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Evaluating the costs, work patterns and efficiency (CORE) of comprehensive primary healthcare (CPHC) in India (The CPHC CORE study): a top-down micro-costing study protocol

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ABSTRACT

Introduction Primary healthcare is broadly acknowledged as the cornerstone of any strategy aimed at achieving Universal Health Coverage (UHC). This study aims to evaluate the costs, work patterns and efficiency of comprehensive primary healthcare (CPHC) in India.

Methods and analysis We will use a top-down microcosting approach to estimate the economic cost of services delivered at the primary healthcare facilities in India. A multistage stratified random sampling approach will be applied to select the primary healthcare facilities—*Ayushman Arogya Mandirs* (AAMs), formerly Health and Wellness Centres (HWCs). First, states will be selected based on key supply-side and demand-side healthcare indicators. Second, two districts will be chosen in each state based on advanced functionality criteria of AAMs. Finally, AAM-subhealth centres (SHCs) and AAM-primary health centres (PHCs) will be randomly selected within each district, implying a total of 48 SHCs and 24 PHCs. Data on both quantity and prices of capital (such as space, building, equipment and furniture) and recurrent resources (including salaries, medicines, consumables, stationery and overheads) used for delivering primary healthcare services during the period from April 2022 to March 2023 will be collected. All costs will be reported in current India Rupees (₹) and US Dollar (USD) ($) at an exchange rate of $1 = ₹86. A time and motion study will be undertaken to collect data from a total of 48 Community Health Officers (CHOs) and 48 auxiliary nurse midwives (ANMs) over a period of 6 days. This will be complemented by interviews to ascertain time spent on various services and activities. The data will be analysed to derive the annual cost of delivering CPHC services at an AAM, unit cost of individual services as a part of the 12 CPHC packages, as well as time spent by the healthcare workers (CHO and ANM) on various activities and services. Finally, a data envelopment analysis will be used to assess the level of technical efficiency in delivering primary healthcare services. The evidence on cost generated through the study will be useful for decisions related to better planning of healthcare services by aligning the work pattern to desired goals, efficient resource allocation, as well as future research on cost-effectiveness and benefit incidence over health accounts of primary healthcare services.

Ethics and dissemination The study has been approved by the Institute Ethics Committee of the Post Graduate Institute of Medical Education and Research, Chandigarh, India vide IEC no: PGI/IEC/2023/EIC000588. The study results will be published in peer-reviewed journals and presented to the policymakers at the national level. Furthermore, the cost estimates generated by the study will be integrated into the National Health System Cost Database for India, providing information to policymakers and researchers.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ First nationally representative costing study in India at primary healthcare facilities, since the introduction of *Ayushman Bharat*—Health and Wellness Centres (*Ayushman Arogya Mandirs*).
⇒ Use of standard economic costing methodology involving top-down microcosting approach, which is more preferable to capture real-world costs.
⇒ Due to the lack of disaggregated data, apportioning statistics will be applied which may introduce some uncertainty in service-specific costs.

INTRODUCTION

Primary healthcare is widely recognised as the foundation of any strategy for achieving Universal Health Coverage (UHC).[1 2] According to the World Bank, 90% of all health needs can be effectively addressed at the primary health centre (PHC) level, with only 10% requiring hospital-based services.[3] From the Alma-Ata Declaration in 1978 to the Millennium Development Goals

(MDGs) (2000), followed by the Sustainable Development Goals (SDGs) (2016) and culminating in the Astana Declaration in 2018, there has been a notable emphasis on primary healthcare at the global level. Investing in the establishment of high-quality, accessible and equitable primary healthcare services represents the most pragmatic, efficient and effective initial action for countries striving to achieve UHC.[4–6]

In India, the subhealth centres (SHCs) and PHCs form the base of the pyramid for healthcare delivery system and provide primary healthcare to the population.[7] In 2018, the Indian government furthered its commitment to UHC through the introduction of *Ayushman Bharat*, comprising two key components: the comprehensive primary healthcare (CPHC) through the upgradation of the existing SHCs and PHCs as *Ayushman Arogya Mandirs* (AAMs), formerly Health and Wellness Centres (HWCs) and the health insurance for the secondary and the tertiary care. The scale-up to CPHC has implied an increase in the basket of services from 6 to 12 (figure 1). To enable the provision of this broader range of services, a new cadre of health workforce—mid-level health provider or Community Health Officer (CHO) has been created, besides an augmentation in terms of provision of drugs and general infrastructure to provide services.[8]

First, given the significant reforms introduced by the CPHC programme, it is challenging to generalise estimates from previous studies. These studies were conducted before the introduction of *Ayushman Bharat* and are limited to specific regions, with variations in resource availability, pricing and service utilisation across different states.[7 9–12] Therefore, it is crucial to address these disparities and provide more accurate and recent insights. Second, while several of these economic analyses have assessed the cost-of-service delivery through frontline health workers, there is limited evidence on their work patterns, which influences the overall efficiency of service delivery.[13–15] This assumes even greater significance given the additional personnel (CHO) in the CPHC team, as well as more than doubling of the type of services to be delivered.

