Health Technology Assessment Report

Cost-effectiveness and budget impact analysis of the COPD screening and control program in Kerala (SWAAS)

Regional Technical Resource Centre for Health Technology Assessment
Achutha Menon Centre for Health Science Studies,
Sree Chitra Tirunal Institute for Medical Sciences and Technology, Trivandrum
in collaboration with
Health Technology Assessment India (HTAIn) Secretariat,
Department of Health Research (DHR),
Ministry of Health and Family Welfare (MoHFW), New Delhi

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Introduction

Chronic obstructive pulmonary disease (COPD) is the chronic inflammatory reaction in the airways and lungs to gases or harmful particles. According to the Global Initiative for Obstructive Lung Disease (GOLD), COPD is a preventable and treatable disease among chronic respiratory diseases (CRD). Globally, the estimated prevalence is 251 million cases with 3.17 million annual deaths.[1] In 2004, COPD was the fourth leading cause of death and is projected to become the third leading cause by 2030.[2] In terms of the main causes of chronic morbidity, COPD was rated 11th in 2002 but is anticipated to move up to 7th place in 2030.[2]

India and China make up 33% of the world's population and are responsible for 66% of COPD deaths globally.[3] The largest number of deaths will be in the Southeast Asian region, where mortality due to COPD is expected to grow by 160%,[2] totaling more than the combined numbers of deaths due to malaria, tuberculosis, and HIV/AIDS. The Global Burden of Disease (GBD) study estimated the state-level prevalence, morbidity & mortality due to various diseases in India (Figure 1). The prevalence of COPD among population aged 30 years and above in India was 7%.[4] Kerala has a slightly higher burden with a COPD prevalence of 10% (measured as chronic bronchitis) based on the Indian study on epidemiology of asthma, respiratory symptoms and chronic bronchitis in adults (INSEARCH study).[5]

Considering the figures from the India State-Level Disease Burden Initiative as part of GBD 2016,[6] the number of COPD cases in Kerala can be estimated to be nearly 15.3 lakhs and the number of asthma patients among adults can be estimated to be nearly 12.5 lakhs. This shows that around 28 lakhs people in Kerala are suffering from either COPD or asthma, which is a huge disease burden that needs to be addressed with appropriate strategies. In addition to the mortality, COPD also places a huge burden on the health system in terms of outpatient (OP) and inpatient (IP) workload at all tiers of the health system. Almost 10 to 20% of the patients seeking outpatient services in public sector hospitals in Kerala have either or both COPD and asthma.

Several of these patients need repeated hospital care due to frequent exacerbations limiting their activities of daily living. Such repeated hospital visits exhaust valuable resources in terms of materials and manpower. Structured public health programmes at the primary care level for the management of CRDs will go a long way in addressing this challenge. The major issues in Kerala with regard to COPD are rising prevalence due to an ageing population (see Figures 1 & 2) and increasing health care expenditure for COPD management. These lead to insufficient treatment, poor symptom control and increased exacerbations forming a vicious circle.

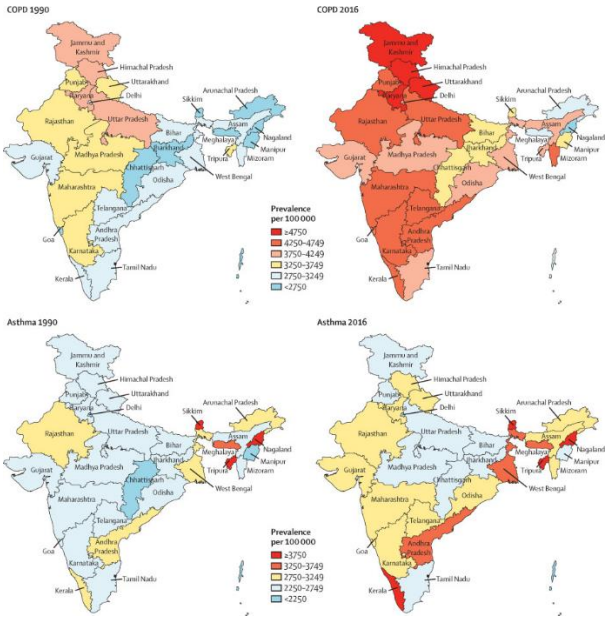

Figure 1:Crude prevalence of COPD and asthma in the states of India, 1990 and 2016 (Source: Salvi, Sundeep, et al. The Lancet Global Health 6.12 (2018): e1363-e1374.)

Kerala population by Age Group (2011)

Age group	Male	Female	Total		M per 100 F
			Persons	Share (%)	
00-04	1,247,534	1,205,558	2,453,092	7.34	103.482
05-09	1,303,190	1,251,922	2,555,112	7.65	104.095
10-14	1,438,917	1,383,853	2,822,770	8.45	103.979
15-19	1,328,299	1,282,253	2,610,552	7.81	103.591
20-24	1,298,826	1,366,983	2,665,809	7.98	95.014
25-29	1,203,978	1,400,114	2,604,092	7.80	85.991
30-34	1,128,217	1,327,284	2,455,501	7.35	85.002
35-39	1,161,819	1,417,854	2,579,673	7.72	81.942
40-44	1,117,424	1,295,074	2,412,498	7.22	86.283
45-49	1,105,598	1,242,932	2,348,530	7.03	88.951
50-54	931,191	996,954	1,928,145	5.77	93.404
55-59	861,527	880,881	1,742,408	5.22	97.803
60-64	685,136	729,535	1,414,671	4.23	93.914
65-69	459,232	542,902	1,002,134	3.00	84.588
70-74	326,562	406,810	733,372	2.20	80.274
75-79	208,317	293,050	501,367	1.50	71.086
80-84	118,544	183,899	302,443	0.91	64.461
85-89	59,903	104,352	164,255	0.49	57.405
90-94	17,967	34,963	52,930	0.16	51.389
95-99	5,746	11,044	16,790	0.05	52.028
100+	2,188	3,243	5,431	0.02	67.468
Age not stated	17,297	17,189	34,486	0.10	100.628
Total	16,027,412	17,378,649	33,406,061		92.225

Figure 2: Kerala population by age group (Census 2011)

Diagnosis of COPD is often made at later stages of the disease thereby lowering the opportunities for secondary prevention strategies (e.g., smoking cessation, limiting exposure to indoor and outdoor air pollution). The Step Wise Approach to Airway Syndromes (SWAAS) programme was launched in the state of Kerala with the aim of diagnosing and treating CRDs from the primary care level itself. Equipment (spirometer, etc.) for measuring pulmonary function and drugs for treatment were made available on a pilot basis in select Family Health Centres (FHCs) under the SWAAS programme.

Drugs like formoterol, budesonide, tiotropium, and the nebulizing solution of ipratropium, which were essential for patients with COPD, were made available. The equipment supplied included a mini-spirometer, pulse oximeter, oxygen concentrator, oxygen mask, nebulizer, nasal prongs, and mouthpieces for spirometry. Continuous supply of already available drugs and equipment necessary for the treatment of patients was also ensured under the SWAAS program. There is relatively little information available on the money the health system will save because of the implementation of such CRD control measures. Developed countries are currently in the process of assessing the economic viability of CRD control programs. The economic impact of the SWAAS program needs to be determined for further scaling up of CRD control programs.

