Situational Analysis of the impact of COVID-19 pandemic on digital health research initiatives in South Asia

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Abstract

The objective of this paper was to evaluate and compare the quantity, and sustainability of digital health initiatives in the South Asia region pre-pandemic and during the COVID-19 pandemic.

The study used a two-step methodology of a) Descriptive analysis of digital health research articles published from 2016-21 from South Asia in terms of stratification of research articles based on diseases and conditions they were developed, geography, tasks wherein the initiative was applied. b) A simple and replicable tool was developed by authors to assess the sustainability of digital health initiatives using Experimental or Observational study designs.

The results from descriptive analysis highlight; a) 40% increase in the number of studies report in 2020 when compared to 2019, b) The three most common diseases and conditions wherein substantive digital health research has been focused are Health Systems Strengthening, Ophthalmic Disorders, and COVID-19, c) Remote Consultation, Health Information delivery and Clinical Decision support systems are the top three commonly developed tools.

We developed and estimated the inter-rater operability of the sustainability assessment tool was ascertained with a Kappa value of 0.806 (± 0.088).

We conclude that the COVID-19 pandemic had a positive impact on digital health research with improvement in the number of digital health initiatives and improvement in sustainability score of studies published during COVID-19.

Background

The World Health Organization Global Digital Health Strategy 2020-25 defines digital health as the field of knowledge and practice associated with the development and use of digital technologies to improve health. (1) The FITT framework developed by Ammenwerth et.al (2) for classification of Information Technology initiatives, broadly classifies the digital health initiatives into three tasks Health Information Exchange, Data Science and Surveillance(3). The WHO Global Digital Strategy stated its vision as “improving health for everyone, everywhere by accelerating the development and adoption of appropriate, accessible, affordable, scalable and sustainable person-centric digital health solutions”. The vision document has highlighted four strategic objectives; a) Institutionalization of digital health in the national health system, b) Integrated strategy to ensure the success of digital initiatives, c) Promote appropriate use of digital technologies for health, d) Address the impediments faced by least developed countries implementing digital health technologies.

The COVID-19 pandemic disrupted the global healthcare systems, the increasing COVID-19 cases diverted the available health care infrastructure, resources, manpower towards controlling the pandemic, while the delivery of normal healthcare services, related to maternal and child care, Non Communicable diseases was disrupted(4–7). The disruption in normal delivery of health care services presented an opportunity for digital health initiatives to fill in the gap, with as many as 264 research papers on digital health indexed in PubMed in the year 2020 on digital health from the South Asia region as compared to 82 research papers indexed in the year 2019. The three-fold increase in Medline indexed research papers implies an increased interest of medical practitioners, researchers, academicians in digital health from developing countries like India, Bangladesh, Vietnam, Thailand, Sri Lanka, Indonesia.

An increase in quantity is one aspect of the global digital health vision, the Quality of research undertaken and key steps are taken in the development phase to ensure the sustainability of the initiative are the two aspects that are explored to a limited extent.

In the proposed situational analysis, covers above mentioned aspects in digital health research in South Asian countries, which is home to about a quarter of the total world population. This research paper aims systematic analysis of the change in patterns measured through a review of published literature in pre-COVID-19 and during the COVID-19 pandemic.

Objective – The objective of this paper was to evaluate and compare the quantity, and sustainability of digital health initiatives in the South Asia region pre-pandemic and during the COVID-19 pandemic

Methods

A comprehensive search strategy was developed including search terms, Digital Health, mHealth, telehealth, e-health, health information exchange, Data Science, Surveillance with appropriate bullion operators "And/Or". The search was limited to the Medline database and restricted to South Asia, English Language and 5 years (2016-2020).

Search terms: (((((Digital Health) OR (mHealth)) OR (tele health)) OR (e health)) AND (((Health information exchange) OR (Data Science)) OR (Surveillance)) AND (y_5[Filter])) AND (((South East Asia) OR (India)) OR (South Asia) AND (y_5[Filter]))

The study has been divided into two sections of

A) Descriptive Analysis on Number of Research articles published on digital health

All the search results will be screened for eligibility based on

- Any research article published from January 2016 till March 2021
- The research articles must be focused on either Health information exchange, Data Science, or Surveillance tasks using digital tools

The descriptive analysis will include the number of research articles published year on year from January 2016 till March 2021, stratification of research articles based on diseases and conditions they were developed, geography, tasks wherein the initiative was applied.

1. B) Assessment of Sustainability

The eligibility criteria for assessment of quality are

- Research articles published between January 2016 till March 2021
- Research articles wherein the focus was on development, validation, scaling up of the digital initiative
- Research articles using Randomized Controlled trials, Quasi-Experimental, Case-Control, Cross-Sectional, Diagnostic and Pilot study designs

The exclusion criteria for assessment of quality are

- Research articles including Review Articles, Policy articles, Letter to Editors, Correspondence were excluded from quality assessment
- Economic Evaluation studies, Qualitative analysis studies were excluded from quality assessment

A review of various tools available for assessment of sustainability across various sectors like Manufacturing(8,9), Corporate Management(10), Multisectoral sustainability assessment tool(11), and Program Sustainability Assessment tool(12), Clinical Sustainability Assessment tool(13) developed by Centre for public health systems sciences, Washington University in St. Louis, however, none were found suitable to assess the sustainability of digital health initiatives, thus a simple tool was developed based on the objectives and vision stated in Global Digital Health Strategy 2020-2025 and principles of Public Health Data Standards(14). Two independent raters AM, SB and AS reviewed the eligible studies for three key areas a) Multisectoral and Cross-Sectoral engagement, b) Standards and Interoperability, c) People-Centric Approach. The sustainability score for the study was determined as the average score given by two independent raters. Table 1, presents the detailed tool used for assessing the sustainability

Table 1 - Tool of assessment of sustainability

Study Citation	
Section A – Multisectoral and Cross-Sectoral Engagement	
Q1) Does the study involve a multisectoral team? Consider a) Were all the authors from the medical field only b) Are the data scientists/development engineers/IT Consultants acknowledged in the paper?	Yes £ No £ Can't Say £ *(If your answer is Yes +1, NO -1, Can't Say 0)*
Q2) Does the study involve engagement with sectors other than health? Consider a) Concerning the study objective, did the study mention any other sectors like nutrition, agriculture b) Were the study endpoints or outcome assessment involved data from other sectors	Yes £ No £ Can't Say £ *(If your answer is Yes +1, NO -1, Can't Say 0)*
Section B - Standards and Interoperability	
Q3) Does the study mention adherence to any standards of data components, data interchange, application-level support? Consider a) Data Components - Reference Information Model, data elements, data types, terminology – Standards - HL-7, SNOMED, LOINC, UMLS b) Data interchange - Structured and free form documents, images – Standards - HL-7, ASTM c) Application-level support - Disease registries, implementation manuals – Standards - HIPAA, HL-7, ASTM, ISO	Yes £ No £ Can't Say £ *(If your answer is Yes +1, NO -1, Can't Say 0)*
Section C – People-Centric Approach	
Q4) Does the study mention stakeholder analysis/ community needs assessment/ with end-users for the development of initiative? Consider a) Does the study cite the previous study published on gap analysis, stakeholder analysis, qualitative survey to understand the needs of the end-users? b) Does the study involve a section or subsection wherein end-users were involved in the development of a digital health initiative	Yes £ No £ Can't Say £ *(If your answer is Yes +1, NO -1, Can't Say 0)*
Q5) Does the study mention scope of collecting feedback from the end-users? Consider a) Was there any mention of the collection of feedback from the end-users in the paper b) In the case of applications has feedback being collected and suitable changes being made to improve user-friendliness	Yes £ No £ Can't Say £ *(If your answer is Yes +1, NO -1, Can't Say 0)*

Results

A) Descriptive Analysis on Number of Research articles published on digital health

Our search strategy yielded a total of 563 articles on Medline, with the primary screening of article title and abstract 186 articles were found to be satisfying eligibility criteria. From 2016 to 2020 the number of research articles published on digital health has been steadily increasing and the trend over the past five years is visualized in Figure1.

