Cost-effectiveness of population-based screening for diabetes and hypertension in India: an economic modelling study

Gunjeet Kaur, Akashdeep Singh Chauhan, Shankar Prinja, Yot Teerawattananon, Malaisamy Muniyandi, Ashu Rastogi, Gaurav Jyani, Karikalan Nagarajan, PVM Lakshmi, Ankur Gupta, Jerard M Selvam, Anil Bhansali, Sanjay Jain

Summary

Background India faces a high burden of diabetes and hypertension. Currently, there is a dearth of economic evidence about screening programmes, affected age groups, and frequency of screening for these diseases in Indian settings. We assessed the cost effectiveness of population-based screening for diabetes and hypertension compared with current practice in India for different scenarios, according to type of screening test, population age group, and pattern of health-care use.

Methods We used a hybrid decision model (decision tree and Markov model) to estimate the lifetime costs and consequences from a societal perspective. A meta-analysis was done to assess the effectiveness of population-based screening. Primary data were collected from two Indian states (Haryana and Tamil Nadu) to assess the cost of screening. The data from the National Health System Cost Database and the Costing of Health Services in India study were used to determine the health system cost of diagnostic tests and cost of treating diabetes or hypertension and their complications. A total of 962 patients were recruited to assess out-of-pocket expenditure and quality of life. Parameter uncertainty was evaluated using univariate and multivariable probabilistic sensitivity analyses. Finally, we estimated the incremental cost per quality-adjusted life-year (QALY) gained with alternative scenarios of scaling up primary health care through a health and wellness centre programme for the treatment of diabetes and hypertension.

Findings The incremental cost per QALY gained across various strategies for population-based screening for diabetes and hypertension ranged from US$0·02 million to $0·03 million. At the current pattern of health services use, none of the screening strategies of annual screening, screening every 3 years, and screening every 5 years was cost-effective at a threshold of 1-time per capita gross domestic product in India. In the scenario in which health and wellness centres provided primary care to 20% of patients who were newly diagnosed with uncomplicated diabetes or hypertension, screening the group aged between 30 and 65 years every 5 years or 3 years for either diabetes, hypertension, or a comorbid state (both diabetes and hypertension) became cost-effective. If the share of treatment for patients with newly diagnosed uncomplicated diabetes or hypertension at health and wellness centres increases to 70%, from the existing 4% at subcentres and primary health centres, annual population-based screening becomes a cost saving strategy.

Interpretation Population-based screening for diabetes and hypertension in India could potentially reduce time to diagnosis and treatment and be cost-effective if it is linked to comprehensive primary health care through health and wellness centres for provision of treatment to patients who screen positive.

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Department of Community Medicine and School of Public Health (G Kaur MPH, A S Chauhan PhD, S Prinja MD, G Jyani MPH, PVM Lakshmi MD), **Department of Endocrinology** (A Rastogi DM, A Bhansali DM), **Department of Cardiology** (A Gupta DM), **Department of Internal Medicine** (S Jain DM), **Post Graduate Institute of Medical Education and Research, Chandigarh, India; Saw Swee Hock School of Public Health, National University of Singapore, Health Intervention and Technology Assessment Program, Nonthaburi, Thailand** (Y Teerawattananon PhD); **National Institute for Research in Tuberculosis, Chennai, India** (M Muniyandi PhD, K Nagarajan PhD); **Department of Health & Family Welfare, Government of Tamil Nadu, Chennai, India** (J M Selvam MD)

Correspondence to:
Dr Shankar Prinja, Department of Community Medicine and School of Public Health, Post Graduate Institute of Medical Education and Research, Chandigarh 160012, India
shankarprinja@gmail.com

Introduction

Low levels of disease awareness and poor care seeking are the two major barriers for timely detection and treatment of diabetes and hypertension.[1] Consequently, several countries have initiated screening programmes for early detection of these diseases, which vary from targeted and facility-based screening to population-wide community-based screening. Several cost-effectiveness analyses have evaluated these screening programmes.[2–5] However, very few of these analyses considered screening both diabetes and hypertension, which is the usual scenario in health programmes.[2,3] A population level microsimulation-model analysis from India concluded that, with current screening methods, community level screening for diabetes is unlikely to be cost-effective.[6]