Review of literature

Approximately 1 in 12 people worldwide are affected by asthma or chronic obstructive pulmonary disease (COPD);[7] once regarded as two distinct disease entities, these two conditions are now recognized as heterogeneous and often overlapping conditions.[8]

Definition

Chronic Obstructive Pulmonary Disease (COPD) - COPD is an inflammatory airway disease, one that affects small airways. In chronic bronchitis, there are inflammatory infiltrates in the airways, especially the mucus secretory apparatus, whereas in emphysema, there are clusters of inflammatory cells near areas of alveolar-tissue breakdown.[9] Chronic bronchitis and emphysema often coexist, although there are patients in whom one phenotype predominates.[10] COPD usually becomes symptomatic with breathlessness in persons older than 40 to 45 years of age and is frequently associated with chronic cough, phlegm, wheezing, or a combination of these. Airway obstruction results from smooth-muscle contraction, airway mucus, tissue breakdown, or a combination of these, with loss of lung elastic recoil leading to airway closure. This form of airway obstruction is progressive in many patients. COPD is caused primarily by smoking, although passive smoking, air pollution, and occupational exposures can cause the condition as well.[11]

Asthma - Asthma is a condition in which your airways narrow and swell and may produce extra mucus. This can make breathing difficult and trigger coughing, a whistling sound (wheezing) when you breathe out and shortness of breath. It affects people of all ages and often starts during childhood. This is manifested as decreased flow rates over the entire vital capacity and a diminished forced expiratory volume in 1 second (FEV1) that usually reverts completely after the attack.[12] Certain things can set off or worsen asthma symptoms, such as pollen, exercise, viral infections, or cold air. These are called asthma triggers. When symptoms get worse, it is called an asthma attack.[13] Bronchial hyperresponsiveness, an enhanced bronchoconstrictor response to inhaled stimuli, is a common and core feature of asthma but is not sufficiently specific to establish a firm diagnosis.

Asthma-COPD overlap syndrome (ACOS): The term “asthma–COPD overlap syndrome” (ACOS) has been applied to the condition in which a person has clinical features of both asthma and COPD. Asthma–chronic obstructive pulmonary disease (COPD) overlap syndrome (ACOS) is characterized by persistent airflow limitation with several features usually associated with asthma and several features usually associated with COPD. ACOS may be a special phenotype of a spectrum of chronic obstructive airway diseases, in which asthma and COPD are at the two opposite ends.[14] It is not a separate disease, but rather a way for doctors to recognize the mix of symptoms and select a treatment plan that is most appropriate for you. Current evidence suggests that it is premature to recommend the

designation of ACOS as a disease entity in primary and specialist care. More research is needed to better characterize patients and to obtain a standardized definition of ACOS that is based on markers that best predict treatment response in individual patients.

Epidemiology and risk factors

The estimated global prevalence of COPD is 384 million cases in 2010 which is a prevalence of 11.7% (95% CI 8·4%–15·0%).[15] There are an estimated three million deaths annually due to COPD. With increasing prevalence of smoking in developing countries, and aging populations in high-income countries, the prevalence of COPD is expected to rise over the next 30 years, and it is predicted that by 2030 there will be 4.5 million COPD related deaths annually.[2] The prevalence of COPD was higher in smokers and ex-smokers compared to non-smokers and higher in the more than 40-year group compared to those less than 40 years old and higher in men than women.

The major risk factors for COPD include smoking, environmental tobacco smoke exposure, biomass fuel smoke exposure, occupational exposures, age, genetic factors, previous history of diseases like Asthma and TB. The number of cases of COPD in India increased from 28·1 million (27·0–29·2) in 1990 to 55·3 million (53·1–57·6) in 2016, an increase in prevalence from 3·3% (3·1–3·4) to 4·2% (4·0–4·4).[3] COPD is the second most common cause of NCD-related deaths in India, with the age-specific prevalence of COPD increasing rapidly after the age of 30 years. It was noted that the prevalence of COPD among individuals between 5 and 29 years ranged from 0·1%–0·9%, which increased to 1·6%–28·3% among the population aged 30 years or more.[3]

In India, COPD is the second most leading cause of DALYs with the 36% mean percentage change in the number of DALYs from 1990 to 2016 (Figure 1). The rate of DALYs per case due to COPD was 1·7 times higher than the global average in 2016.[3] A study conducted on COPD patients by Mahmood et al. in Uttar Pradesh reported that 56·5% of patients were nonsmokers, indicating the major role of second-hand smoke and other risk factors.[16] People from low socioeconomic status are more likely to develop COPD. This is because they are more likely to smoke, be exposed to indoor air pollution, and have other risk factors for COPD.[17,18]

In a study conducted by Viswanathan et al. in Kerala, the prevalence of self-reported asthma was 2·82% (95% CI 2·52–3·12) and that of chronic bronchitis was 6·19% (95% CI 5·76–6·62) while other CRDs which did not fit to either constitute 1·89%.[19] The prevalence of asthma among males was 2.44% (95% CI 2·05–2·85) while that of females was 3·14% (95% CI 2·71–3·57). Chronic bronchitis prevalence was 6·73% and 5·67% among males and females respectively.[19] Most of the female patients were non-smokers, the risk factor in this group mainly being domestic cooking fuel smoke exposure. In contrast,

in western countries COPD is mainly a disease of smokers. In addition to the mortality caused by COPD, it also places a huge burden on the health services in terms of OP and IP workload.

Currently, 10-15% of patients over forty years old who visit the general OPD of Government healthcare institutions seek treatment for COPD, asthma, or ACOS. Repeated hospitalizations for exacerbations by the same patients consume a significant amount of time and money from the healthcare system. Previous research studies from India suggest the economic impact in terms of direct and indirect cost is on the higher side (direct medical cost: Rs. 29,885 ± 11,995·33 or US$ 300–500 approximately; direct nonmedical cost: Rs. 7,441·25 ± 2,228·90 or US$ 90–155 approximately) and is associated with absenteeism at the job for a significant duration of time.[20]