When the studies were stratified based on study design, Review Articles and Guidelines made up to 65% of all the studies published on digital in past five years with a maximum number of review articles published in 2020. Figure 2 visualizes the study design and year was a trend. The year on year trend presented an average of 10% increase in Review Articles, 5% increase in Letter to Editors and Correspondence,4% in Diagnostic studies and 2-3% increase in Experimental Studies, Cohort Studies, Pilot and Development studies on digital health between 2016 to 2021.

The studies were stratified based on diseases and conditions for which digital initiative was primarily targeted, across the 5 years' timeline. Health Systems Strengthening which included initiatives such as capacity building amongst healthcare staff, geo-spatial analysis for improving access to healthcare services, using data science to improve the availability of essential medicines, was the area wherein the highest digital health initiatives were focused. Ophthalmic disorders and COVID-19 was the second and third conditions to be frequently researched. The year on year trend analysis of conditions wherein digital health initiatives were primarily targeted, Ophthalmic Disorders and Health Systems Strengthening recorded <20% increase, Cancer Screening, Cardiovascular Disorders, Mental Health recorder 4-6% increase on an average from 2016-21.

Negative year on year trend was seen for Dental Sciences, Dermatology, Drug safety, Elderly Care, HIV prevention and control, Injuries and Accidents, Kidney and Urinary tract disorders, Leprosy Management, Neurological Conditions, Nutrition, Orthotic Disorders, Sexual and Reproductive Health, Stroke, Tobacco and Alcohol Cessation, Tuberculosis Prevention and Control, Vaccination, Vector-Borne Disease Prevention and Control

The study used the FITT framework to classify digital tools on tasks, the broad classification was Health Information Exchange, Data Science, and Surveillance. Further classification and definition with examples of each digital tool is presented in Table 2

Table 2 - Types of digital tools

Task wise classification	Sub Classification	Definition	Example
Health Information Exchange (HIE)	Data Sharing	Any tool a platform has to support data sharing between heterogeneous computer systems of different organizations(15)	Health Information and management system
Information delivery	A tool used for delivery of information (preventive, curative) to the end-users	SMS's sent for a reminder of upcoming health visit,	
Remote Consultation	Consultation by remote telecommunications, generally for diagnosis or treatment of a patient at a site remote from the patient or primary physician(16)	Consultation using Skype, Zoom	
Intelligent Diagnosis	Intelligent Diagnosis systems are capable of identifying the nature of a problem by examining the observed symptoms and possibly an explanation or justify the same(17)	Algorithm-based diagnosis of risk of developing Diabetes	
Data Science	Patient-Generated Health Data	Health-related data created, gathered or inferred by or from patients and for which the patient controls data collection and data sharing(18)	Digital Diary
Predictive Analytics	Predictive analytics is a branch of advanced analytics that makes predictions about future outcomes using historical data combined with statistical modelling, data mining techniques and machine learning(19)	Predictions on chances of raining	
Clinical Decision Support System	Tools designed to be direct aid to clinical decision making, in which the characteristics of an individual patient are matched to a computerized clinical knowledge base and patient-specific assessments or recommendations are then presented to the clinician for a decision(20)	Image-based computer-assisted screening of oral lesions for cancer screening	
Big Data Mining	Big data analytics covers the integration of heterogeneous data, data quality control, analysis, modelling, interpretation and validation(21)	Using Air Pollution data to develop Air Quality Index	
Surveillance	Risk Screening	Continuous risk assessment of a condition, or population through multiple screening surveys(22)	NA
Realtime data collection and visualisation	Ongoing collection of data and presentation of data in a pictorial or graphical format (23)	COVID-19 dashboards	
Contact	Digitalization of identification and follow-up of	NA	

Tracing	persons who may have come into contact with a person infected with the infectious diseases(24)

The studies on remote consultation were most commonly reported, followed by information delivery systems and clinical decision support systems as visualized in Figure 4.

Cross-tabulation of Conditions and type of digital tool used is visualized in Figure 5; Health Information Exchange has been the most common digital tool for the majority of conditions, while all the digital initiatives in Metabolic Disorders (Diabetes), Tobacco and Alcohol Cessation, HIV prevention and Control were found to of Health Information Exchange. Surveillance initiatives were commonly employed for Vector-Borne Diseases Control, Cardiovascular disorders, COVID-19 and Health Systems Strengthening. Data Science initiatives were common for Ophthalmic Disorders, Health Systems Strengthening.

The year on year trend analysis of digital tool used, presented an average annual increase in Health Information Exchange tools recorded 5% annual increase, under HIE, Remote consultation recorded a 9% average annual increase, followed by a 7% increase by Health Information Delivery. Data Science tools recorded a 0.5% annual increase, under DS tools only Clinical Decision Support Systems recorded a 2.5% average annual increase, whereas Big data Mining, Predictive Analysis and Patient-Generated Health Data tools recorded a negative year on year trend.

The Surveillance tools usage trend presented a 0.5% average annual increase for 2016-2021 with Real-time Data Collection and Visualization tools showing a 2% increase.

The Descriptive analysis highlights

- COVID-19 pandemic has positively impacted digital health research with a 40% increase in the number of studies report in 2020 when compared to 2019
- The three most common diseases and conditions wherein substantive digital health research has been focused on are Health Systems Strengthening, Ophthalmic Disorders, and COVID-19.
- Remote Consultation, Health Information delivery and Clinical Decision support systems are the top three commonly developed tools from 2016 -2021

The details of all the studies included, their classification based on year, diseases, digital tools are included in the supplementary material.

B) Assessment of Sustainability

Validation of Sustainability assessment tool

We use inter-rater operability as an indicator to measure the ease of replicability of the tool. An independent rater, assessed 30 randomly selected studies using a computer-generated list for the 87 articles assessed in section B of this study. Cohen's Unweighted Kappa was used to determine the inter-rater operability. Overall Kappa value was 0.806 (SD ±0.088). The highest inter-rater operability was seen for Q1 (Does the study involve multisectoral team?) with Kappa value 1 (100%), lowest inter-rater operability was seen for Q3 (Does the study mention adherence to any standards of data components, data interchange, application-level support?) with Kappa value 0.54 (SD±0.036).

Kappa Value for other questions was

Q2 (Does the study involve engagement with sectors other than health?) – 0.91 (SD 0.066)

Q4 (Does the study mention stakeholder analysis/ community needs assessment/ with end-users for development of initiative?) – 0.84 (SD 0.042)

Q5 (Does the study mention scope of collecting feedback from the end-users?) – 0.71 (SD 0.06)

The interpretation of results was divided into Studies published pre COVID-19 pandemic (2016-2019) and during the COVID-19 pandemic (2020-2021). Analysis was reported for study design

Experimental Study Design

All the experimental studies pre-pandemic and during pandemic had an active involvement of IT, Data management team while developing the intervention and were either part of the team writing manuscript or dully acknowledged indicating the multisectoral team involved in developing and testing of the initiatives.

10 out of 18 experimental studies involved engagement of multiple sectors, for example, Swendenmen et, al (25) included behavioural scientist, HIV care providers, Front line health workers for the implementation of the study.

All the experimental studies mentioned adherence to data standards like WHO or ICDS classification of diseases, however, adherence to data interchange standards like HL7, was not mentioned.

All the experimental studies have either conducted a gap analysis or referred to previously published authors papers on gap analysis, community needs assessment for the development of initiatives

All the experimental studies have mentioned feedback collection from end-users, delivery providers and have mentioned changes made in digital initiative upon receiving feedback.

Overall the average sustainability of experimental studies on digital health was 80%, and there was no statistically significant difference in overall sustainability score between the studies published Pre-pandemic (85.6%) and During Pandemic (76.4%) (p-value -0.33).

Table 3 and Figure 6 presents the study wise assessment score summary and percentage of sustainability scores based on the author's judgement.