India has implemented population-based screening for diabetes and hypertension as part of the National Program for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke.[1] In addition, the Ayushman Bharat Health and Wellness Centre programme aims to provide comprehensive primary health care for the treatment of diabetes and hypertension at

Research in context

Evidence before this study

We did a systematic literature review of published work in PubMed and Google Scholar between the inception of both databases and March, 2018, using the search terms "cost-effectiveness analysis", "economic evaluation", "screening", "type 2 diabetes", "diabetes" and "hypertension". We found no previous cost-effectiveness analysis comparing various screening strategies for diabetes and hypertension in India by type of test, age, and frequency at the programmatic level. Most studies (n=14) were from other country settings, considered only one of the diseases, and reported mixed results. Two studies that evaluated the cost-effectiveness of the WHO Package of Essential Noncommunicable programme (or targeted screening) reported it as cost-effective. One study that evaluated population-based screening for diabetes in Brazil reported it to be cost-ineffective.

Added value of this study

This study evaluated the lifetime costs and consequences of population-based screening for diabetes and hypertension from a programmatic lens in a lower-middle-income country setting. It found that population-based screening at frequencies ranging from annual to every 20 years were not cost-effective given current levels of health-care system use by patients diagnosed with diabetes or hypertension in India. However, we estimate that if the proportion of newly diagnosed diabetic or hypertensive patients that are treated at local primary care Health and Wellness Centers increased to more than 20%, screening at 3 to 5 year intervals could be cost-effective. If the proportion receiving treatment at HWCs increased to 70%, annual population-based screening could be a cost-saving strategy.

Implications of all the available evidence

Early detection and treatment of diabetes and hypertension through widespread screening is a potential strategy to reduce the substantial lifetime health and cost burdens associated with these illnesses in India. Strengthening comprehensive primary health care in the public sector to deliver treatment for uncomplicated diabetes or hypertension could render population-based screening programmes cost-effective. However, the absence of data for the risk of developing various complications by age group, stratified by glycaemic and blood pressure control for the Indian population, is a key limitation that future research should address.

health and wellness centres (HWCs)[7]. These HWCs will be created with the transformation of 150000 subcentres and primary health centres to HWCs with an expanded scope of services, including care for non-communicable diseases.

See Online for appendix

As a result of these developments, the Indian Government's Health Technology Assessment agency commissioned the present cost-effectiveness analysis for screening for diabetes and hypertension. In this study, we aimed to report the incremental cost per quality-adjusted life-year (QALY) that would result from alternate scenarios of screening diabetes or hypertension, such as using alternate tests, adjusting the population age group for screening, changing the frequency of screening, and using an alternate combination of health-care use in the context of HWCs compared with routine health-care use.

Methods

The hybrid model

We developed a hybrid model, which incorporated a decision tree and Markov model, to estimate the cost-effectiveness of several alternative scenarios of population-based screening for diabetes or hypertension in a hypothetical population of 100000 people aged 30 years old who were followed throughout their lifetime. We then used this model to compare population-based screening against a counterfactual scenario of current screening methods practice in India. In the counterfactual scenario, which relied on the coverage of opportunistic screening or detection based on the onset of symptoms, 0·3% of the population was routinely diagnosed with either diabetes or hypertension.[6]

Our hybrid decision model was comprised of three parts (appendix p 4). The first part consisted of a decision tree that predicted the number of individuals who would be detected with either prediabetes, diabetes, hypertension, or a comorbid state. These individuals were further stratified into true positive, false negative, true negative, or false positive, depending on the sensitivity and specificity of the screening method. The second part tracked the transition of people with diabetes or hypertension, or a comorbid state (both diabetes and hypertension), over annual cycles to identify the occurrence of disease-related complications. To reflect the real-world scenario, each disease condition in the model was further divided into one of the following health states: diagnosed and treated, diagnosed and untreated, or undiagnosed. The third part comprised of five Markov models for individual complications, including retinopathy, nephropathy, foot ulcer, coronary heart disease, and stroke. The second and third parts predicted the health outcomes in terms of life-years, QALYs, and costs. We used a lifetime horizon and a societal perspective that included health system and out-of-pocket expenditures for both screening and treatment of disease and its complications.[8] Future costs and consequences were discounted at 3%.[8]