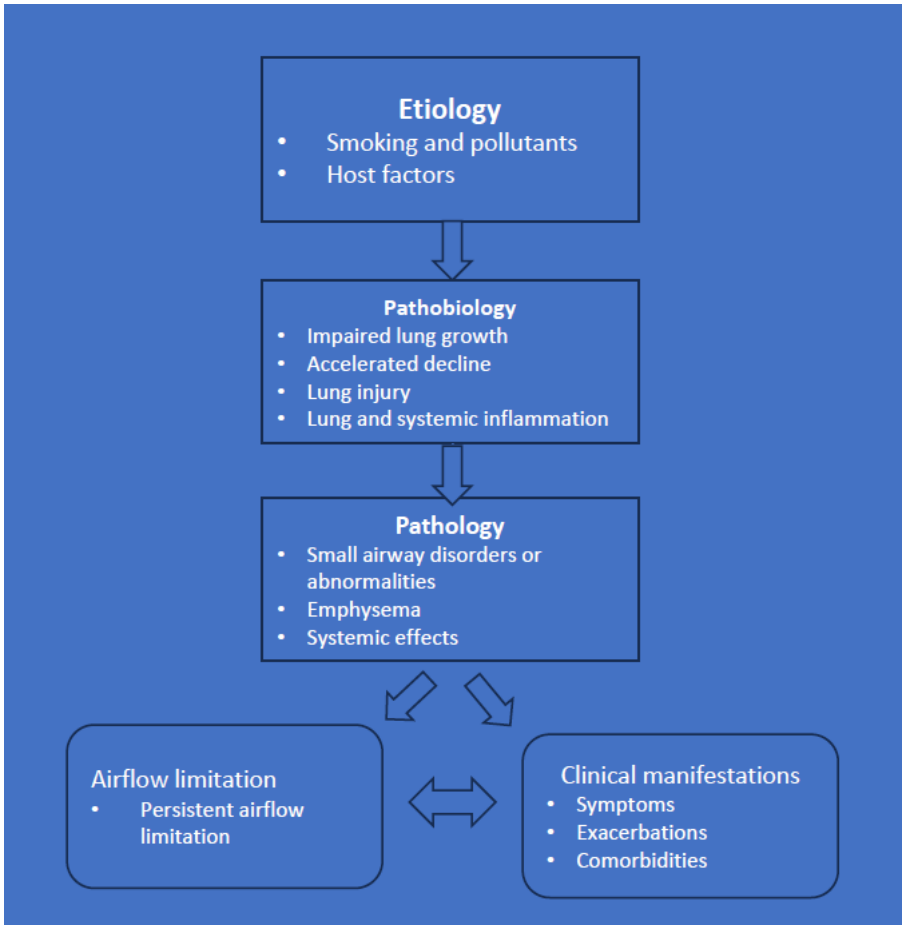

Figure 3: Aetiology, pathobiology, and pathology of COPD leading to airflow limitation and clinical manifestations

Classification of airflow limitation severity in COPD

COPD should be considered in any patient who has dyspnoea, chronic cough or sputum production, and /or a history of exposure to risk factors for the disease. The GOLD classification is an important tool for managing COPD. The GOLD classification of COPD is a system used to assess the severity of COPD based on a patient's airflow limitation, symptoms, and risk of exacerbations. It is used to guide treatment decisions and monitor disease progression.

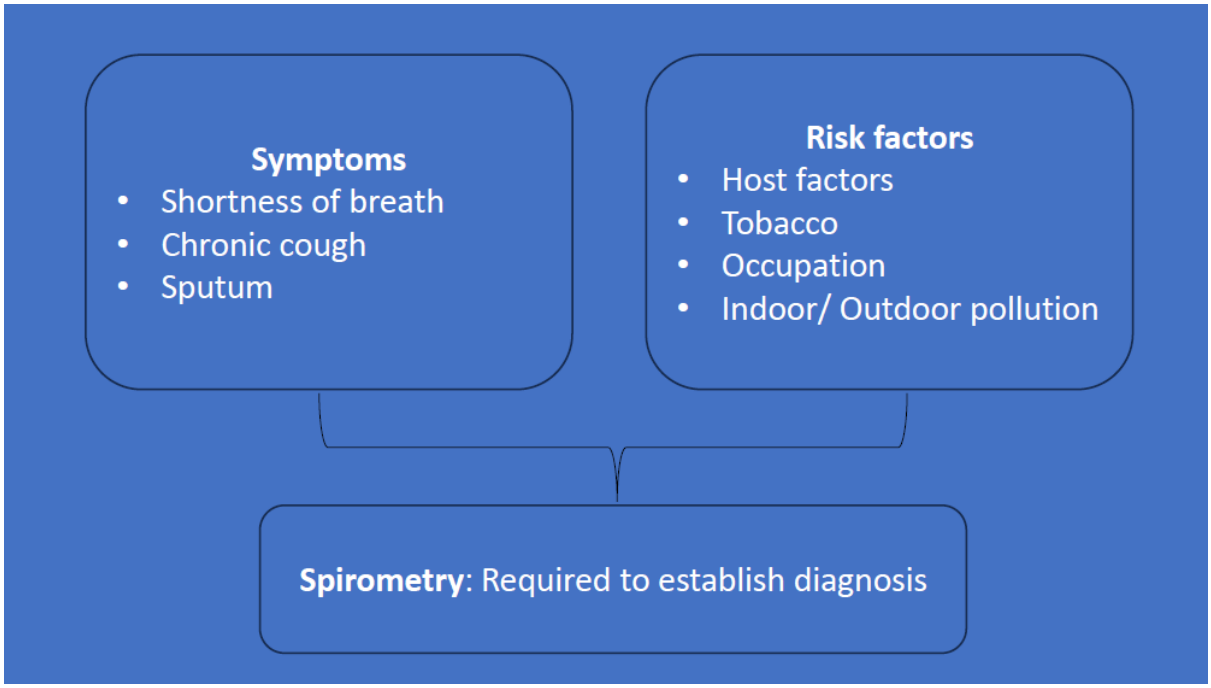

Figure 4: Pathways to the diagnosis of COPD

In pulmonary function testing, a postbronchodilator FEV1/FVC ratio of <0·7 is commonly considered diagnostic for COPD. The Global Initiative for Chronic Obstructive Lung Disease (GOLD) system categorizes airflow limitation into stages. In patients with FEV1/FVC <0·7:

- GOLD 1 - mild: FEV1 ≥80% predicted.
- GOLD 2 - moderate: 50% ≤ FEV1 <80% predicted.
- GOLD 3 - severe: 30% ≤ FEV1 <50% predicted.
- GOLD 4 - very severe: FEV1 <30% predicted.

Current strategies for COPD at the national and state level

Since 2012, there have been several attempts to conduct good quality COPD prevalence studies in India. Without capturing the exact burden, it was difficult to convince the policymakers to initiate action against COPD. This was one reason why there was no dedicated public health program for COPD at the national or state level until 2017. Multiple calls were made at the regional and national level for the setting up of a National COPD Prevention and Control Program. COPD is now supposedly covered under the National NCD program. Since many risk factors for these conditions overlap, components of the preventive aspects exist in the NPCDCS. However, this program called the "National Program for Prevention and Control of Cancer, Diabetes, CVD and Stroke (NPCDCS)" only briefly addresses COPD without clear guidelines on how facilities for diagnosis and treatment can be organized. The

healthcare policy saw a minor change when COPD, along with chronic kidney disease (CKD), was included among the list of major NCDs in the NPCDCS. Guidelines were being issued to the States for initiating "Population-based Screening of common NCDs" utilizing the services of the Frontline-workers and Health-workers under the existing Primary Healthcare System. But the focus of these orders was mainly on diabetes, hypertension, and cardio-vascular diseases.