Table 3 - Assessment of Sustainability of Experimental Studies

	Author	Does the study involve a multisectoral team?	Does the study involve engagement with sectors other than health?	Does the study mention adherence to any standards of data components, data interchange, application-level support?	Does the study mention stakeholder analysis/ community needs assessment/ with end-users for the development of the initiative?	Does the study mention scope of collecting feedback from the end-users?
During COVID-19 pandemic	Shekhawat et.al 2020(26)	Yes	No	Yes	Yes	Yes
	Swendeman et.al 2020(25)	Yes	Yes	Yes	Yes	Yes
	Johri et.al 2020(27)	Yes	No	Yes	Yes	Yes
	Suryavanshi et.al 2020(28)	Yes	Can't Say	Yes	Yes	Yes
	Nandita et.al 2020(29)	Yes	Yes	Yes	Yes	Yes
Pre COVID-19 Pandemic	Modi et.al 2019(30)	Yes	No	Yes	Yes	Can't Say
	Zhilian et.al 2019(31)	Yes	Yes	Yes	Yes	Yes
	Joshep et.al 2019(32)	Yes	Yes	Can't Say	Yes	Yes
	Saran et.al 2019(33)	Yes	Yes	Yes	Yes	Yes
	Gross et.al 2019(34)	Yes	Can't Say	Yes	Yes	Yes
	Jiang et.al 2019(35)	Yes	Yes	Yes	Yes	Yes
	Peiris et.al 2019(36)	Yes	Yes	Yes	Yes	Yes
	Roohippor et.al 2019(37)	Yes	No	Yes	Yes	Yes
	Prabhakaran et.al 2018(38)	Yes	No	Can't Say	Yes	Yes
	Zhang et.al 2017(39)	Yes	Yes	Can't Say	Yes	Yes
	Ajay et.al	Yes	No	Yes	Yes	Yes

2016(40)					
Anand et.al 2016(41)	Yes	Yes	Yes	Yes	Yes
Sharma et.al 2016(42)	Yes	Yes	Yes	Yes	Yes

Cohort Study Design

80% of the Cohort studies had active involvement of IT, Data management team while developing the intervention and were either part of the team writing manuscript or dully acknowledged indicating the multisectoral team involved in developing and testing of the initiatives. The pattern of engagement with multisectoral was similar in studies reported before the COVID-19 pandemic and during the COVID-19 pandemic. However, in all the cohort studies assessed, engagement of multiple sectors was not seen amongst 80% of studies (needs rephrasing).

65% of Cohort studies reported adherence to WHO/ ICDS standards for the classification of diseases, however, studies have not mentioned adherence to data interchange standards like HL7.

All the cohort studies assessed have mentioned gap analysis and needs assessment for the development of the initiative. About 60% mentioned feedback collection from end-users, delivery providers and have mentioned changes made in digital initiative upon receiving feedback.

Overall the average sustainability of Cohort studies on digital health was 40%, and there was no statistically significant difference in overall sustainability score (how has this score been calculated and what is the validity of the tool may be to consider reporting in the form of yes and no) between the studies published Pre-pandemic (25.3%) and During Pandemic (35.6%) (p-value 0.45).

Table 4 and Figure 7 presents the study wise assessment score summary and percentage of sustainability scores based on the authors' judgement.

Table 4 - Assessment of Sustainability, Cohort studies

	Author	Does the study involve a multisectoral team?	Does the study involve engagement with sectors other than health?	Does the study mention adherence to any standards of data components, data interchange, application-level support?	Does the study mention stakeholder analysis/ community needs assessment/ with end-users for the development of the initiative?	Does the study mention scope of collecting feedback from the end-users?
During COVID-19 pandemic	Saw et.al 2020(43)	Yes	Can't Say	No	Yes	Yes
	Baroutsout et.al 2020(44)	Yes	No	Can't Say	Yes	Yes
	Tyler et.al 2020(45)	Yes	No	Yes	Yes	Can't Say
	Garg et.al 2020(46)	Yes	No	Yes	Yes	Yes
	Mahadevan et.al 2020(47)	No	No	Yes	Yes	No
	Rachmani et.al 2020(48)	Yes	No	Yes	Yes	Yes
Pre COVID-19 pandemic	Shah et.al 2019(49)	Yes	Yes	Can't Say	Yes	Yes
	Farnham et.al 2017(50)	Yes	No	Yes	Yes	Yes
	Balakrishnan et.al 2016 (17)	No	No	Yes	Yes	Yes

Cross-Sectional Study

25% of the Cross-Sectional studies had active involvement of IT, Data management team while developing the intervention and were either part of the team writing manuscript or dully acknowledged indicating the multisectoral team involved in developing and testing of the initiatives. The percentage of active involvement of multisectoral team was higher in cross-sectional studies reported during COVID-19 as compared to Pre COVID-19 reported studies. However, amongst 80% of cross-sectional studies assessed, engagement of multiple sectors was not seen.

90% of cross-sectional studies reported during the COVID-19 pandemic reported adherence to WHO/ ICDS standards for the classification of diseases, whereas only 10% of cross-sectional studies reported pre COVID-19 reported adherence to WHO/ ICDS standards for the classification of diseases.

30% of cross-sectional studies have mentioned gap analysis, needs assessment for the development of the initiative. About 40% of studies have mentioned feedback collection from end-users, delivery providers and have mentioned changes made in digital initiative upon receiving feedback.

Overall the average sustainability of Cross-Sectional studies on digital health was 40%, and there was a statistically significant difference in overall sustainability score between the studies published Pre-pandemic (45.3%) and During Pandemic (27.7%) (p-value 0.002).

Table 5 and Figure 8 presents the study wise assessment score summary and percentage of sustainability scores based on the authors' judgement.

Table 5 – Assessment of Sustainability, Cross-Sectional Study

	Author	Does the study involve a multisectoral team?	Does the study involve engagement with sectors other than health?	Does the study mention adherence to any standards of data components, data interchange, application-level support?	Does the study mention stakeholder analysis/ community needs assessment/ with end-users for the development of the initiative?	Does the study mention scope of collecting feedback from the end-users?
During COVID-19 pandemic	Ravindran et.al 2021(51)	No	No	Yes	Yes	Yes
	Ward et.al 2020(52)	Yes	Yes	Yes	Yes	Yes
	Huang et.al 2020(53)	No	No	Yes	No	Yes
	Singh et.al 2020(54)	No	No	Yes	No	Yes
	Vijayasundaram et.al 2020(55)	No	No	Yes	No	Yes
	Xiong et.al 2020(56)	Yes	Yes	Yes	No	No
	Das et.al 2020(57)	No	No	Yes	No	No
	Shenoy et.al 2020(58)	No	No	No	Yes	Yes
	Charumathi et.al 2020(59)	Yes	No	Yes	No	No
	Shreshta et.al 2020(60)	No	No	Yes	No	No
	Chuenphitthayavut et.al 2020(61)	Yes	No	Yes	No	No
Pre COVID-19 pandemic	Kogan et.al 2019(62)	Yes	No	No	No	No
	Dandge et.al 2019(63)	No	No	No	No	No
	Soni et.al 2018(64)	No	N0	No	No	No
	Bhatt et.al 2018(65)	No	No	No	Yes	Yes
	Shah et.al 2018(49)	Yes	No	No	No	No
	Chahar et.al	No	No	Yes	No	No

2018(66)					
Birur et.al 2018(67)	No	No	No	Can’t Say	Yes
Lee et.al 2018(68)	Yes	No	No	No	Yes
Kazi et.al 2017(69)	Yes	No	No	Yes	No
Devasahay et.al 2017 (70)	Yes	No	No	No	No
Lan Hoang et.al 2016(71)	Can't Say	No	No	No	No

Diagnostic studies

70% of the Diagnostic studies had active involvement of IT, Data management team while developing the intervention and were either part of the team writing manuscript or dully acknowledged indicating the multisectoral team involved in developing and testing of the initiatives. The percentage of active involvement of multisectoral team was higher in diagnostic studies reported Pre COVID-19 pandemic as COVID-19 reported studies. However, amongst 95% of diagnostic studies assessed, engagement of multiple sectors was not seen.