Intervention and comparator

We simulated the costs and consequences of population-based screening and subsequent treatment for diabetes or

hypertension under the National Program for Prevention and Control of Cancer, Diabetes, Cardiovascular Diseases and Stroke programme over the lifetime of a cohort of 100000 people aged 30 years old.[1] For our base case model, we considered population-based screening annually with random blood glucose followed by fasting glucose and blood pressure measurement in the group aged between 30 and 65 years. The comparator scenario comprised of the usual practice of detection of diabetes or hypertension based on coverage of opportunistic screening or detection based on the onset of symptoms as per current health-care seeking behaviour.[9,10]

Several alternative screening scenarios were modelled. Firstly, we compared the type of blood glucose testing methods (ie, random blood glucose, fasting glucose, glycated haemoglobin [HbA1c], and the oral glucose tolerance test). In addition, we varied the frequency of screening (ie, annually, or every 3, 5, 10, 15, or 20 years) and population age group to be screened (ie, 30–65 years or 45–65 years; appendix p 5). The existing pattern of treatment seeking for people with diabetes or hypertension was modelled in both intervention (the population-based screening group) and comparator (the current practice group) groups.[9] An alternative population-based screening scenario was modelled in which, at the base model coverage for screening and treatment for diabetes, hypertension or a comorbid state, we serially increased the share of treatment at primary care level for people with a positive diagnosis, from the existing level of 4% to 10%, and then every 10% increment until the annual screening strategy became cost-saving. Thus, the overall coverage of treatment remained constant, but the patterns of care seeking were changed.

Model assumptions

We assumed that the movement from non-diabetes to diabetes occurs through the prediabetic dysglycaemic state.[11] Incidence of prediabetes stratified by age (as reported in the CURES study)[12] and hypertension (as reported in the CARRS study)[13] were used for our model. The number of patients with either diabetes, hypertension, or a comorbid state who were 30 years old and were detected at the commencement of the decision model were estimated on the basis of their age-specific prevalence estimates. In each of the subsequent cycles, the number of patients with diabetes or hypertension were estimated using annual age-specific incidence rates. A previously published Indian study[14] and The UK Prospective Diabetes Study (UKPDS) clinical trial[15,16] were used for assigning risks of developing microvascular and macrovascular complications. A similar risk of developing complications was assumed for patients who were diagnosed but who were untreated, and for patients who were undiagnosed. Both of these groups were considered to represent the uncontrolled disease condition, with a higher assumed risk of developing complications than patients who were diagnosed and treated.

The cutoffs to ascertain that a person was in a controlled or uncontrolled state for each disease condition were chosen in concurrence with previously published Indian studies.[17,18] In the absence of any Indian data for the risks of complications stratified by level of glycated haemoglobin (ie, HbA1c) and systolic blood pressure, the stratified risks reported by the UKPDS trial[15,16] were used. We assumed risks of developing complications in a controlled health state for patients with diabetes using HbA1c values less than 7% and for patients with hypertension using systolic blood pressure under 140 mm Hg.

Markov models for complications, including retinopathy, nephropathy, foot ulcer, coronary heart disease, and stroke were developed. To account for a probability of more than one complication (microvascular and macrovascular complications), a combination of nephropathy and coronary heart disease was considered as this was the most common combination of complications in India.[14] Age-specific all cause-mortality rate (as per the Indian Sample Registration Survey) was applied to all health states.[19] Disease-specific mortality was assumed to occur as a result of complications, including myocardial infarction, stroke, end stage renal disease, and more than one complication state.[20,21] Individual Markov models for each complication and their details are provided in the appendix (pp 6–10).

A systematic review and meta-analysis to assess the diagnostic accuracy of blood glucose tests (ie, random blood glucose, fasting plasma glucose, and HBA1c) was done.[22] In the absence of sufficient number of studies to do a meta-analysis for a random blood glucose test, we used sensitivity and specificity as reported in a community-based Indian study.[23] Key model parameters are provided in the appendix (pp 11–22).