In addition, there were overlapping efforts to address the burden of COPD using the components of the Stop TB Strategy (the strategy for TB control from 2006 to 2015), and the "Health System Strengthening" included the "Practical Approach to Lung Health" strategy. The latter was primarily meant to tackle obstructive airway diseases and pneumonias. This strategy was pilot tested for India in Kerala. The guidelines were developed, and the pilot testing was done in Kollam district. A preliminary analysis done showed that this pilot study resulted in reduced usage of antibiotics and steroid injections in the PHCs where this was implemented.[21]

Table 1: Key indicators for considering a diagnosis of COPD

Consider COPD, and perform spirometry, if any of these indicators are present in an individual over age 40. These indicators are not diagnostic themselves, but the presence of multiple key indicators increases the probability of a diagnosis of COPD. Spirometry is required to establish a diagnosis of COPD.
Dyspnea that is: • Progressive over time • Characteristically worse with exercise • Persistent
Chronic cough: • May be intermittent and may be unproductive. • Recurrent wheeze
Chronic sputum production: • Any pattern of chronic sputum production may indicate COPD.
Recurrent lower respiratory tract infection
History of risk factors: • Host factors (such as genetic factors, congenital/ developmental abnormalities etc.). • Tobacco smoke (including popular local preparations) • Smoke from home cooking and heating fuels • Occupational dusts, vapors, fumes, gases, and other chemicals.
Family history of COPD and / or childhood factors: For example, low birthweight, childhood respiratory infections etc.

Setting for the development of the SWAAS programme in Kerala

Most COPD patients in the crowded OPDs of Primary Healthcare Centers (PHCs) and Community Healthcare Centers (CHCs) were treated symptomatically rather than being given a medical diagnosis,

which made it likely that their condition would deteriorate over time. This was because COPD was a disease that worsened over time due to lung damage. In the absence of sufficient care, COPD symptoms would deteriorate as well, and the patient would have more frequent exacerbations—periods of deteriorating symptoms that may be fatal. At the moment, 10-15% of patients over forty who visit the general OPD of government healthcare facilities seek treatment for COPD, asthma, or ACOS. The healthcare system must expend a substantial number of resources treating people who must be hospitalized repeatedly for exacerbations.

Mortality reduction in COPD can occur only by properly formulating strategies for management of COPD and incorporating smoking cessation, oxygen therapy and non-invasive ventilation for COPD care. With the state of Kerala aiming for reducing mortality from NCDs, this can be achieved only when a strategy for addressing COPD in the form of a public health program is developed and implemented reaching out to the COPD patients at peripheral level, who might be currently undiagnosed or not getting access to ideal management. With this objective, Kerala state has developed a public health program for COPD (including ACOS).

SWAAS – The COPD control program

What does SWAAS aim for?

The aims of the Kerala COPD control program (SWAAS) were:

- **Identification of COPD in the early stages of the diseases**
    - This would make it possible to implement preventive strategies which would address progression of the disease, so that there are fewer COPD patients in Kerala who first approach the health service in advanced stages of COPD, almost as a respiratory cripple.
- Develop a structured program for **COPD diagnosis and treatment**, starting from the primary care level leading up to the tertiary care level, including the Medical Colleges.
    - Proper management of COPD patients, including provision of oxygen when indicated, medical intensive care during exacerbations and proper management of stable COPD.
- Use the option of **Pulmonary rehabilitation** well, using available resources and by developing indigenously acceptable pulmonary rehabilitation techniques.
    - A study has shown that pulmonary rehabilitation, which is widely recommended therapeutic strategy in COPD in all international guidelines, is currently not available for more than 90% of COPD patients in Kerala and a structured pulmonary rehabilitation program is available only to less than 1% of COPD patients.

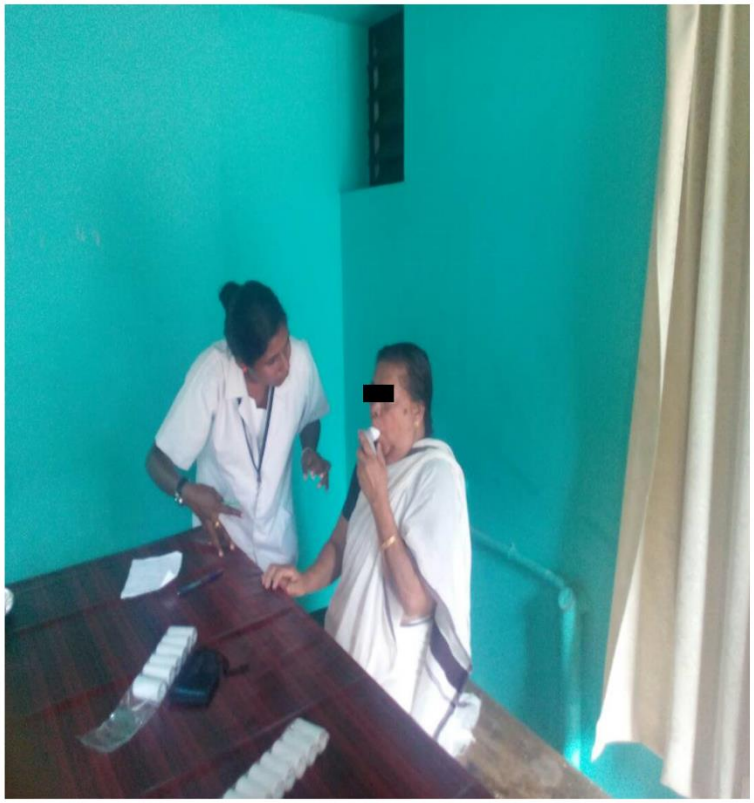

Figure 5: A patient taking a pulmonary function test in a SWAAS clinic in Kerala

Structure of the proposed Kerala COPD Control Program

The Kerala COPD control program would be implemented in a phased manner.

- Screening and diagnosis using questionnaire, spirometry, and medical examination (Figure 3).
- Staging of disease
- Guideline based treatment for COPD/ ACOS
- Provision of inhaler medications (Figure 4)
- Pulmonary rehabilitation programme
    - Smoking cessation clinics
    - Exercise clinics
    - Depression screening
    - Dietary advice
- Referral and follow-up services

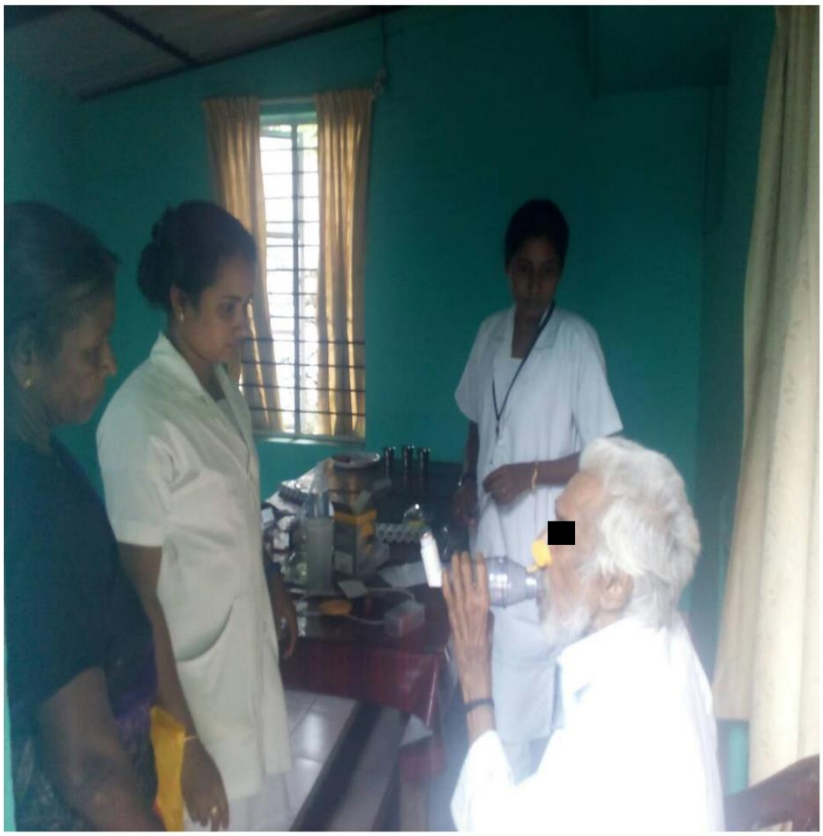

Figure 6: A COPD patient is given training on inhaler technique using spacer and a mouthpiece