60% of Diagnostic studies reported adherence to WHO/ ICDS standards for the classification of diseases, majority of studies reported during the COVID-19 pandemic were able to provide information on adherence to standards

25% of Diagnostic studies assessed have mentioned gap analysis, needs assessment for the development of the initiative. About 30% of studies have mentioned feedback collection from end-users, delivery providers and have mentioned changes made in digital initiative upon receiving feedback.

Overall the average sustainability of Diagnostic studies on digital health was 45%, and there was no statistically significant difference in overall sustainability score between the studies published Pre-pandemic (45%) and During Pandemic (55%) (p-value 0.5)

Table 6 and Figure 8 presents the study wise assessment score summary and percentage of sustainability scores based on the authors' judgement.

Table 6- Assessment of Sustainability, Diagnostic Study

	Author	Does the study involve a multisectoral team?	Does the study involve engagement with sectors other than health?	Does the study mention adherence to any standards of data components, data interchange, application-level support?	Does the study mention stakeholder analysis/ community needs assessment/ with end-users for the development of the initiative?	Does the study mention scope of collecting feedback from the end-users?
During COVID-19 pandemic	Rajvanshi et.al 2021(72)	Yes	Yes	Yes	Can't Say	Yes
	Kannure et.al 2021(73)	No	No	No	No	
	Satgunam et.al 2020(74)	No	No	Yes	No	No
	Tham et.al 2021(75)	Yes	No	Yes	No	No
	Praveen Raj et.al 2020(76)	Yes	No	Yes	No	No
	Bulten et.al 2020(77)	No	No	Yes	Yes	Yes
	Dan Milea et.al 2020(78)	No	No	Yes	Yes	Yes
	Mondal et.al 2020 (80)	No	No	Yes	No	Yes
	Tahsin kurc et.al 2020 (79)	Yes	No	Yes	No	No
Pre COVID-19 pandemic	Shantharam et.al 2019(80)	Yes	No	No	Yes	Yes
	Sumsum Sunny et.al 2019(82)	Yes	No	No	No	No
	Muller et.al 2019(81)	Yes	No	Yes	No	No
	Vorakulpipat et.al 2019(82)	Yes	No	No	No	No
	Beane et.al 2019(83)	Yes	No	No	Yes	Yes
	Ramkumar et.al 2018(84)	Yes	No	No	Yes	Yes
	Kumar et.al 2018(85)	Yes	No	Yes	No	No

Koesoemadinata et.al 2018(86)	Yes	No	Yes	No	No
Kimberly M et.al 2018(87)	Yes	No	Yes	Yes	Yes
Maity et.al 2017(88)	Yes	No	Yes	No	No
Malhotra et.al 2017(90)	No	No	No	Yes	Yes

Pilot Studies and Development studies

We used the definition given by Stewart PW(89) for Pilot and Development studies as “small study to test research protocols, data collection instruments, sample recruitment strategies, and other research techniques in preparation for a larger study” however pilot randomized studies were included in experimental studies.

75% of the Pilot and Development studies had active involvement of IT, Data management team while developing the intervention and were either part of the team writing manuscript or dully acknowledged indicating the multisectoral team involved in developing and testing of the initiatives. The percentage of active involvement of multisectoral team was similar for studies report Pre COVID-19 pandemic and during COVID-19 reported studies. However, amongst 95% of diagnostic studies assessed, engagement of multiple sectors was not seen.

80% of Pilot and Development studies reported adherence to WHO/ ICDS standards for the classification of diseases.

50% of Pilot and Development studies assessed have mentioned gap analysis, needs assessment for the development of the initiative. Similarly, 50% of studies have mentioned feedback collection from end-users, delivery providers and have mentioned changes made in digital initiative upon receiving feedback.

Overall the average sustainability of Pilot and Development studies on digital health was 65%, and there was no statistically significant difference in overall sustainability score between the studies published Pre-pandemic (56%) and During Pandemic (63%) (p-value 0.28)

Table 7 and Figure 9 presents the study wise assessment score summary and percentage of sustainability scores based on the authors judgement

Table 7- Assessment of Sustainability, Pilot and Development studies

	Author	Does the study involve a multisectoral team?	Does the study involve engagement with sectors other than health?	Does the study mention adherence to any standards of data components, data interchange, application-level support?	Does the study mention stakeholder analysis/ community needs assessment/ with end-users for the development of the initiative?	Does the study mention scope of collecting feedback from the end-users?
During COVID-19 pandemic	Bafna et..al 2020(90)	No	No	Yes	No	No
	Nikita et.al 2020(91)	No	No	Yes	Yes	
	Hegde et.al 2020(92)	Yes	No	No	No	
	AnLee et.al 2020(93)	Yes	No	Yes	No	No
	Misra et.al 2020(94)	Yes	No	Yes	Yes	Yes
	Thornber et.al 2020(95)	Yes	No	No	Yes	Yes
Pre COVID-19 pandemic	Ayyanar et.al 2019(96)	Yes	No	Yes	No	No
	Ahmed et.al 2019(97)	No	No	Yes	No	No
	Devraj et.al 2019(98)	Yes	No	Yes	Yes	Yes
	Drusbosky et.al 2019(99)	Yes	No	Yes	No	No
	Jain et.al 2019(100)	Yes	No	No	Yes	Yes
	Verma et.al 2018(101)	No	Yes	Yes	No	No
	Rao et.al 2018 (102)	Yes	No	Yes	Yes	Yes
	Aggarwal et.al 2018(103)	Yes	No	Yes	No	No

Devraj et.al 2018(104)	Yes	No	Yes	Yes	Yes

The assessment of sustainability analysis indicates

- Experimental studies and Cohort studies had incorporated factors contributing to sustainability and involvement of teams, sectors, feedback was reported across a majority of studies irrespective of Pre COVID-19 pandemic or During the COVID-19 pandemic
- Cross-Sectional studies, conducted during pandemic improved on parameters of assessment of sustainability and the difference between sustainability assessment Pre COVID-19 Pandemic and During COVID-19 pandemic was statistically significant
- Diagnostic Studies and Pilot and Development studies had incorporated limited factors contributing to sustainability irrespective of Pre COVID-19 pandemic or During the COVID-19 pandemic

Discussion

This study is the first to our knowledge, which has systematically analyzed and presented evidence from the sustainability perspective of digital health research initiative across South Asia. A systematic review by Bassi et. al(108) in 2018 looked at the current status and future perspectives of mHealth from Health Systems perspectives, the review highlighted the poor quality of evidence generated through mHealth research. Another review by Bassi et.al (109) in 2020 presented the review COVID-19 related mobile apps and highlight gaps to inform the development of future mHealth initiatives, wherein the functionality of mobile applications was assessed to adjunct risk assessment efforts. Another systematic review by Kondylakis et. al(110) raised concerns about the quality of research studies published on the development and implementation of COVID-19 Mobile applications.

The COVID-19 pandemic saw a huge increase in research of digital health initiatives, our study hypothesis was based on the increased number that has affected the sustainability of the research initiatives; and the intrinsic factors of research initiatives like multisectoral involvement, gap analysis, stakeholder engagement.

In this paper, we descriptively analyzed the impact of the COVID-19 pandemic on the volume of research in digital health. To ascertain the sustainability, we searched for standardized tools available for sustainability assessment, however, the tools didn't suit the needs presented in this study. This led to the development of a simple tool for the assessment of sustainability. The assessment of sustainability was undertaken for 87 articles and the tool can determine intrinsic sustainability factors and give summary estimates on how well the authors incorporate sustainability in digital health research.

In our study we found the number of digital health interventions research increased significantly during the COVID-19 pandemic, and most authors took initiative to have oversight on the sustainability of their digital health initiatives. Contrary to our hypothesis, the sustainability score of cross-sectional studies was higher for studies published during the COVID-19 pandemic as compared to studies published before the COVID-19 pandemic.

From our study its is clear that choice of digital tool, disease and study design vary highly based on study objectives and research, however, the patterns presented over five years show higher research interest in Ophthalmic Disorders, Health Systems Strengthening, while Health Information Exchange tools have been

exclusively used. The underlying reasons can be further explored and taken up for further research and help derive recommendations at a policy level.