Third, while investing more money on health is important, having the best value of the money spent is also equally important. In view of this, while additional financing for CPHC will be required, it is important to design models of care that optimise efficiency and effectiveness. Efficient use of resources has become an important priority of policymakers across the health systems in the world.[16] Technical efficiency (TE) indicates the extent to which a given decision-making unit (DMU),

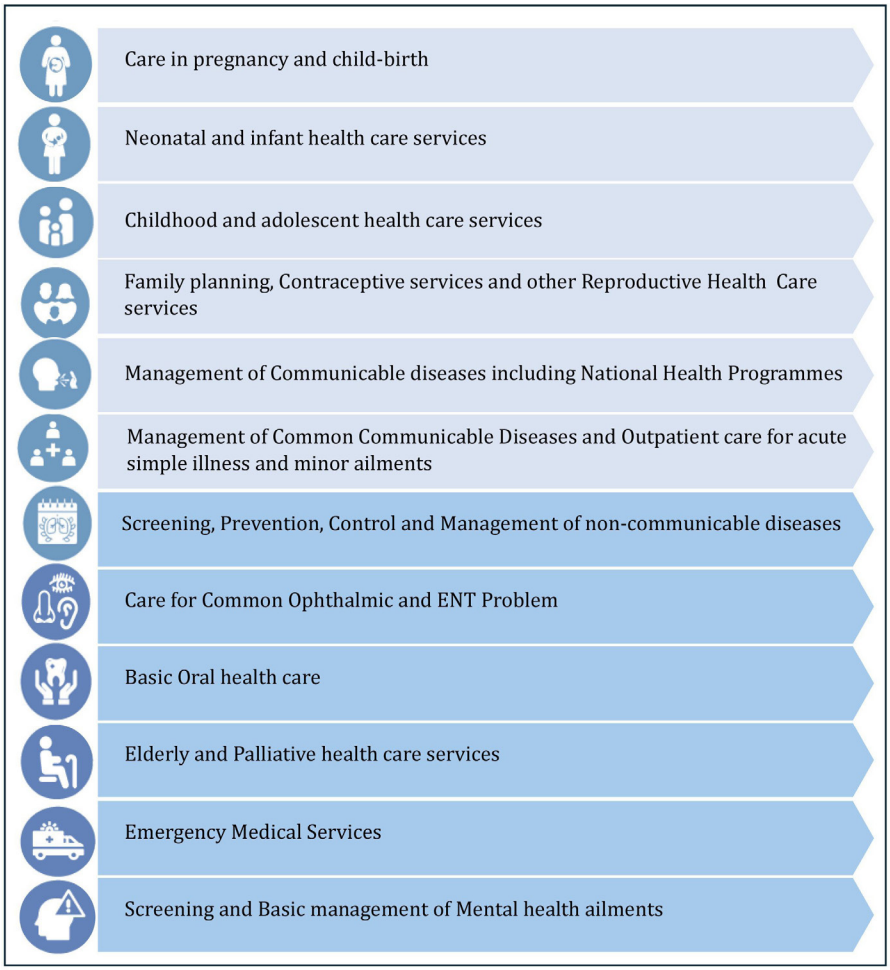

Figure 1 The comprehensive primary healthcare (CPHC) package with expanded range of services. ENT, ear, nose and throat.

or in our case an AAM, is minimising the use of inputs in producing its chosen outputs, or maximising its outputs given its chosen level of inputs. There are studies on the assessment of health facilities' efficiency globally.[17–20] However, such evidence is limited in India as the previous studies are much outdated and do not represent the expanded range of services under the CPHC package.[21–23] Moreover, these studies have focused on evaluating the relationship of resource use with specific individual services. However, typical primary healthcare facilities provide multiple services and utilise the resources in a model of horizontally integrated healthcare delivery. This requires a comprehensive and nuanced approach to evaluating efficiency by considering all resources and services.

In order to bridge these important evidence gaps for policymaking, first, we will estimate the total and unit costs of CPHC services, addressing the need for reliable cost data to support evidence-based decision-making. Second, we will assess the work-time distribution of key healthcare personnel at the SHC-AAMs, the CHO and auxiliary nurse midwives (ANM). Finally, we will measure the extent of TE of the SHC-AAMs for delivering the CPHC services and identify factors influencing the extent of efficiency.

METHODOLOGY

The CPHC-CORE study commenced in October 2024 and is expected to be completed by September 2025.

Study design

We will undertake a top-down microcosting study methodology to collect cost data from a health system perspective.[7 9–11 24 25] Annual data on quantity and prices of all capital and recurrent resources, as well as the volume of services delivered from April 2022 to March 2023, will be used to estimate the cost of different services provided at the primary healthcare facilities in India under the CPHC. The current study would be used to generate the estimates regarding the total and unit costs of the 12 services delivered under the CPHC.