Apparatus for setting up a pulmonary rehabilitation unit:

- Weights
- Bands
- Cycle ergometer
- Pulse oximeter
- Yoga mats

Drugs required:

- Nebulizer solutions
    - Salbutamol, ipratropium, and budesonide/ fluticasone solution.
- Metered dose inhalers
    - Formoterol + Budesonide, Salbutamol + Ipratropium, Tiotropium.
- Tablets
    - Salbutamol, Deriphyllin, Montelukast, antihistamines (levocetirizine and desloratadine), prednisolone.
- Nasal sprays
    - Fluticasone
- Injectables
    - Inj. Deriphyllin, Inj. Methyl Prednisolone, Inj. Hydrocortisone

The equipment required for the functioning of the program at various levels of the healthcare system are given in Table 1.

Table 2: Equipment required for the Kerala COPD control program

Level	Equipment/ Drug
PHC	Mini spirometer
	Pulse-oximeter
	Oxygen concentrator
	Weighing machine
	Apparatus/ facility for measuring height
	Nebuliser
	Oxygen masks
	Nasal prongs for oxygen inhalation
	Mouth pieces for using with mini spirometer
Taluk	Mini spirometer
	Pulse oximeter
	Oxygen concentrator
	Weighing machine
	Apparatus/ facility for measuring height
	Nebuliser
	Oxygen masks
	Nasal prongs for oxygen inhalation
	Mouth pieces for using with mini spirometer
	Masks for using with NIV
District	Mini spirometer
	Spirometer
	Pulse oximeter
	Oxygen concentrator
	Weighing machine
	Apparatus/ facility for measuring height
	Nebulizers

	Non-invasive ventilation (NIV) machine
	Mechanical ventilator
	Oxygen masks
	Nasal prongs for oxygen inhalation
	Mouth pieces for using with mini spirometer
	Masks for using with NIV

Why this economic evaluation study?

In respiratory diseases, short-term clinical-effectiveness and cost-effectiveness have been demonstrated for targeted case finding programs (e.g.: Tuberculosis control program). But it is unclear whether these translate into future long-term benefits for a regular screening programme like SWAAS. Furthermore, some of the results of the economic analysis (cost per case detected/ cost per exacerbation averted) are not easily comparable with results from other health programmes. In the absence of long-term trial data, model-based economic evaluations are needed. We report the results of a model-based economic evaluation of the long-term costs and benefits of a regular programme of systematic active case-finding of COPD cases over routine practice, using data from health system in Kerala and published literature. The model outcome is expressed as an ICER (in cost per quality-adjusted life-year (QALY) gained). In India, the cost-effectiveness threshold rule typically follows one GDP-per-capita/QALY.

Aims and Objectives

The aim of this study is to determine the cost-effectiveness and budget impact of undertaking a COPD Control Program in Kerala (SWAAS) which focuses on screening and early detection through active case finding compared to routine practice and providing optimal treatment including inhaler medications.

Objectives of the study

Primary objective

1. To determine the cost-effectiveness of the COPD Control Program in Kerala (SWAAS)

Secondary objective

1. To determine the budget impact of implementing the COPD Control Program in Kerala (SWAAS).

Methods

PICOT

Table 3: Description of components of PICO

PICOT	Description of the components of PICO
Population	All patients >40 years with relevant chronic respiratory symptoms or a risk factor (smoking) and without a prior diagnosis of COPD
Intervention	COPD control program – SWAAS - Screening and early detection through active case finding, staging of disease, and providing adequate treatment
Comparator	No COPD control program - Routine practice where patients are diagnosed during episodes of exacerbation or during visits to hospital for other illnesses.
Outcome	- Implementation cost of the SWAAS program - QALY gain from the SWAAS program. - Incremental cost effectiveness ratio - Budget Impact analysis

Study design and intervention

A Markov decision model was built with *'TreeAgePro 2022'* and Microsoft Excel to estimate the cost effectiveness of screening and early detection of COPD cases through active case finding, staging of disease, and providing adequate treatment compared to routine care. A cost–utility analysis was undertaken to calculate the cost per QALY gained from a health service perspective. The population in the study comprised of patients >40 with relevant chronic respiratory symptoms or a risk factor (smoking) and without a prior diagnosis of COPD. For the population-based screening using field workers, a respiratory symptom screening questionnaire is used to identify eligible patients (respiratory symptomatic or presence of risk factor). They will be requested to visit the Medical Officer at the FHC/PHC who will do the clinical examination. The MO will identify patients who requires pulmonary function test (PFT) & schedule an appointment for the PFT. After diagnosis medications will be started by the FHC/PHC MO as per the GOLD guidelines. The inhaler technique demonstration, smoking cessation advice and breathing exercise training will be given from the FHC. The patient will be referred to concerned sub-Centre for follow up.

Model structure

The health states were broadly grouped into undiagnosed disease, diagnosed disease and dead (absorbing state). COPD health states were defined according to the traditional Global Initiative for Chronic Obstructive Lung Disease (GOLD) severity classification with stages 1–4 based on airflow obstruction.