Conclusion And Recommendation

We conclude that the COVID-19 pandemic had a silver lining and it positively impacted Digital health research, with improving the number of research initiatives undertaken from South Asia and with researchers able to develop a long term vision for digital health initiatives.

The momentum and interest in digital health gained due to the COVID-19 pandemic should be sustained post-pandemic world and with our sustainability analysis, there is certain confidence about the researchers able to develop a vision to sustain the initiative, much however depends on extrinsic factors like availability of skilled manpower, conducive policy environment, access to internet and hardware amongst target population.

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Figures

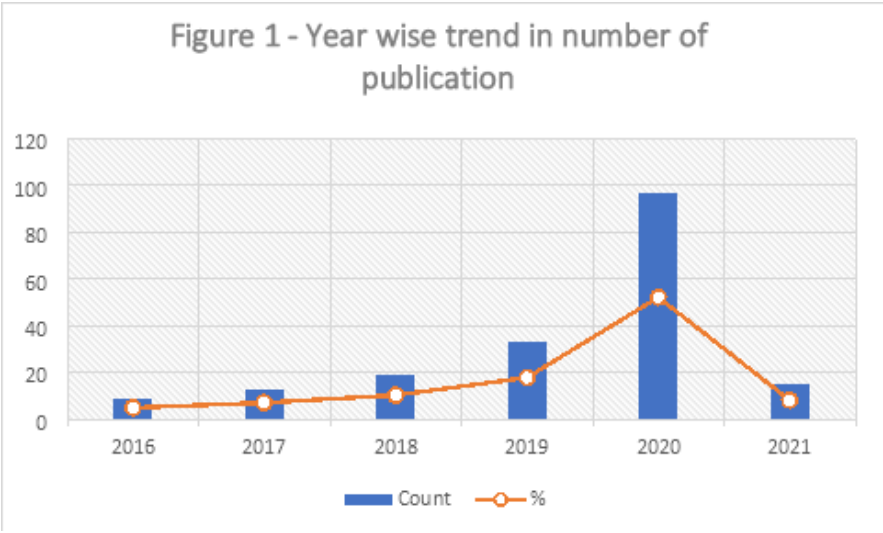

Figure 1

Year wise trend in number of publication

Figure 2

Study design wise and year wise stratification

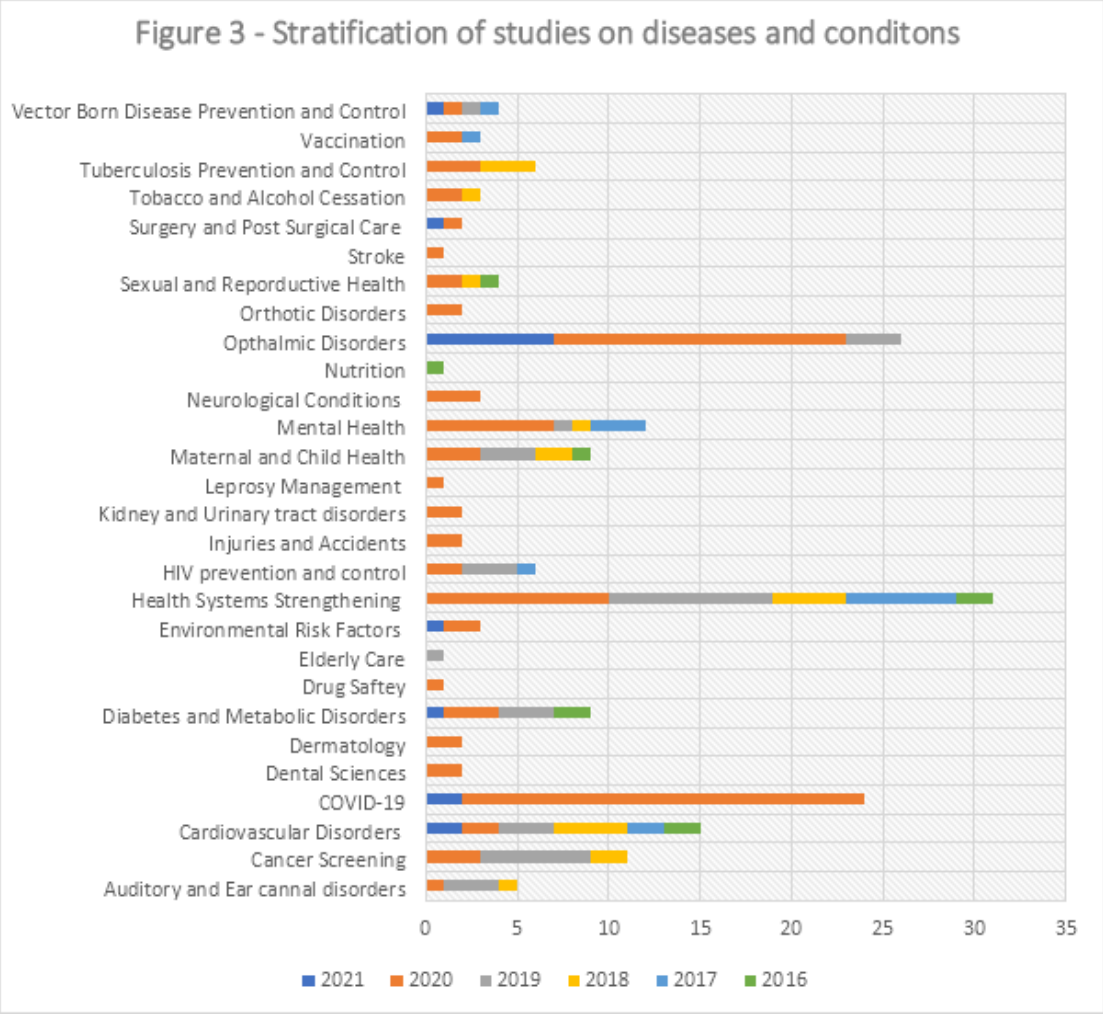

Figure 3

Stratification of studies on diseases and conditions

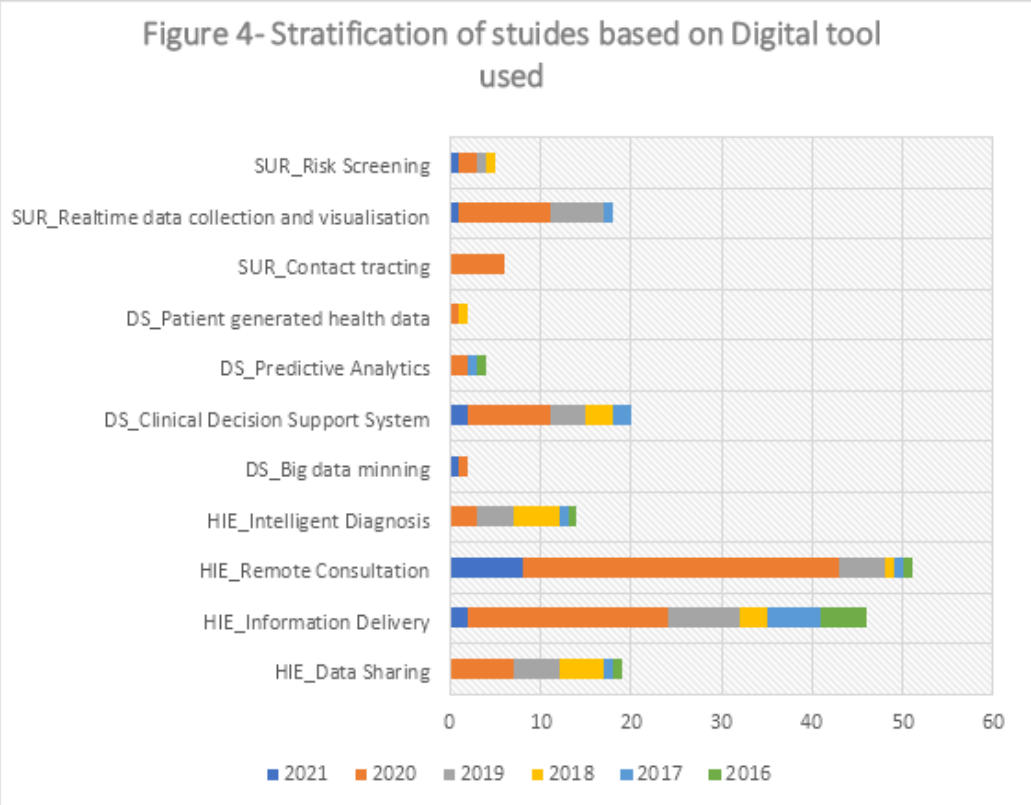

Figure 4

Stratification of studies based on digital tool used

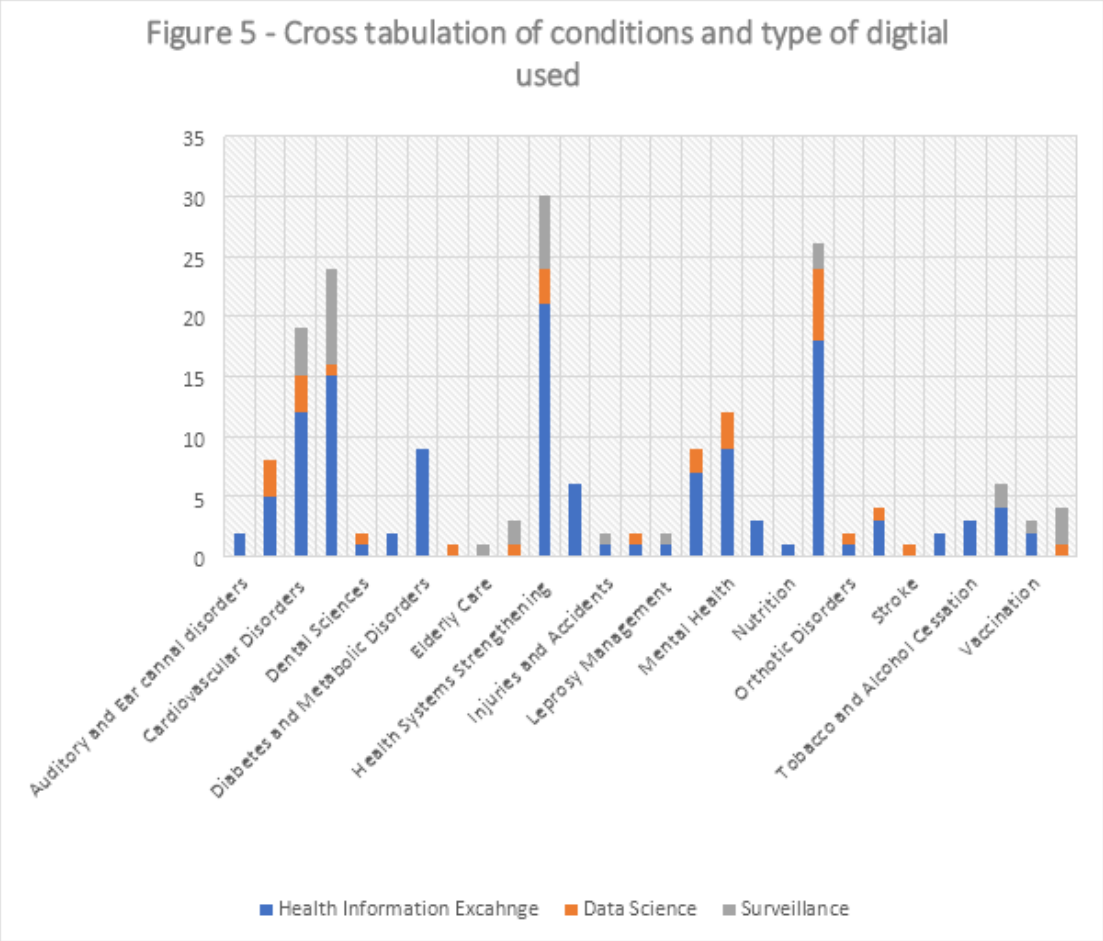

Figure 5

cross tabulation of conditions and type of digital used

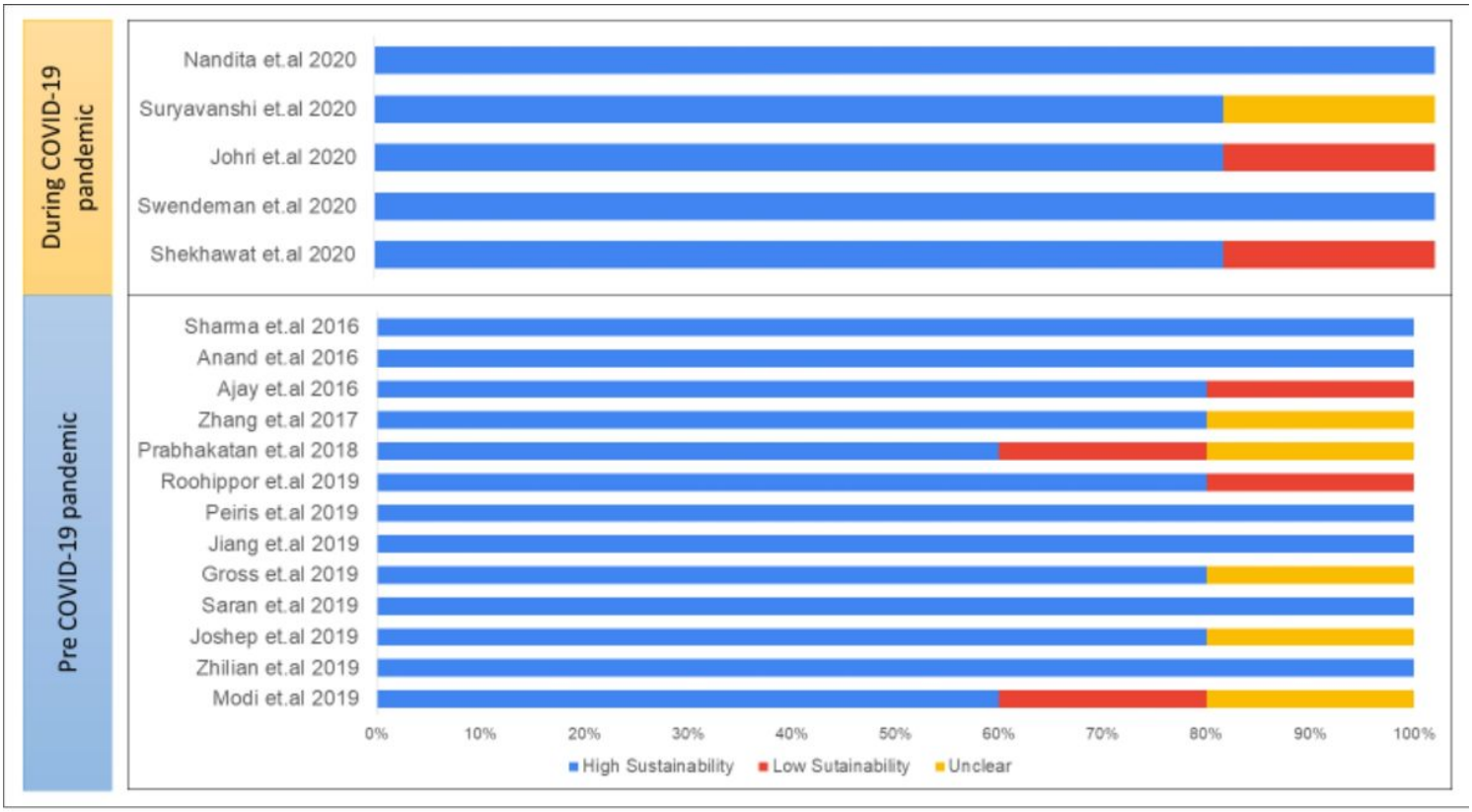

Figure 6- Sustainability assessment, Experimental studies (What do the three colors represent A legend is needed

Figure 6

Sustainability assessment, Experimental studies (What do the three colors represent A legend is needed