Costing

Both the intervention and control scenarios included the cost of screening and routine diagnosis, the cost of treating diabetes or hypertension, and the cost of treating complications. Data for the cost of screening were collected using a combination of bottom-up and top-down costing methods from randomly selected sub-centres in two districts of Haryana and Tamil Nadu. Details of data collection and analysis are available in the appendix (pp 23–24).

The health system cost of treating diabetes or hypertension at different levels of health-care delivery was ascertained from the national health system cost database.[24] The treatment seeking pattern for uncomplicated diabetes and hypertension in the public and private sectors was based on our analysis of the National Sample Survey 71st round data[9] and report of National Health Accounts for India.[25] For individuals with complications, it was assumed that treatment for

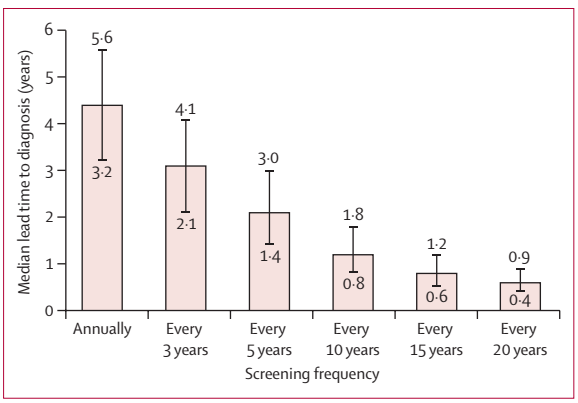

Figure 1: **Median lead time for diagnosis with screening compared with the counterfactual scenario**
Error bars represent the 2·5th and 97·5th percentiles.

specialised care would be sought at the tertiary level of health care only. Costs for treatment of complications were derived from the ongoing Cost of Health Services in India study[26,27] and the provider payment rate from the national social insurance scheme in India.[28] All costs were updated to the value for the year 2018 using the consumer price index when necessary and reported in Indian National Rupees (INR) and US dollars (US$), in which 1US$ was equal to 70 INR.[29]

Out-of-pocket expenditure for the treatment of diabetes and hypertension for primary and secondary care in public and private facilities was obtained by the authors analysis of the unit-level data from the National Sample Survey 71st round survey.[9] A primary survey was done using 962 patients with diabetes with and without hypertension to assess the out-of-pocket expenditure of seeking treatment at a public sector tertiary care hospital that caters to six north Indian states and a union territory (appendix p 25).

Quality of life

To ascertain health-related quality of life (HRQOL), both primary data and secondary sources were used. A total of 234 patients with diabetes, 300 patients with hypertension, and 428 patients with both diabetes and hypertension visiting the outpatient clinic of a public sector tertiary care hospital in north India were interviewed using the EuroQol Quality of Life (EQ-5D-5L) questionnaire.[30] Separate utility scores were generated for patients with and without complications. For deriving the HRQOL for complications associated with some health states, we reviewed the published evidence (appendix pp 24–25).

Sensitivity and scenario analyses

We did univariate and multivariable probabilistic sensitivity analyses to account for parameter uncertainty.[31] Under probabilistic sensitivity analyses, gamma distribution was assigned to cost parameters, beta distribution for HRQOL estimates and transition probabilities, normal distribution for effectiveness, and uniform distribution for other parameters (appendix p 26). Finally, the median value of incremental cost-effectiveness ratio along with 2·5th and 97·5th percentile was computed using 999 Monte Carlo simulations.

Currently, 74·6% of patients with diabetes or hypertension access outpatient care from the private sector.[9] Although 3·8% of patients with diabetes or hypertension access treatment at subcentres and primary health centres, 21·4% use secondary and tertiary level public facilities.[9,25] However, as part of the Ayushman Bharat Health and Wellness Centre programme, comprehensive primary health care is being strengthened by the creation of HWCs. It is envisaged under this programme that HWCs would provide routine outpatient care for diabetes or hypertension. We modelled alternative scenarios in which a serially incremental proportion of total patients who seek care are treated at the HWC level. The overall proportion of patients who seek care remains the same as the base case. The details for the cost of services at the HWC level are reported elsewhere.[32] We used these data for calculating HWC costs and to derive the unit costs of treating diabetes or hypertension at HWCs (appendix pp 26–27).