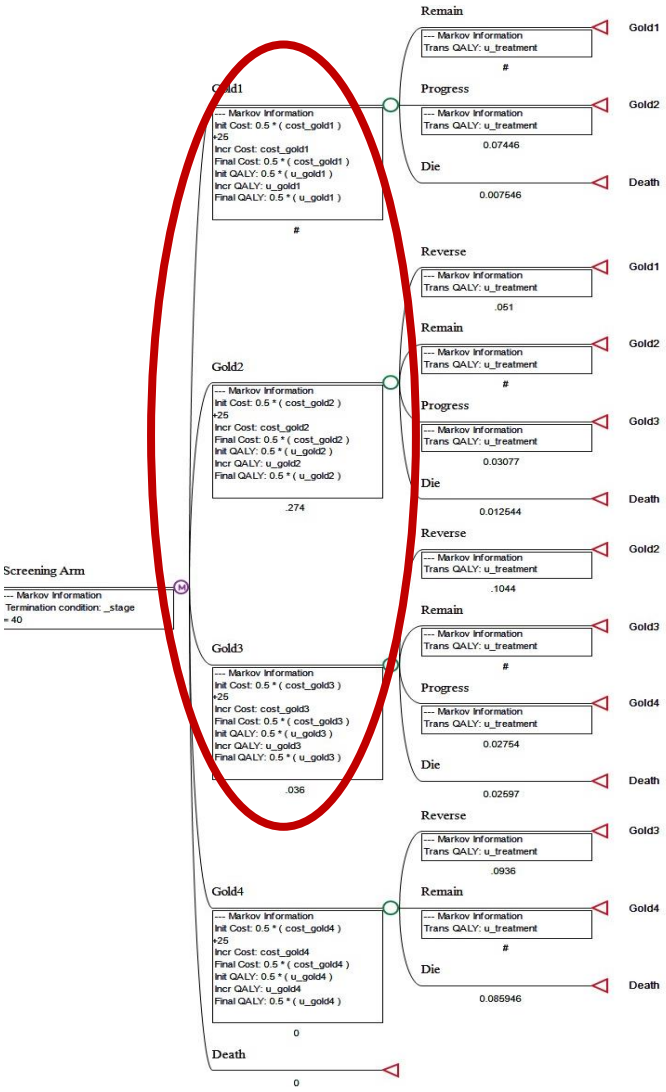

Figure 7: Transition health stages of Markov Model

However, the GOLD stage 4 health state was not made available for undiagnosed patients based on expert consensus. It was agreed that patients with COPD as severe as GOLD stage 4 will develop exacerbations that would be picked up by the healthcare system. Therefore, the chances of identifying a new COPD case as severe as GOLD stage 4 was negligible. The model had a time cycle of one year since COPD was a slowly progressing disease. The time horizon was forty years assuming an average life expectancy of 80 years. The red circle in Figure 5 indicates that GOLD 1-3 is available for the base case starting cohort.

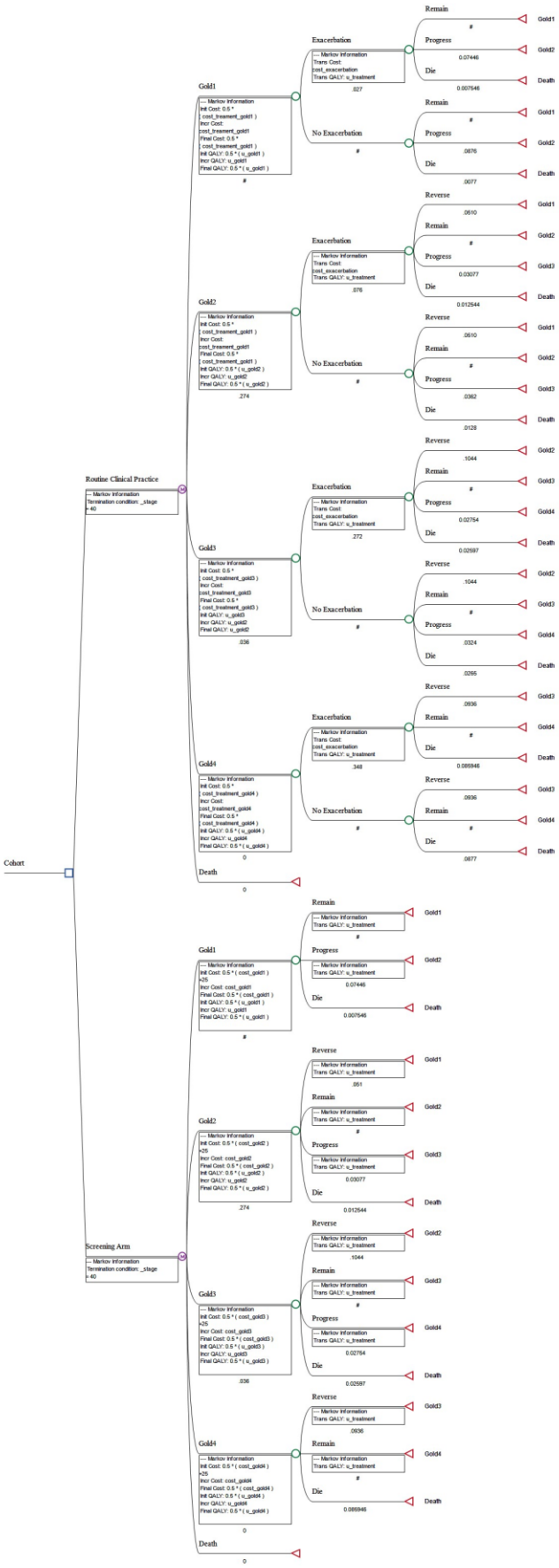

Figure 8: Decision Tree Model

The complete decision tree model is shown in Figure 6. The base case starting cohort of patients was distributed across undiagnosed GOLD 1, GOLD 2, and GOLD 3 health states. Based on the INSEARCH study,[5] the state had a COPD prevalence of ~10% among people over 40 years. Prevalence studies from large databases of COPD cohort data[22] have shown that the ratio of COPD patients with GOLD 1: GOLD 2: GOLD 3 severity is 69.0: 27.4: 3.6. Once a patient developed COPD, the model allowed movement to the immediate next worse GOLD stage. Direct deterioration beyond the next stage within a 12-month period was not allowed because COPD was assumed to progress slowly (e.g., movements from GOLD 1 directly to 3 and from GOLD 2 to 4 were not allowed). Transition from an undiagnosed to a diagnosed health state was permitted but not the reverse. Undiagnosed GOLD stage health states were assumed to have the same baseline transitions to worse undiagnosed GOLD stages as diagnosed health states. There was a risk of exacerbation and death within any health state. The case-finding processes were modelled as events within each health state.

Data values used in the model

Transition probabilities between GOLD stages were obtained from The Health Improvement Network (THIN) database,[22] including about 2 million with diagnosed COPD.[23] Severe exacerbations (i.e., those requiring inpatient stay were considered in this evaluation as these episodes alone account for over 84% of all COPD-related healthcare costs).[24] Age-specific all-cause mortality rates were obtained from the life tables for India and applied accordingly. Treatment effects were taken from published literature suggesting reductions in risk of exacerbations, which in turn reduces the risk of mortality, and also decreases the progression of the disease. The transition probabilities, treatment effects in various GOLD stages, and the probability of exacerbation are extracted from published literature and given in Table 3.

Resource use and costs

Estimation of healthcare costs for the diagnosed and treated GOLD stages followed the existing costing framework. Cost of COPD-related inhaled pharmacotherapy was calculated using data from the SWAAS Pilot centres and Kerala Medical Services Corporation Limited (KMSCL). No cost was attached to routine care or comorbidities since these were assumed to be the same for both arms. Consumption rate and the cost of metered dose inhalers and the cost estimates for providing emergency care without hospital admission to COPD patients (Cost/ patient/ visit) are shown in Table 4 and 5 respectively.