Sampling technique

We will use a multistage stratified random sampling approach (figure 2) to select the primary healthcare facilities—AAM-SHCs and AAM-PHCs. First, states will be selected based on key supply-side and demand-side healthcare indicators (table 1). Subsequently, two districts will be chosen in each state based on advanced functionality criteria of AAMs comprising a total of 12 districts in India.[26] Finally, four SHCs and two PHCs will be randomly selected within each district, implying a total of 48 SHCs and 24 PHCs within India.

State selection

For the state selection, we first identified the key supply-side and demand-side healthcare indicators influencing disease morbidity and treatment-seeking behaviour.[27–30] In order to aggregate the individual indicators into a single summary measure, the characteristics of the data play a crucial role in determining the appropriate aggregation method. Measurement scales can be classified into four generic categories based on whether the indicators are measured on interval or ratio scale, and whether these are comparable or not. Given that our indicators exhibited properties of a ratio scale and were non-comparable, we adopted the geometric mean methodology to construct the composite index.[31] This approach has been widely utilised in the computation of the Human Development Index (HDI) and the UHC indicator.[32 33]

All the states were first ranked in ascending order based on their composite index scores and categorised into tertiles. Two states were selected from each tertile, ensuring representation from the North, South, East, West, Central and North-east regions of India. The detailed methodology for constructing the composite index is provided in online supplemental file S1.

District selection

The AAMs generally are scored for NHM conditionality on the basis of certain indicators, and this scoring is given by the Ministry of Health and Family Welfare (MoHFW). This scoring comprises 10 key indicators, namely advanced functionality criteria, footfall at AAMs, medicine and diagnostics at AAMs, functional AAMs providing wellness services, quality care, leveraging IT, continuum of care, community engagement, payment of performance-linked payments (PLPs) and team-based incentive (TBIs).[26] Of these, the advanced functionality criteria that determine the functional AAMs providing all 12 expanded range of services were chosen as the primary criteria for selection of districts. We obtained district-wise data regarding the proportion of AAMs meeting the advanced functionality

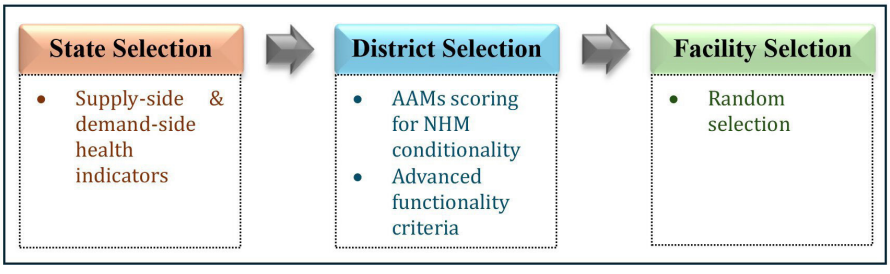

Figure 2 Multistage stratified random sampling. AAM, Ayushman Arogya Mandir; NHM, National Health Mission.

Table 1 Key supply-side and demand-side healthcare indicators of states

State/UT	Jharkhand	Madhya Pradesh	Maharashtra	Meghalaya	Rajasthan	Tamil Nadu	India (range)	Sources of data
Geographical location	East	Central	West	North-east	North	South	–	–
Mothers who had at least four antenatal care visits (%)	38.6	57.5	70.3	52.2	55.3	89.9	58.1 (20.7–93.0)	NFHS—5[41]
Children aged 12–23 months fully vaccinated based on information from the vaccination card only 12 (%)	79.2	83.3	81.7	80.0	85.3	90.4	83.8 (71.3–96.5)	NFHS—5[41]
Ever undergone a screening test for cervical cancer (%)	0.5	0.8	2.3	0.6	0.4	9.8	1.9 (0.2–9.8)	NFHS—5[41]
Infant mortality rate (per 1000 live births)	25.0	43.0	16.0	29.0	32.0	13.0	28 (3.0–43.0)	SRS—2022[42]
Self-reported morbidity (%)	6.7	3.9	8.8	0.9	4.9	6.1	7.5 (0.8–24.5)	NSS—75th round (2017–2018)[43]
Monthly per-capita OOPE as a share of MPCE	11.0	12.2	14.5	10.7	11.8	9.1	13 (1.0–18.6)	SDG India Index Report (2023–2024)[44]
SHC/1 lakh population	12.2	17.1	15.6	12.9	24.1	17.7	17.314 (10.0–46.2)	HDI (2022–2023)[45] MJS (GOI)[46]
Health-workforce density (per 10 000 population)	6.4	36.7	69.9	35.4	56.1	86.5	49.45 (6.4–144.0)	SDG India Index Report (2023–2024)[44]
Per capita NSDP—2022–2023 (constant prices) (₹)	60 938	63 379	153 664	69 997	84 935	166 590	(29 909–295 114)	RBI statistics (2022–2023)[47]

₹: Indian National Rupee (INR).
GOI, Government of India; HDI, health dynamics of India; INR, Indian national rupee; MJS, Ministry of *Jal Shakti*; MPCE, monthly per-capita expenditure; NFHS, National Family Health Survey; NSDP, net state domestic product; NSS, National Sample Survey; OOPE, out-of-pocket expenditure; RBI, Reserve Bank of India; SDG, sustainable development goals; SRS, sample registration system.

