPearls Publishing.
2. World Health Organization. (2020). Surveillance strategies for COVID-19 human infection: interim guidance, 10 May 2020 (No. WHO/2019-nCoV/National_Surveillance/2020.1). World Health Organization.
3. Retrieved 21 April 2020, from https://www.cdc.gov/.
4. Backer, J. A., Klinkenberg, D., & Wallinga, J. (2020). Incubation period of 2019 novel coronavirus (2019-nCoV) infections among travellers from Wuhan, China, 20–28 January 2020. Eurosurveillance, 25(5), 2000062
5. Bhosale, S., & Kulkarni, A. P. (2020). Is A Problem Shared, A Problem Halved? Not Always! The Novel Coronavirus COVID-19 Outbreak. Indian Journal of Critical Care Medicine: Peer-reviewed, Official Publication of Indian Society of Critical Care Medicine, 24(2), 88.
6. Dhillon, P., Sampurna Kundu, C. S., Ram, U., Dwivedi, L. K., Yadav, S., & Unisa, S. (2020). Case-Fatality Ratio and Recovery Rate of COVID-19: Scenario of Most Affected Countries and Indian States.
7. Shekhar, S. (2020). A Quantitative Framework for Expanding Testing Capacity of COVID-19 in India.
8. Indian Council of Medical Research. Press Release: Note on COVID-19 Laboratory Preparedness in India. New Delhi: ICMR; 6 March, 2020. Available from: https://www.icmr.gov.in/pdf/covid/labs/ICMR_PressRelease_COVID_19.pdf, accessed on May 8, 2020.
9. Department of Health Research. Establishment of a network of laboratories for managing epidemics and Natural Calamities (VRDL). New Delhi: Ministry of Health and Family Welfare, Government of India; 2020
10. Gupta, N., Potdar, V., Praharaj, I., Giri, S., Sapkal, G., Yadav, P., ... & Munivenkatappa, A. (2020). Laboratory preparedness for SARS-CoV-2 testing in India: Harnessing a network of virus research & diagnostic laboratories. The Indian Journal of Medical Research, 151(2-3), 216.
11. 2020. India-Coronavirus-Covid-19-Public-Private-Testing-Centers-By-State/. [online] Available at: <https://www.statista.com/statistics/1104075/> [Accessed 1 June 2020].
12. Retrieved 30 May 2020, from https://ncdc.gov.in/showfile.php?lid=461
13. Ghosh, P., Ghosh, R., & Chakraborty, B. (2020). COVID-19 in India: State-wise Analysis and Prediction. medRxiv.Biswas A, Bannur S, Jain P, Merugu S. COVID-19: Strategies for Allocation of Test Kits. arXiv preprint arXiv:2004.01740. 2020 Apr 3.
14. Jernigan, D. B., Lindstrom, S. L., Johnson, J. R., Miller, J. D., Hoelscher, M., Humes, R., ... & Balish, A. (2011). Detecting 2009 pandemic influenza A (H1N1) virus infection: availability of diagnostic testing led to rapid pandemic response. Clinical infectious diseases, 52(suppl_1), S36-S43
15. Advisory_on_feasibility_of_sample_pooling.pdf. (2020). Retrieved 15 May 2020, from https://www.icmr.gov.in/pdf/covid/strategy/.
16. Testing_Strategy_v5_18052020.pdf. (2020). Retrieved 10 May 2020, from 16. https://www.icmr.gov.in/pdf/covid/strategy/.
17. covid19india.org. Retrieved 31 May 2020

18. Advisory_Antibody_Testing_04042020.pdf. (2020). Retrieved 11 May 2020, from https://www.icmr.gov.in/pdf/covid/strategy/.
19. Abraham, P., Aggarwal, N., Babu, G. R., Barani, S., Bhargava, B., Bhatnagar, T., ... & Kurup, K. K. (2020). Laboratory surveillance for SARS-CoV-2 in India: Performance of testing & descriptive epidemiology of detected COVID-19, January 22-April 30, 2020.