Table 4: Transition probabilities and treatment effects

	GOLD 1	GOLD 2	GOLD 3	GOLD 4	Dead
Exacerbation (probability)					
Severe exacerbation[25]	0.0270	0.0760	0.2720	0.3480	-
Mortality after severe[26]	0.0703	0.0703	0.0703	0.0703	-
Treatment effect (OR)					
All-cause mortality[27]	0.9800	0.9800	0.9800	0.9800	-
Severe exacerbation[27]	0.8500	0.8500	0.8500	0.8500	-
Progression to the next GOLD stage	0.8500	0.8500	0.8500	0.8500	-
Transitions (probability)[23]					
GOLD 1	0.9047	0.0876	0.0000	0.0000	0.0077
GOLD 2	0.0510	0.9001	0.0362	0.0000	0.0128
GOLD 3	0.000	0.1044	0.8368	0.0324	0.0265
GOLD 4	0.000	0.000	0.0936	0.8187	0.0877

Median total cost per exacerbation episode was INR 44,390 (Inter-quartile range [IQR]: INR 33,354–63,642; US$739.8, IQR: 555.9–1060.7).[28] Hospital costs constituted the largest component of the costs (71%) followed by other costs directly borne by the patient himself (29%), medicine costs (14%), transportation charges (2%) and diagnostic tests (3%). Indirect costs to caregivers (median INR 1,544, IQR: INR 0–17,370 INR; US$25.7, IQR: US$0–289.5), calculated as financial loss due to missed workdays, accounted for 4% of the total cost.[28]

Table 5: Consumption rate and the cost of metered dose inhalers

Medication	**(a) Unit cost (INR)**	**(b) Metered dose**	**(c) Assumed Dose required**	**(d) Duration of usage of one inhaler**	**(e) Number of inhalers required per year**	**(f) Total cost per patient per year** (a*e) (INR)**
Formetrol + Budesonide Inhaler	277.70	120	4 puffs/day	30 days	12	3332.40
Tiotropium inhaler	394.71	200	2 puffs/day	100 days	4	1578.84
Salbutamol Inhaler	130.47	200	4 puffs/day	50 days	8	1043.76

** Cost of spacer/ mouthpiece is not added

Table 6: Cost estimates for providing emergency care without hospital admission to COPD patients (Cost/ patient/ visit)

Item	**Unit cost (INR)**
Nebulizing solution - salbutamol 2.5 ml/ipratropium (1 ml)	9.7
Deriphyllin 2 ml (Injection)	5.49
Salbutamol (2 mg) (Tablet)	0.5
Syringe 2 ml	2.43
Injection needle	1.41
Gloves	2
OP ticket	2
Other Expenses (Indirect)	75
Total expense for single visit	98.53 (100)
Total expense for multiple visit (at least 6 visits per month)	**INR 600**

One-way sensitivity analysis

A series of one-way sensitivity analysis was conducted to assess how the key parameters such as the starting proportion of the cohort, time horizon, transition probability, mortality rate, exacerbation rate, cost of treatment etc. affected the results. We ran almost every parameter that was used in the model, but we finally retained only 12-15 parameters the impacted the results the most.

Results

Cost utility analysis

The base case results (see table 7) show that compared to the passive routine practice, the active screening strategy for early identification and treatment of COPD patients was a cost saving option.

Table 7: Base-case result cost utility analysis

Base-case result cost utility analysis						
Strategy	**Cost**	**Incr. Cost**	**Effectiveness**	**Incr. Eff.**	**ICER**	**NMB**
Screening Arm	3955.158		0.6392			104715.205
Routine Clinical Practice	4787.876	832.718	0.6057	-0.03346	-24882.4139	98193.2407

Incr. Cost – Incremental Cost
Incr. Eff – Incremental Effectiveness
ICER – Incremental Cost Effectiveness Ratio
NMB – Net Monetary Benefits

One-way sensitivity analysis

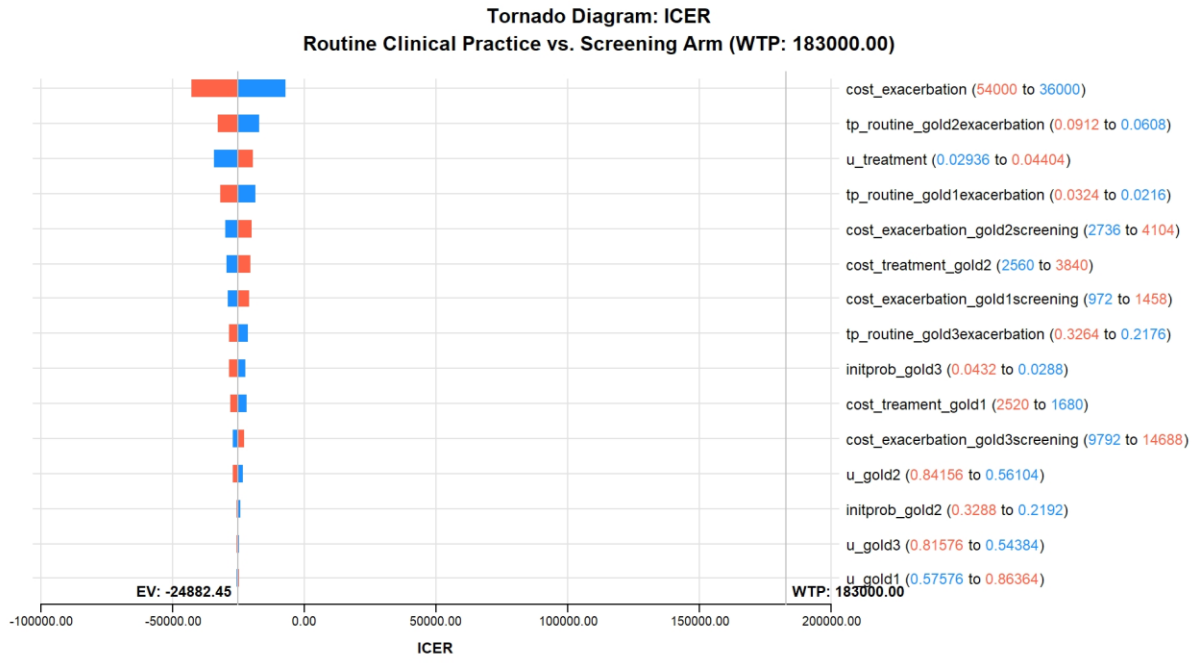

Figure 9: One-way sensitivity analysis

The ICER was most sensitive to the cost of treatment of exacerbation. This was somewhat expected, since the cost of the monthly inhalational medications although significant and recurrent in nature, the cost of inpatient care for exacerbations were almost 10-fold in comparison. The model was sensitive to the magnitude of the additional impact of treatment, the exacerbation rates from each GOLD stage and the GOLD stages of the initial cohort.

Budget impact analysis

The INSEARCH study showed that the state has a COPD/ ACOS prevalence of 10% in people older than 40 years of age. Numerous other studies conducted even more recently estimate the state's COPD prevalence in the range of 6-9% for the same age group. We conducted a scenario analysis based on the lowest estimates and the highest estimates. Based on the lowest estimates, the total number of COPD patients in the state is projected to be 786,917 and based on the highest estimates the total number of COPD patients in the state is estimated to be 1,322,945.

The population of Kerala was taken from the previous census data (2011). The age structure was also taken from the 2011 census data. Based on it, the total number of people above forty years were calculated. The age specific COPD prevalence was extracted from the literature, and they were used to calculate the crude prevalence of COPD patients in each age group. Based on interviews with clinicians and policy experts, it was agreed that at least 45-55% of the patients sought their healthcare from the private sector.