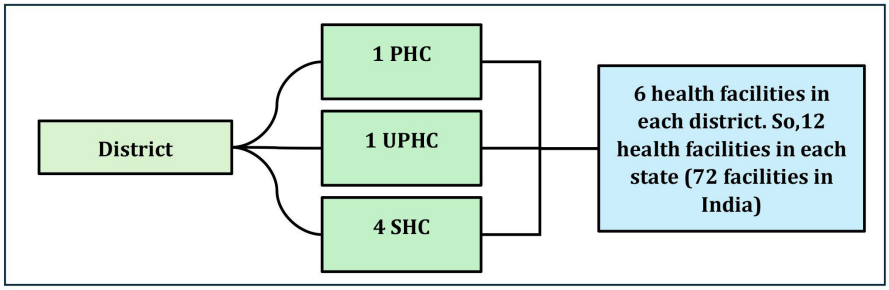

Figure 3 Selection of primary healthcare facilities. PHC, primary health centre; SHC, subhealth centre; UPHC, urban primary health centre.

criteria for all the six states from the National Health Systems Resource Centre (NHSRC)—the technical assistance body of MoHFW. Two districts were randomly selected from the top five ranked districts under the advanced functionality criteria. This stratification based on functionality criteria was considered appropriate so as to provide an opportunity to derive the cost for the model of as many possible services under CPHC.

Selection of facilities

From each selected district, a list of AAM-SHCs, AAM-PHCs and AAM-urban primary health centres (UPHCs) will be compiled. Within each district, one PHC, one UPHC and four SHCs will be randomly chosen for the study. This ensures the inclusion of a total of six facilities in each district and a cumulative selection of 12 facilities per state. Consequently, a grand total of 72 facilities across the study will be chosen, providing a robust representation of the country's health infrastructure (figure 3).

Eligibility criteria

The selection will focus on facilities that have been operating as AAM for at least 1 year prior to the reference year, and those that have had a CHO stationed for a continuous period of 1 year.

Patient and public involvement

Patients and/or the public will not be involved in the design, conduct, reporting or dissemination of this research.

Data collection

We obtained the data collection tool used in prior PHC cost analysis studies conducted in India.[7 9 10 24] This data collection tool was customised to align with the updated human resource (HR) structure introduced under AAMs, as well as the services offered as part of the CPHC initiative. The data collection tool is provided as online supplemental file S2.

Identification of cost centres and output generated

A comprehensive list of cost centres will be compiled for each facility at SHC level and PHC level, encompassing both care service centres, which directly attend to patient needs such as antenatal care (ANC), out-patient department (OPD) and non-communicable diseases (NCD) screening camps, immunisation camps etc. and support service centres (like medical records, administration and meetings) (table 2). Care service centres will be further categorised into direct and indirect service centres. Initially, every cost centre contributing to care services will be identified along with its specific output. For instance, the output of an OPD cost centre would be the number of OPD consultations, while an immunisation cost centre output would be the number of doses of vaccines administered. The quantity of output generated in the reference year at each service centre will be extracted from available routine physical or electronic management information system (MIS) records at the facility, following the definition of output. In the case of support centres, a unit of output will also be defined. Once both service centres and their respective outputs are delineated, the inputs required to produce the output for each service centre will be identified and their quantities measured.

Data on input resources

Information regarding both the capital (such as space, equipment and furniture) and recurrent resources (including salaries, medications, consumables and stationery) utilised for healthcare provision during the period from April 2022 to March 2023 will be obtained. To collect the data on the dimensions of the building (in square feet), a facility survey and examination of facility maps will be conducted. Inventory records (excluding consumables) will be reviewed to ascertain the quantity of various equipment and furniture items available at the facility and also whether used in the reference year or not. Additionally, consumable stock registers, pharmacy records, vouchers and indents will be reviewed to evaluate recurrent resource consumption. Data pertaining to staff salaries at the health facility will be sourced from the accounts department. Similarly, expenditures on various overheads such as laundry, dietary needs, utilities (electricity/water), fuel, insurance, and maintenance will be obtained from accounting records. Furthermore, incentives provided to beneficiaries and direct cash expenditures associated with specific grants or funds will be examined using facility records and cross-verified with the district health administration office.