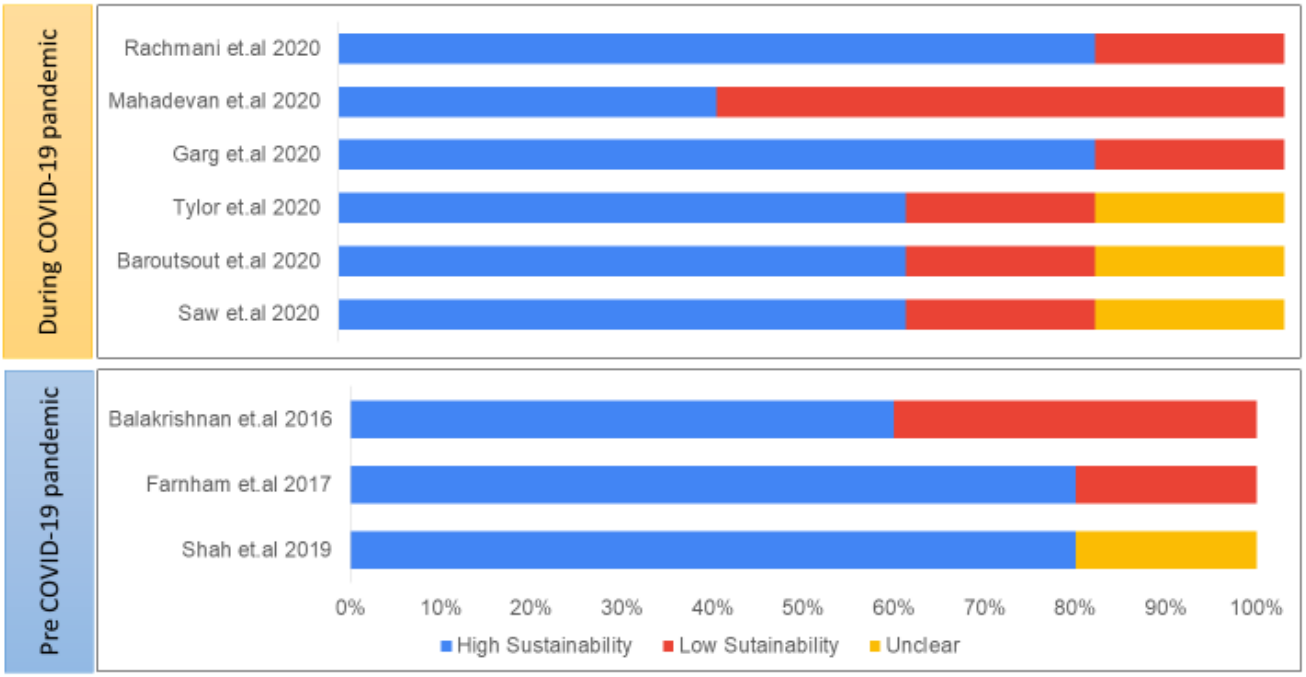

Figure 7

Sustainability Assessment, Cohort studies

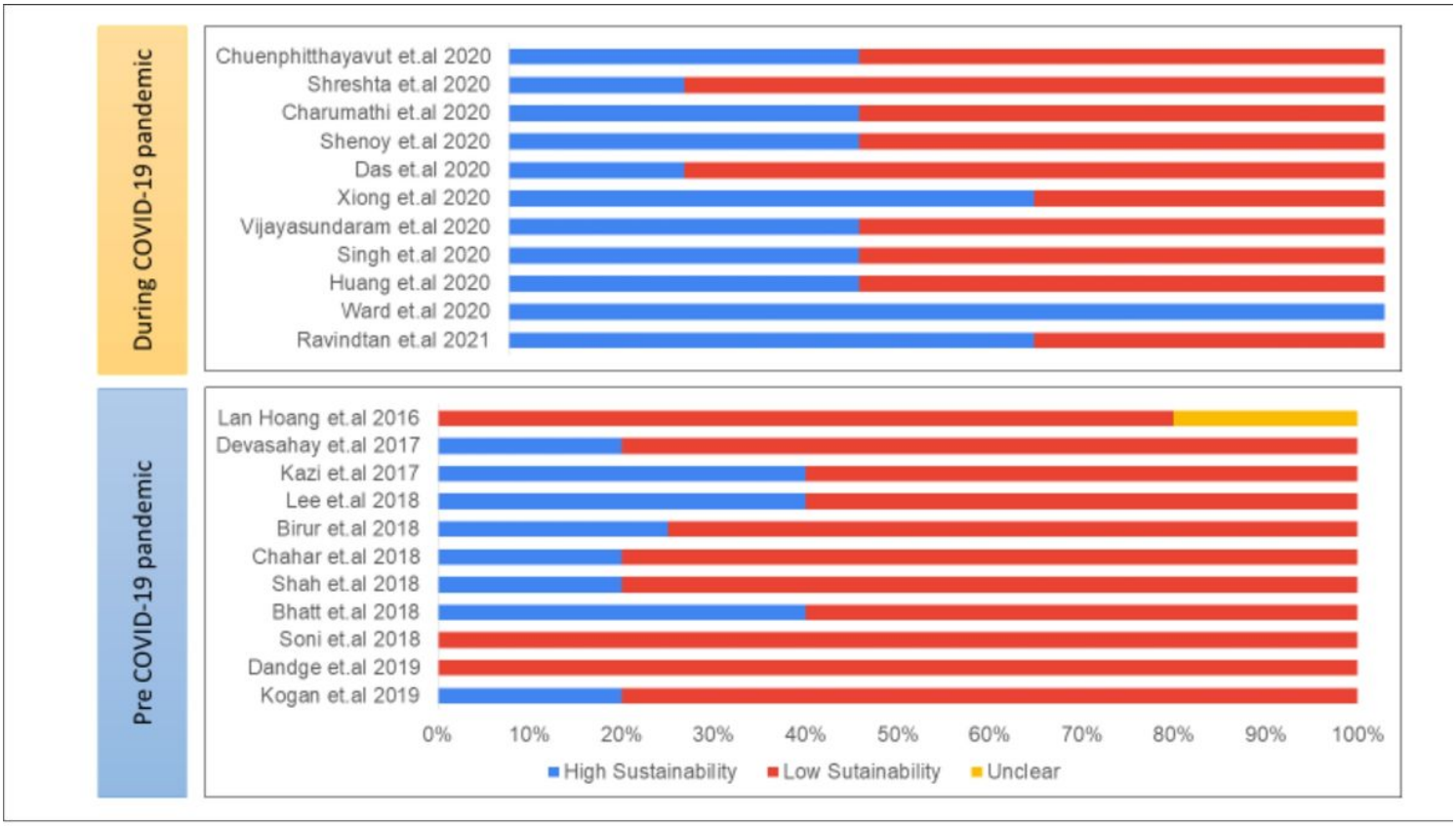

Figure 8 - Sustainability Assessment, Cross Sectional studies

Figure 8

Sustainability Assessment, Cross Sectional studies