At present, there are 848 Family Health Centre's (FHC) within Kerala. Once the screening is complete for the whole population, we expect somewhere between 393458 (~6%) and 661473(~10%) patients to seek COPD care in the government healthcare system. The state, through the initial phase of SWAAS, has undertaken symptomatic screening for close to two lakh individuals and screened 79,405 patients with spirometry and has identified 53,630 new cases of COPD patients. These patients are currently the beneficiaries of the SWAAS program.

Since the COPD programme is also a bundled intervention among a set of targeted interventions against non-communicable diseases, the human resources cost, and the infrastructure cost are very much reduced as opposed to a standalone intervention. The per patient screening cost was calculated to range between INR 38.46 and INR 64.66. The overall screening cost was calculated for all the FHCs, and it came to around INR 25,440,000 (Figure 10).

Based on the lower and upper estimates, the annual treatment cost of the diagnosed COPD patients would range between INR 973,003,086.29 - 1,635,788,480.70 (Table 8). Currently, for providing the metered dose inhalers alone the state is spending INR 87,953,200. Since the programme is still in its early stages and just 10% of the eligible population is on the beneficiary list, this sum is not particularly substantial currently. But as the number of recipients approaches close to 50% of the eligible population, a cost projection is displayed, that sum seems substantial.

Table 8: Overall cost of treatment of COPD patients (lower limit and upper limit)

LL				
stage	prevalence	population	annual RX cost/ patient	annual_overall_cost in INR
GOLD A	37.8	148727	1044	155271297
GOLD B	20.1	79085	1579	124875451
GOLD C	13.4	52723	2623	138293564.7
GOLD D	28.7	112923	4911	554562773.6
	100	393458		**973,003,086.29**
UL				
stage	prevalence	population	annual RX cost/ patient	annual_overall_cost in INR
GOLD A	37.8	250037	1044	261038225.5
GOLD B	20.1	132956	1579	209937488.5
GOLD C	13.4	88637	2623	232495686
GOLD D	28.7	189843	4911	932317080.7
	100	661473		**1,635,788,480.70**

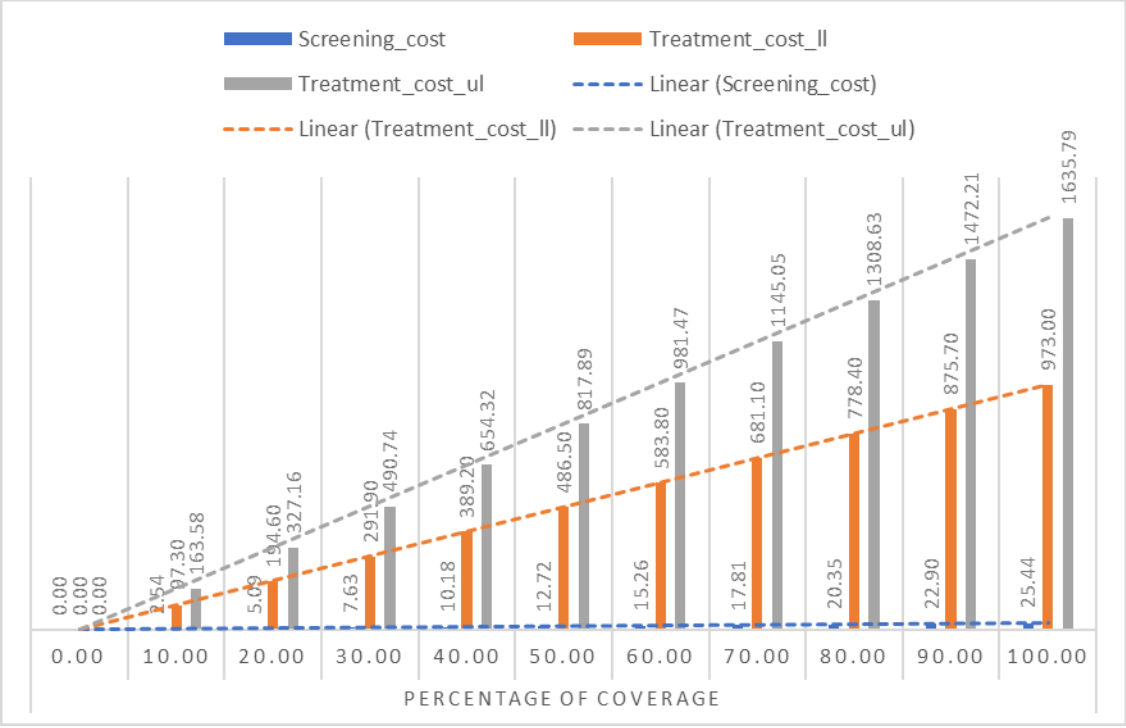

Figure 10:Projected budget impact by beneficiaries enrolled

Discussion

The present study demonstrates that active screening for early identification and treatment of COPD (SWAAS program) offers a cost-saving alternative to the current passive approach. By establishing COPD clinics within existing infrastructure, there is an increase in accessibility to diagnosis, education, and preventive measures. This decentralized approach facilitates early detection and management, potentially reducing the burden on secondary and tertiary healthcare systems.

Our analysis revealed an incremental cost-effectiveness ratio (ICER) of rupees (-) 24882.42 (cost saving). This aligns with existing evidence advocating for early intervention in chronic disease management, where proactive strategies can prevent costly complications like COPD exacerbations. Acute exacerbations represent the principal drivers of direct costs for COPD care.

From a societal perspective, there are substantial indirect costs associated with disability, premature mortality, and lost production from COPD. However, the sensitivity analysis unveils crucial aspects requiring further exploration. The magnitude of treatment effectiveness and the differential exacerbation rates across GOLD stages warrant more research to refine cost-effectiveness predictions for specific patient populations.

Exploring tailored screening approaches based on baseline risk factors could potentially enhance the efficiency and cost-effectiveness of COPD management strategies. Targeting high-risk individuals with GOLD stage II or higher COPD could potentially enhance the clinical and economic impact of the intervention even further.

While the per-patient screening cost for COPD remains manageable, scaling up the program reveals potential financial challenges. Our analysis estimates the total screening cost for all FHCs to be around INR 25,440,000, a manageable figure. However, the projected annual treatment cost for diagnosed COPD patients paints a different picture. The range of INR 973,003,086.29 - 1,635,788,480.70 represents a significant financial burden for the Health Department, especially as the program expands.

This raises several considerations. Firstly, the current program covers only 10% of the eligible population, minimizing the immediate financial impact. However, as the beneficiary list grows, the projected treatment cost will proportionally increase. This necessitates proactive financial planning and resource allocation within the Health Department.

Secondly, collaboration with other agencies like the LSGI (Local Self-Government Institutions) becomes crucial. Exploring joint funding mechanisms and resource sharing can alleviate the pressure on the Health Department's budget. Thirdly, innovative health financing mechanisms could be explored at the LSGI level. Public-private partnerships, community-based funding initiatives, and leveraging health insurance schemes can potentially contribute to sustaining the program's financial viability.

In conclusion, while the early financial implications of the SWAAS program appear manageable, long-term sustainability requires strategic planning and resource mobilization. Exploring avenues for inter-departmental collaboration, innovative financing mechanisms, and further cost-reduction strategies through optimized treatment protocols will be crucial for the program's continued success and its wider implementation in addressing the growing burden of COPD in India.

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