Determining the time allocation of human resources each service centre will involve conducting time allocation

Table 2 Type of outputs, its units and sources of data

Output	Facility level: SHC/PHC	Units	Sources of data	
			Offline	Online
Routine OPD	SHC/PHC	Number of beneficiaries	OPD register	HMIS
ANC service	SHC/PHC	Number of visits	ANC register	HMIS
PNC service	SHC/PHC	Number of visits	PNC register	HMIS
Institutional deliveries	SHC*/PHC	Number of deliveries	Delivery register	HMIS
Medical termination of pregnancy (MTP)	SHC/PHC	Number of MTPs	Delivery register	HMIS
In-patient department	SHC/PHC	Number of patients and average length of stay	IPD register	HMIS
Screening of NCDs (oral cancer, cervical cancer, breast cancer, diabetes, hypertension)	SHC	Number of people screened	NCD register	AAM portal
NCDs follow-up (diabetes and hypertension)	SHC	Number of visits	NCD register	AAM portal
Emergency medical services	SHC/PHC	Number of patients	Emergency register	HMIS
Active and passive surveillance	SHC	Number of slides prepared	Surveillance register	HMIS
CBAC forms filled	SHC	Number of forms filled	CBAC record	AAM portal
Ophthalmology screening	SHC/PHC	Number of persons screened	Screening/OPD register	AAM portal/ HMIS
Dental screening	SHC/PHC	Number of persons screened	Screening/OPD register	AAM portal/ HMIS
ENT screening	SHC/PHC	Number of persons screened	Screening/OPD register	AAM portal/ HMIS
Family planning (number of condoms distributed, number of oral pills, number of injectable contraceptives, number of IUCD procedures)	SHC/PHC	Number of beneficiaries	Family planning register	HMIS
Teleconsultation service	SHC/PHC	Number of teleconsultations done	OPD register	HMIS
Yoga	SHC	Number of sessions conducted	Yoga register	AAM portal
Routine immunisations	SHC/PHC	Number of doses administered (antigen-wise)	Immunisation register	HMIS
Village Health and Nutrition Days (VHND)	SHC	Number of days organised	VHND register	HMIS
IEC activities	SHC/PHC	Number of IEC activities conducted	IEC register	†
Outreach: house to house surveys	SHC	Number of surveys conducted	Survey register	†
Adolescent health camps	SHC/PHC	Number of camps organised	Outreach activity register	HMIS

*Type B: provide all recommended services including facilities for conducting deliveries at the subcentre itself.
†State-specific portals (if any).
ANC, antenatal care; CBAC, community-based assessment checklist; ENT, ear, nose and throat; HMIS, health management and information system; IEC, information education and communication; IUCD, intra-uterine contraceptive devices; MTP, medical termination of pregnancy; NCD, non-communicable diseases; OPD, out-patient department; PHC, primary healthcare centre; PNC, postnatal care; SHC, subhealth centre; VHND, village health and nutrition days.

interviews using a pretested semistructured interview schedule, which has been utilised in previous costing studies.[7 9 10 24 34] The human resources include the Medical Officers, Staff Nurses, Public Health Supervisors, Laboratory Technicians, CHOs, multipurpose health workers (male and female-ANM), accredited Social Health Activists (ASHAs), among others, who deliver services at these centres (table 3).

To assess the time allocation of each staff cadre across activities like patient care, outreach services, administration, data recording and reporting, at least 50% of the staff from each cadre at every facility will be interviewed. A list detailing the cadre of staff at each facility will be

Table 3 Types of inputs for each output, data collection unit and sources of prices of input

Output	Inputs	Data collection unit	Sources of data
For each output generated in the cost centres, data regarding all the inputs will be collected	Human resource	Human resource (annual gross salary including allowances)	Account Officer at block PHC, CHC and district level (state specific)
	Capital	Area in square feet	Facility maps and rental land price of the area through key informant interviews
	Equipment	Quantity in numbers (used during the reference period only)	Procurement price/actual bills/rate contract list of the respective states/providers
	Drugs and consumables	Number of drugs and consumables consumed	Procurement price/actual bills/rate contract list of the respective states/providers
	Non-consumables (furniture)	Quantity in numbers (used during the reference period only)	Procurement price/actual bills/rate contract list of the respective states
	Overheads (electricity, water, telephone, etc)	Expenditure (₹) from the accounts department	Actual expenditure bills

₹: Indian National Rupee (INR).
CHC, community health centre; PHC, primary health centre.

compiled, followed by random selection and interviews with 50% of the staff. In case only one personnel of a particular staff category is available, the same will be included in the study. The recall period for these interviews will be service specific, that is, monthly, quarterly, biannually or annually depending on the frequency of any service delivered within the year, which will then be extrapolated to estimate annual time allocations.