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results

In the control scenario, the lifetime risk of developing prediabetes was estimated to be 57% (53–60), 44% (40–48) for diabetes, and 79% (77–81) for hypertension. The incidence of diabetes was estimated to be 0·027 (0·024–0·030) per person per year, with a mean age of diagnosis at 56 years. In the absence of screening, we estimated 5704 (5244–6296) cases of stroke, 22 324 (19 652–25 307) cases of myocardial infarction, 7332 (6341–8426) cases of end stage renal disease, 7584 (6275–9028) cases of amputation, and 3595 (2706–4589) cases of blindness due to diabetes or hypertension in the lifetime of 100 000 30-year-olds (appendix p 29).

With the implementation of population-based screening in the group aged between 30 and 65 years, annual screening led to an early detection of diabetes or hypertension that was 4·4 (95% CI 3·2–5·6 [data obtained from the probability sensitivity analysis]) years earlier than current practice (figure 1). Screening every 3 years led to a 3·0 (2·1–4·1) year early detection, and screening every 5 years led to a 2·1 (1·4–3·0) year early detection compared with current practice. Further, in a cohort of 100 000 30-year-olds, we estimated a reduction in cases of stroke ranging from 0·3% (n=18) to 4·4% (n=249), myocardial infarction from 0·2% (n=40) to 2·1% (n=470), end stage renal disease from 1·7% (n=124) to 19·3% (n=1415), amputation from 2·0% (n=151) to

	Number of complications averted (%)					Incremental health outcomes (2·5th and 97·5th percentiles)		
	Stroke	Myocardial infarction	End stage renal disease	Amputation	Blindness	Deaths averted	Life-years gained	QALYs gained
Annually	249 (4·4%)	470 (2·1%)	1415 (19·3%)	1666 (22·0%)	598 (16·6%)	1302 (923–1793)	5633 (3927–7871)	26 010 (11 625–37 855)
Every 3 years	109 (1·9%)	264 (1·2%)	790 (10·8%)	920 (12·1%)	352 (9·8%)	619 (401–935)	2644 (1707–3985)	12 012 (5308–19 054)
Every 5 years	72 (1·3%)	171 (0·8%)	504 (6·9%)	612 (8·1%)	232 (6·5%)	406 (255–626)	1725 (1075–2652)	7942 (3289–12 622)
Every 10 years	37 (0·6%)	71 (0·3%)	268 (3·7%)	321 (4·2%)	120 (3·3%)	211 (130–331)	888 (536–1404)	4173 (1459–6807)
Every 15 years	20 (0·4%)	52 (0·2%)	196 (2·7%)	246 (3·2%)	90 (2·5%)	155 (95–246)	669 (397–1065)	3141 (966–5142)
Every 20 years	18 (0·3)	40 (0·2%)	124 (1·7%)	151 (2·0%)	55 (1·5%)	96 (57–151)	387 (214–622)	1979 (306–3311)

QALY=quality-adjusted life-year.

Table 1: **Lifetime health outcomes of population-based screening compared with current practice for diabetes or hypertension in a cohort of 100 000 30 year olds, by frequency of screening**

22·0% (n=1666), and blindness from 1·5% (n=55) to 16·6% (n=598), between 20 year and annual screening frequencies (table 1, figure 2). The number of deaths averted were estimated to be highest with annual screening (1302 [923–1793] per 100 000 population), followed by screening every 3 years (619 [401–935] per 100 000 population), every 5 years (406 [255–626] per 100 000 population), and least with screening every 20 years (96 [57–151] per 100 000 population; table 1). Gains in life-years and QALYs are shown in table 1 and for alternative tests in the appendix (pp 29–33). The number of complications and health outcomes estimated for population-based screening in the group aged between 45 and 65 years are shown in the appendix (pp 42–46).

The lifetime cost incurred in current practice in a cohort of 100 000 30-year-olds was estimated to be 12 697 million INR (11 758 million–13 652 million), of which 0·85 million INR (0·67 million–1·05 million) was incurred on routine diagnosis (table 2). Among various screening scenarios by frequency, the cost of screening ranged from 7·0 INR million to 57·0 million INR, whereas treatment costs (including out-of-pocket expenditure) ranged from 12 936 million INR to 18 791 million INR. Findings on cost of additional strategies are provided in the appendix (pp 34–37). If the HWCs deliver the primary outpatient care for patients who are newly diagnosed with uncomplicated diabetes or hypertension, the total societal cost of annual screening and management would be 11 630 million INR ($166 million) in the scenario in which HWCs accounted for 70% of the treatment share and 18 262 million INR ($261 million) in the scenario in which HWCs account for 10% of the treatment share (appendix p 53).