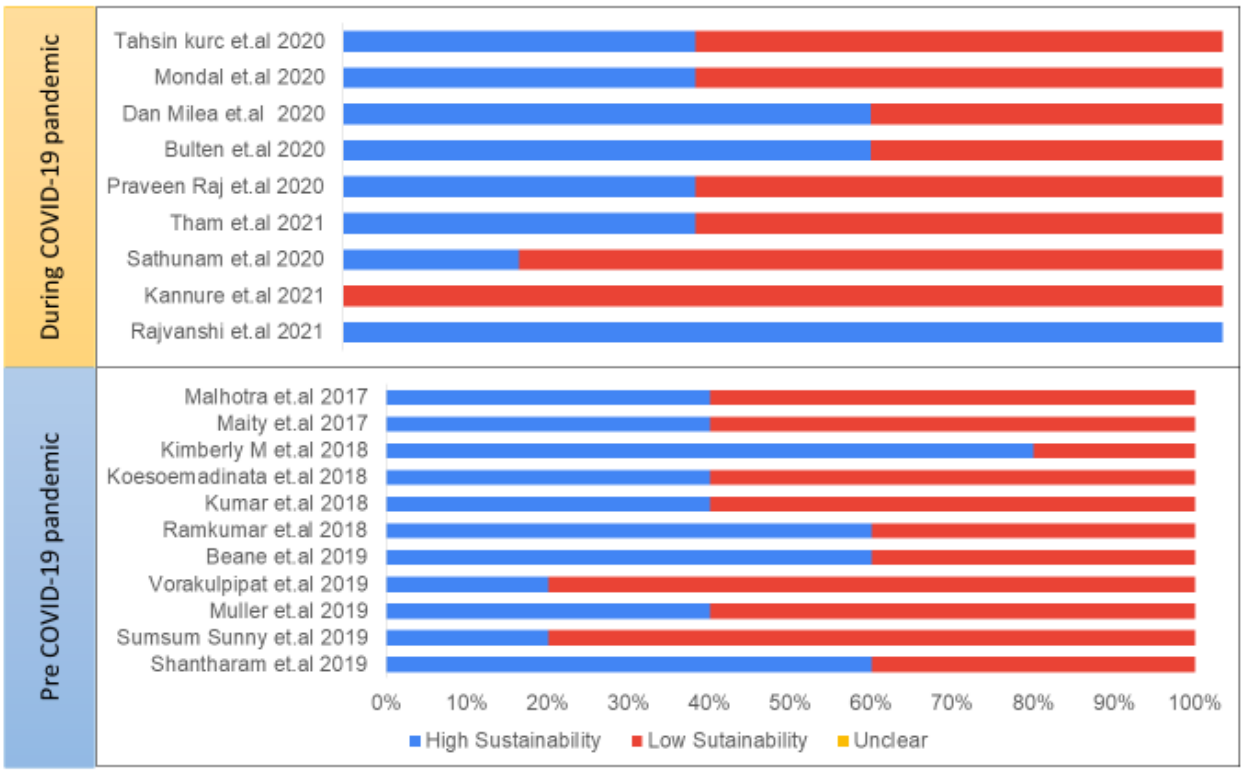

Figure 9

Sustainability Assessment, Diagnostic studies

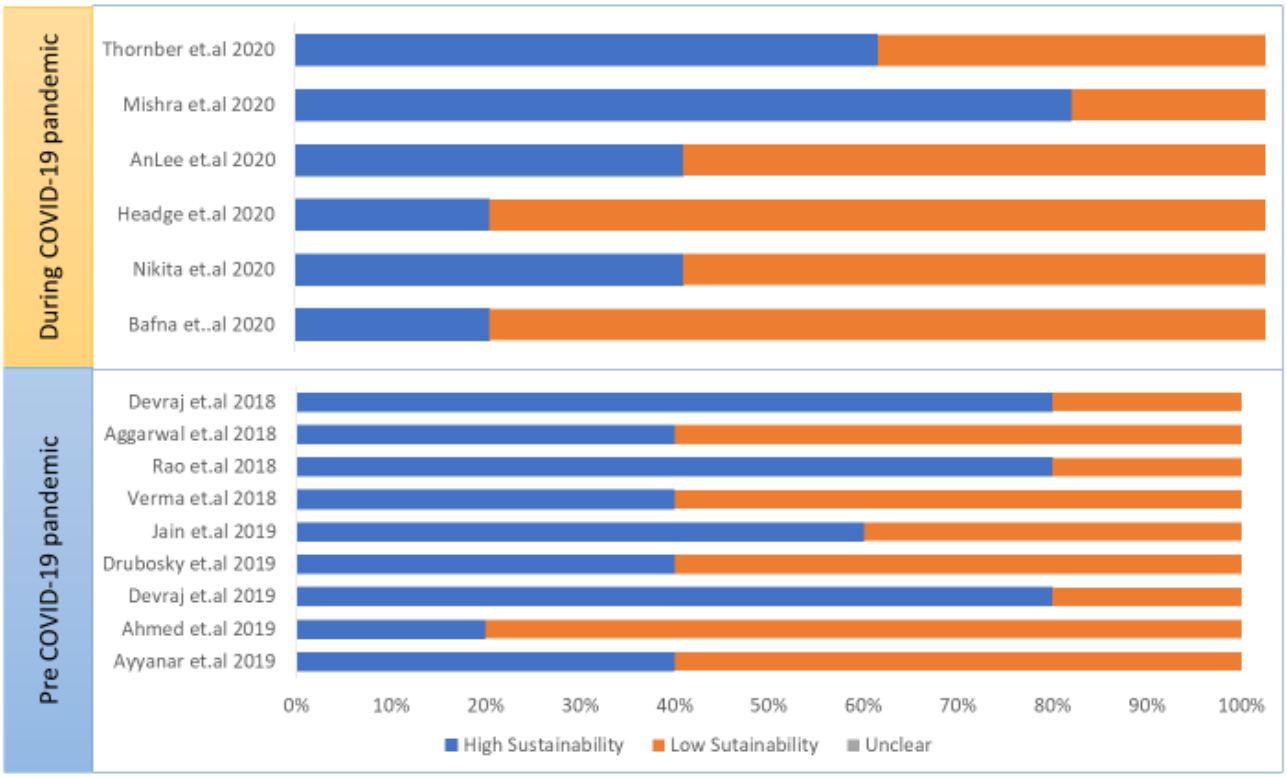

Figure 10

Sustainability Assessment, Pilot and Development studies

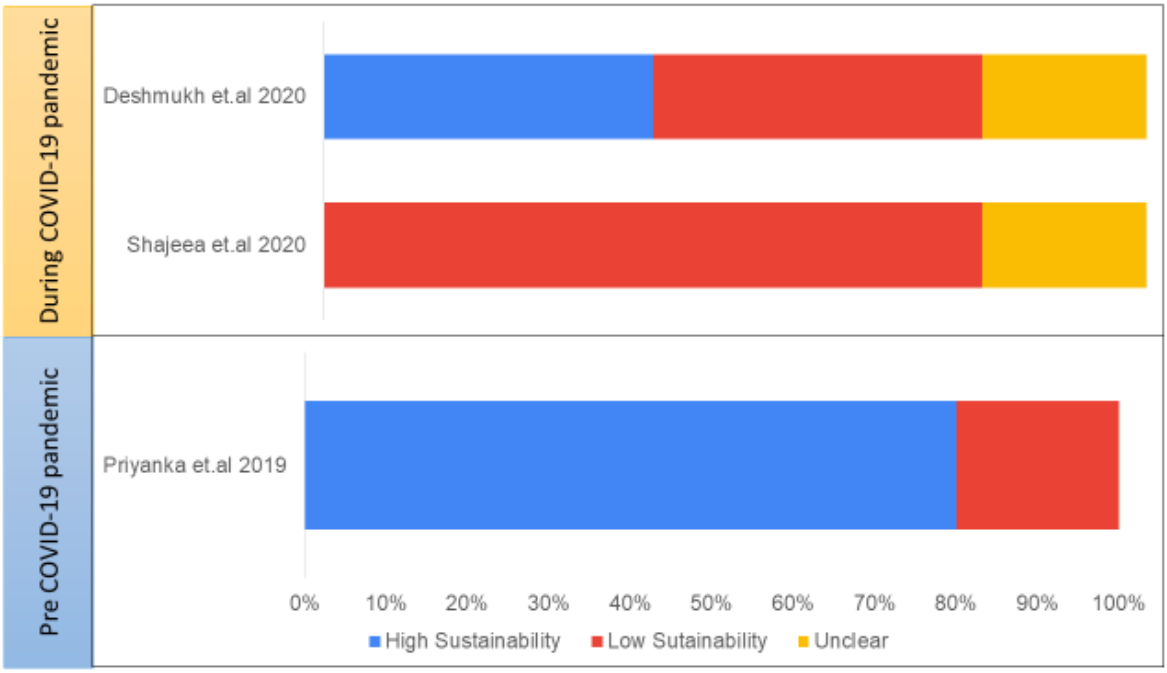

Figure 11