The interviews will encompass an examination of activity types, distinguishing between fixed schedules and routine activities. Fixed schedules encompass less frequent activities, occurring daily, weekly, fortnightly, monthly, quarterly, semiannually or annually. Within this fixed framework, each day is dedicated to a specific activity, and the frequency of each activity throughout the reference year will be documented. For routine activities, the focus will be on the time spent per person for a specific activity and the number of beneficiaries per day for that particular task. Utilising the collected data, calculations will be made to estimate the annual time dedicated to each activity.

To validate the data collected through time-allocation interviews, the data will be gathered through ongoing direct observations of a single CHO and one ANM at each of the eight SHCs within each state. Trained data collectors will shadow the participants during their working hours throughout the week, spanning six consecutive days from Monday to Saturday. In the event that a participant is unavailable on a specific day, observation will be rescheduled for the corresponding day of the following week. The commencement and conclusion times of each activity will be recorded using a stopwatch. In instances where participants engage in multitasking, observers will prioritise noting the primary task related to direct service delivery, considering other concurrent tasks as secondary.

Valuation of costs

The valuation of each item will be done based on the financial prices of the reference year, specifically 2022–2023. We will utilise the current procurement prices of medicines, consumables, equipment and other necessities for facilities. The total salaries, inclusive of incentives and other allowances for each staff member, will be acquired from their pay slips provided by the accounts department. To assess the opportunity cost of the space utilised in each cost centre, we will employ the market rental value of land when leased to private vendors. In order to obtain information on the rental prices, we will conduct a key-informant survey to gather rental prices from the vicinity of the selected health facilities. The cost estimation for buildings and space will involve multiplying the floor area by the rental value. All costs will be denominated in current Indian rupees (₹) and US Dollar (USD) ($) (1US$ =₹86).

Data analysis

Total and unit cost for each service delivered

The overall cost of each capital resource will be annualised using the functional lifespan of the capital resources and a discounting of 3% as per current Indian methodological guidelines for economic analysis.[35] The annual cost of each recurrent input will be calculated by multiplying the unit price by the number of consumed inputs within the reference year. All input costs for the care or support centre will then be summed up to obtain the total cost. The cost of joint resources will be allocated based on appropriate apportioning statistics listed in table 4.

The time allocation information will be utilised to calculate apportioning statistics for analysing shared expenses. Following the detailed examination of cost components, the unit cost or average cost per beneficiary for specific services or programmes under the CPHC services will be derived. Subsequently, the allocated cost of the support and indirect service centres, such as laundry, kitchen and so on, will be added to the costs of the respective cost centre to obtain a total annual cost of providing each output. Finally, the unit cost of individual output generated will be calculated such as cost per OPD consultation,

Table 4 Apportioning statistics for joint resources

Input resources	Level of data collection	Allocation level	Apportioning statistics
Human resource	Facility	Cost centre	► Based on the time allocation interviews, salary will be apportioned to each cost centre. ► For shared human resources, salary will be apportioned based on the number of beneficiaries/patients.
		Output	► Number of beneficiaries/visits/patients. ► IPD: number of patients X average length of stay.
Capital	Facility	Cost centre	► The total space of the facility will be divided into each room based on the square feet. ► The total cost of each room will be apportioned into each output based on the time. ► Common areas like waiting areas, corridors and so on will be allocated based on the footfall of the facility.
		Output	► Number of beneficiaries/visits/patients. ► IPD: number of patients X average length of stay.
Equipment	Facility	Cost centre	► Equipment used in each output delivered will be apportioned based on the number of beneficiaries/patients and time taken per beneficiary/patient.
		Output	► Number of beneficiaries/visits/patients. ► IPD: number of patients X average length of stay.
Drugs and consumables	Facility	Cost centre	► Drugs and consumables used in delivering each output.
		Output	► Number of beneficiaries/visits/patients. ► IPD: number of patients X average length of stay.
Non-consumables (furniture)	Facility	Cost centre	► Furniture used in each output delivered will be apportioned based on the number of beneficiaries/patients and time taken per beneficiary/patient. ► Furniture used in common areas like waiting areas, corridors and so on will be allocated based on footfall of the facility.
		Output	► Number of beneficiaries/visits/patients. ► IPD: number of patients X average length of stay.
Overheads (electricity, water, telephone, etc)	Facility	Cost centre	► Cost will be apportioned based on the proportion of area and time.
		Output	► Number of beneficiaries/visits/patients. ► IPD: number of patients X average length of stay.

IPD, in-patient care.

cost per ANC services provision, cost per single dose of vaccine administered, etc. For instance, the unit cost per OPD consultation will be calculated as the ratio of the total cost of inputs like human resource, equipment, drugs, capital and so on, used for OPD consultation to the number of OPD consultations.

Quantitative data obtained from time and motion study will be descriptively analysed to validate the data collection through time allocation interviews. We will calculate the time duration per participant, per week and per activity within predefined categories, utilising measures such as mean, range and median. Activities will be classified into various health packages and service types. Comparative analyses of the work patterns of CHOs and ANMs will be conducted by estimating differences in the meantime contributed to various health packages and service types.