The incremental cost per QALY gained with population-based screening was estimated to vary between 0·9 and 1·6 times India's per-capita GDP for the years 2018–19 (appendix p 53). This implied that, under the present scenario of care-seeking, even after accounting for different methods of detection, population age groups, and frequency of screening for diabetes and hypertension, screening was not cost-effective (appendix pp 38–41, 47–51). In the scenario in which HWCs provided primary care to 20% of patients who were newly diagnosed with uncomplicated diabetes or hypertension, screening the group aged between 30 and 65 years every 5 years or 3 years for either diabetes, hypertension, or comorbid (both diabetes and hypertension) became cost-effective against 1-time per capita GDP of India (table 3). If the coverage of treatment at HWCs increased to 70%, annual population-based screening became a cost saving strategy, with a reduction of 9·5% in out-of-pocket expenditure compared with current practice (appendix p 54).

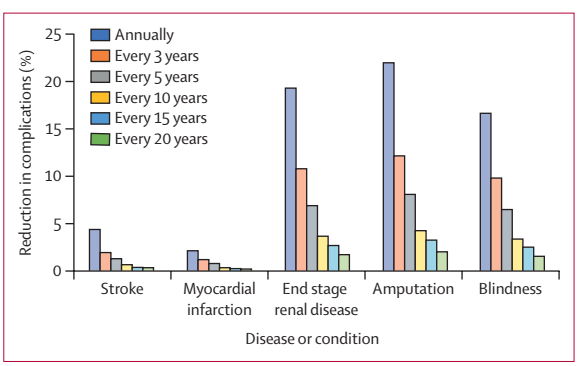

Figure 2: **Estimated percent reduction in complications using population-based screening for diabetes or hypertension in the group aged between 30 and 65 years**

The incremental cost per QALY gained was highly sensitive to change in HRQOL estimates for uncomplicated hypertension alone (–53·2% for lower limit and 15·9% for upper limit) and diabetes and hypertension (–41·2% for lower limit and 22·6% for upper limit). Probabilistic analysis showed that at current levels of health-care use, none of the population-based screening scenarios at alternate frequencies were cost-effective at a threshold of 1-time per capita GDP (for the years 2018–19) in India (figure 3). Even a screening strategy of once in 20 years had only a 60% probability to be cost-effective at a willingness to pay threshold of 1-time per capita GDP.

Discussion

To our knowledge, this is the first study to assess the cost-effectiveness of India's population-based screening

	Screening cost	Health system cost of treatment (uncomplicated cases)	Health system cost of treatment (complicated cases)	Out-of-pocket expenditure (uncomplicated cases)	Out-of-pocket expenditure (complicated cases)	Total cost
No screening	<1 INR (<1–1)*	2 INR (2–4)	631 INR (495–821)	169 INR (140–206)	11 884 INR (10 971–12 800)	12 697 INR (11 758–13 652)
Annually	57 INR (43–74)	116 INR (79–159)	512 INR (404–663)	8400 INR (6487–10 445)	9764 INR (8948–10 669)	18 848 INR (17 190–20 658)
Every 3 years	28 INR (21–37)	56 INR (38–80)	574 INR (452–741)	4161 INR (2984–5560)	10 776 INR (9921–11 674)	15 627 INR (14 349–17 002)
Every 5 years	19 INR (14–25)	38 INR (25–54)	593 INR (467–767)	2785 INR (1974–3794)	10 944 INR (10 098–11 810)	14 407 INR (13 295–15 546)
Every 10 years	11 INR (8–14)	21 INR (14–31)	611 INR (481–793)	1576 INR (1118–2157)	11 268 INR (10 409–12 160)	13 502 INR (12 518–14 500)
Every 15 years	8 INR (6–11)	15 INR (10–22)	616 INR (484–800)	1151 INR (829–1563)	11 354 INR (10 497–12 250)	13 147 INR (12 200–14 072)
Every 20 years	7 INR (5–9)	11 INR (8–6)	622 INR (489–808)	839 INR (620–1132)	11 464 INR (10 602–12 354)	12 953 INR (11 985–13 878)

Values are total lifetime cost per 100 000 population, in INR, millions, with 2.5th to 97.5th percentiles shown. INR=Indian National Rupees. *This represents the costs of current system of incidental screening done in response to symptomatic health complaints. Values are generated from probabilistic sensitivity analysis, and individual components sum might not add up to the overall total cost.