Measuring technical efficiency

The data envelopment analysis (DEA) will be utilised to evaluate the efficiency of facilities delivering PHC services. Each AAM-SHC will serve as the DMU for this assessment. This study will apply a two-stage analysis strategy: first, DEA will be used to measure the productive efficiency score of subcentres. After that, the Tobit regression method will be adopted to identify the factors associated with their productive efficiency.

DEA, which is a non-parametric method, does not require assumptions on functional form and can be used for relative TE analysis with multiple inputs and outputs,[36 37] with each DMU_i (i=1,…., n) producing r outputs $y_i = (y_{1i}, \ldots, y_{ri})$ using s inputs $x_i = (x_{1i}, \ldots, x_{si})$. The appropriate selection of input and output variables is important for the effective application of DEA. Based on a review of previous literature,[22 23 38–40] the input variables included will be human resources in healthcare, medical infrastructure and the financial value of resources utilised to provide services in the AAMs. Output resources will include the services provided at the AAMs such as number of OPDs, number of ANCs and number

Table 5 Definition of input, output and influencing variables for technical efficiency

Category	Variable	Unit	Definition	Source
Input	Human resource (HR)	Person	HR includes CHO, MPHW (male+female), ASHA, outsourced and other state-specific cadres	Attendance register/ interview
	Medical and non-medical equipment	Quantity	Medical and non-medical equipment include the equipment present at the facility and are used in the service delivery	Fixed asset register/ interview/ observation
	Drugs	Quantity	The quantity of drugs consumed at the SHC	Drugs indent register
Output	ANC services	Visits	The number of ANC visits	ANC register
	PNC services	Visits	The number of PNC visits	PNC register
	Routine OPD	Patients	The number of patients attending OPD	OPD register
	NCD screening	Beneficiaries	The number of persons screened	NCD register
	CBAC forms	Number of forms	The number of CBAC forms filled	CBAC record
	Family planning	Number	The number of family planning consultations, procedures, etc	Family planning register
	Emergency medical services	Number	The number of patients visiting emergency services	OPD register
	Antigen-wise immunisation	Number of doses	The number of doses administered (antigen-wise)	Immunisation register
Influencing factors	Distance from higher facility	Kms	The distance from the higher facility to the SHC	Primary data collection
	Gross birth rate (GBR)	%	The number of births recorded in any given year and the average population of the year	Primary data collection
	Literacy rate (LR)	%	The person >7 years of age can read and write compared with the total population >7 years	Census—2011
	Dependency ratio (DR)	%	The dependency ratio is a number of dependents aged 0–14 and over the age of 65, compared with the total population aged 15–64.	Census—2011
	The proportion of the population below 5 years and above 60 years	%	The population below 5 years and above 60 years covered by a facility	Primary data collection
	Population density	Number	Population covered under the facility	Primary data collection
	Total fertility rate (TFR)	%	Average number of children a reproductive woman would bear in her reproductive life span	NFHS
	Per capita SDP	Number	State specific per capita SDP	Reserve Bank of India
	State health index	%	It is the measure of the performance of states on a weighted composite score incorporating 24 health performance indicators	Niti Ayog

ANC, antenatal care; ASHA, Accredited Social Health Activist; CBAC, community-based assessment checklist; CHO, Community Health Officer; DR, dependency ratio; GBR, gross-birth rate; HR, human resources; LR, literacy rate; MPHW, multipurpose health worker; NCD, non-communicable diseases; NFHS, National Family Health Survey; OPD, out-patient department; PNC, postnatal care; SDP, state domestic product; SHC, subhealth centre; SRS, sample registration system; TFR, total fertility rate.

of persons screened for NCDs. The key inputs and output indicators with their unit of measurement, definition and sources of indicators have been listed in table 5.

The choice between input or output orientation should depend on what practice managers can control more effectively—resources or production outcomes. An input-oriented model minimises inputs, while maintaining the current output level, whereas an output-oriented model maximises output, while keeping the inputs constant. In AAMs, most inputs constitute fixed costs, as they are largely determined by facility-specific norms and standards, including designated human

resources and standardised capital items, barring the differences which may arise due to staff vacancies/absenteeism. While recurrent expenditures (eg, drugs and consumables) vary with service volume, the overall allocation of resources for healthcare service delivery at a facility remains largely uniform. Therefore, we will adopt an output-oriented model.

This DEA will comprise a Constant Return to Scale (CRS) model and the Variable Return to Scale (VRS) model. The CRS model assumes that there is a proportional increase in the output with an increase in the input, whereas in the VRS model, an increase in the input may result in either an increase or decrease in the output.[36]

AAMs' TE will be categorised into scale efficiency (SE) and pure technical efficiency (PTE). SE affects the TE as determined by the CRS model. The VRS model will evaluate the PTE, which incorporates the effect of SE. Concerning the distinction between these two models (VRS and CRS), the rate of increase in outputs is presumed to be the same as the rate of increase in inputs in the CRS model. In contrast, the rate of increase in outputs may differ from the rate of increase in inputs in the VRS model because TE and SE will be calculated independently.