Table 2: **Estimates of costs (base case model) by frequencies of screening.**

	Annual screening	Screening every 3 years	Screening every 5 years	Screening every 10 years	Screening every 15 years	Screening every 20 years
Current	234 491 INR	237 742 INR	210 905 INR	188 201 INR	144 252 INR	128 433 INR
10%	210 543 INR	196 134 INR	151 916 INR	84 373 INR	7260 INR	−90 989 INR
20%	168 561 INR	123 968 INR	52 547 INR	−91 411 INR	−223 069 INR	−456 933 INR
30%	126 580 INR	51 802 INR	−46 823 INR	−267 195 INR	−453 398 INR	−822 877 INR
40%	84 599 INR	−20 364 INR	−146 192 INR	−442 978 INR	−683 727 INR	−1 188 821 INR
50%	42 618 INR	−92 530 INR	−245 561 INR	−618 762 INR	−914 057 INR	−1 554 765 INR
60%	637 INR	−164 696 INR	−344 931 INR	−794 546 INR	−1 144 386 INR	−1 920 709 INR
70%	−41 345 INR	−236 862 INR	−444 300 INR	−970 329 INR	−1 374 715 INR	−2 286 653 INR

INR=Indian National Rupees. QALY=quality-adjusted life-year.

Table 3: **Cost-effectiveness of screening for diabetes or hypertension with strengthening of comprehensive primary care, by proportion of diagnosed patients treated at health and wellness centres; values are incremental cost, in INR, per QALY gained**

programme for diabetes and hypertension as part of a national health programme. Overall, we found that population-based screening for diabetes or hypertension alone was not cost-effective at any screening frequency. However, linking the provision of treatment for patients with newly diagnosed uncomplicated diabetes or hypertension at HWCs by strengthening comprehensive primary health care will make screening for these conditions more cost-efficient in Indian contexts; a direction that is also in line with India's national policies.

The Government of India's Ayushman Bharat Health and Wellness Centre programme aims to expand primary care for diabetes and hypertension through the transformation of 150 000 subcentres and primary health centres to HWCs.[7] As of 2016 (the latest available data), 3·8% of patients with diabetes or hypertension access care at subcentres and primary health care levels.[9] A pilot programme in the southern state of Tamil Nadu showed that strengthening these facilities led to a 15–23% increase in their use and decline in extent of out-of-pocket expenditures at the HWC level.[33] Our analysis also showed that shifting the provision of primary care for patients with diabetes or hypertension to HWCs could make population-based screening cost-effective. An increase in HWC share for provision of primary care for patients with diabetes or hypertension to 70%, from the existing 3·8% at subcentres and primary health centres, makes an annual population-based screening a cost saving strategy.

At present, few studies have estimated the cost-effectiveness of population-based screening for diabetes or hypertension.[6] Our findings indicated that screening annually, every 3 years, and every 5 years led to an earlier detection of diabetes and hypertension compared with current practice (figure 1). These findings are somewhat lower than another modelled economic analysis[2] that considered facility-based screening for patients with diabetes or hypertension in the USA. This difference could possibly be attributed to the higher screening coverage and smaller number of dropouts for confirmatory tests with the use of facility-based setting of screening in the study done in the USA.

We found a 12% reduction in the incidence of complications for both diabetes and hypertension with annual screening. However, this risk reduction was found to be higher for microvascular rather than macrovascular complications, as noted in other epidemiological[34] and economic[2,35] analyses. At the population level, we found a gain of 0·05 life-years per person with annual screening, which was higher than that reported in another study[3] in which one-off screening for diabetes or hypertension was evaluated. In an

evaluation for facility-based screening for diabetes or hypertension,[2] a gain of 0·17 QALYs was reported for every 3 year screening at age 30 years, which was similar to the 0·12 QALYs reported in our study.