In addition to the selected input and output variables, there are various exogenous factors documented in previous similar studies that influence the efficiency of any DMU (table 5).[36] To study these factors, Tobit regression will be applied.[40] The efficiency score obtained through DEA shall become the dependent variables in the posthoc regression analysis, and the maximum likelihood of the Tobit regression model will be applied to assess the factors influencing AAMs' efficiency using equation 1.

$$eff = \beta_0 + \beta_1 z_1 + \ldots + \beta_k z_k + \varepsilon \quad (1)$$

where *eff* is the efficiency score, z_i is the value of i^{th} predictor and ε is the error term that follows Normal distribution with mean zero and precision $\sigma^2 > 0$. The software package STATA V.13 (StataCorp, College Station, TX, USA) will be used for analyses.

Data quality assurance

Standard quality checks will be applied during data collection (data recording, data entry, data sharing and receipt of data). To ensure standardisation of the data collection process at all the sites, strict quality control (QC) measures will be undertaken. The major component of QC is protocol compliance which includes standardised data collection and entry. To ensure this, the data collectors at each study site will be rigorously trained by competent trainers using a standard training manual developed for protocol. After the hands-on training, all the data collectors will be put through a process of pilot data collection. Once all the data collectors have achieved a consistent performance and adhere well to protocol compliance, then they will be allowed to proceed beyond the pilot and start data collection. To ensure that quality data are being collected, the QC reports based on ongoing data will be generated at regular intervals to monitor the performance of each data collector and inform them on any deviation from the set standards. Furthermore, based on field visit observations, a personalised feedback process will be followed throughout the data collection period to address any issues faced by any data collector in the data collection process.

ETHICS AND DISSEMINATION

The study has been approved by the Institute Ethics Committee of the Post Graduate Institute of Medical Education and Research, Chandigarh, India vide IEC no: PGI/IEC/2023/EIC000588. The study results will be published in peer-reviewed journals and presented to the policymakers at the national level. Furthermore, the cost estimates generated by the study will be integrated into the National Health System Cost Database for India, providing information to policymakers and researchers.

DISCUSSION

SHCs and PHCs provide healthcare services to a large proportion of the population in India. Detailed cost analysis of provision of primary healthcare services through community health workers in subcentres and primary health centres is available.[9 10] However, the current evidence base on the cost of provision of primary healthcare does not provide evidence on the expanded range of services under the CPHC. So, the current study will provide the total and unit cost estimates of the 12 CPHC services being delivered at the level of SHCs and PHCs in India. Given the scope of our study, the top-down methodology for cost estimation is more appropriate to capture real-world costs, as in the presence of inefficiencies, the bottom-up approach may lead to an underestimation of total costs. So, further research can be done to explore how different costing methodologies, such as top-down and bottom-up, vary in estimating healthcare costs.

Second, the study will report the work and time allocation patterns of CHOs and ANMs recruited at the SHC level, which will reflect the current status of work hours utilisation to effectively deliver CPHC services. Since the introduction of CHO in the CPHC team at the SHC level, there have been several reports citing lack of effective coordination, duplication of roles and crowding out of certain services,[14 15] each of which is detrimental to the success of CPHC. This requires an assessment of the work flow patterns to guide future planning of the roles and responsibilities. Also, the introduction of additional services to the basket of essential health packages always poses a risk to the neglect of certain important services. An assessment of the time devoted to various services and programmes can help programme to adequately adjust time for all healthcare service priorities and digital data recording and reporting systems.

As efficient use of resources is a vital strategy to maximise outputs and achieve UHC, our study also aims to

assess the TE of SHC-AAMs. The increasing demand for healthcare services and limited resources emphasises the need to assess the performance of the CPHC system. Apart from evaluating the efficiency scores of CPHC units across six states in India, we will also identify the factors significantly associated with health system efficiency. This information is required for data-driven decision-making to optimally allocate the resources and improve the efficiency of the system in similar settings. However, one of the key contributions to studying efficiency in primary healthcare is the emphasis on population health outcomes rather than merely activity-based outputs. This approach requires the estimation of specific outcomes, such as avoidable hospitalisations, avertable mortality and the quality of pharmaceutical prescriptions.[19 20] Given the limitations of the current study, our study does not aim to measure efficiency against such outcomes of population health, and further studies which focus on population health outcomes need to be conducted to examine this important area.

Cost data are also an essential prerequisite for undertaking a cost-effectiveness analysis to evaluate the efficiency of healthcare delivery. The Health Technology Assessment in India has identified the generation of cost information for creating a cost database for India. In view of this, the present study will fill important gaps in evidence which could, in turn, strengthen the Health Technology Assessment research.

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