Our modelled estimate of diabetes incidence in the routine care scenario (0·027 per person per year) was in line with other Indian cohort studies on diabetes.[14,36–38] The predicted life expectancy based on our model (42·2 years) approximated the reported average life expectancy at 30 years in India by the sample registration system (43·3 years).[20] An Indian study published in 2021 estimated lifetime risk of diabetes at the age of 20 years stratified by body-mass index from metropolitan cities as 64·6% (95% CI 60·0–69·5) for women and 55·5% (51·6–59·7%) for men.[39] Our modelled lifetime risk for hypertension was lower (79% [77·0–81·0]) than another study[40] (90% [87·0–93·0]) for men and 89% [86·0–92·0] for women), which was justifiable given the fact that the population of interest was aged between 55 and 65 years in the latter study.

Our cost-effectiveness model has several merits. A comprehensive search and meta-analysis were done to estimate the diagnostic accuracy for screening tests in previously undiagnosed patients with diabetes without complications. A previous systematic review[41] on health economic analyses used for evaluating screening programmes for diabetes reported that 48% of the studies included did not consider sensitivity and specificity parameters. Few economic analyses[2,35] had assumed 100% performance and compliance of tests. Our approach incorporated a more pragmatic, real-world consideration of programme effectiveness. We also included a cascade of care, including measuring loss to follow-up at diagnosis and treatment, and hence were less likely to have overestimated the benefits. The cost of screening, treatment of disease and its complications, and quality of life were based on locally collected primary data or data from the national database and pan-India Cost of Health Services in India study.[25,27]

Our study had some limitations. Firstly, the probabilities of developing macrovascular complications were derived from international literature because of a scarcity of risk data for India. More research is needed to generate evidence on age-specific incidence for multiple complications in patients with diabetes or hypertension in Indian populations. Secondly, a scarcity of evidence for lifetime risks of complications in patients with diabetes or hypertension in Indian populations rendered the validation of these model estimates difficult. We suggest more long-term follow-up studies or registries to capture this evidence in Indian contexts as a key future area of research.

In line with recommendations for Indian guidelines, we did not consider productivity losses for patients with and without complications because of the potential for double counting when measuring utility.[8] Thirdly, a scarcity of data for cause-specific mortality (per 1000 general population) for individual complications, and attributable risk for such complication-specific mortality, precluded the adjustment of disease-specific mortality in our all-cause risk of mortality. More robust mortality statistics, which have also been cited by others,[42] is an important area for such modelling studies. Lastly, assured provision of services at HWCs has been shown to lead to higher use and better patient attendance, even in the short term.[43] Hence, such an increase in share of treatment at HWCs, as assumed in our analysis, is plausible in future. However, given current cascade of care and care seeking behaviour, any further increases in share of treatment at HWCs is likely to be achieved over a longer timeframe.

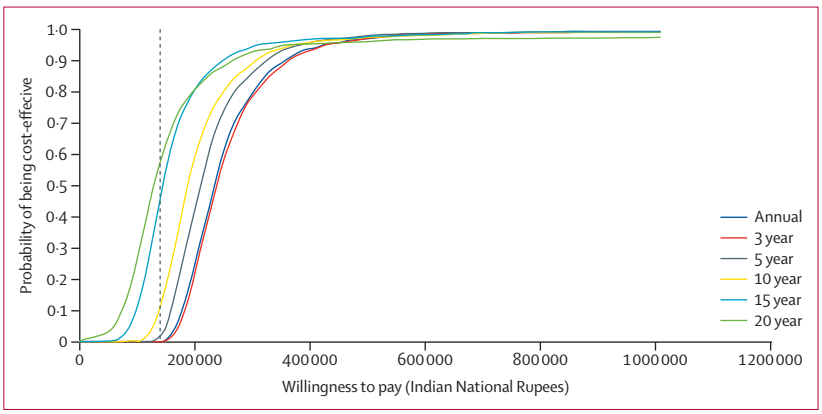

Figure 3: **Cost-effectiveness acceptability curves for screening strategies in the base case model**
The dotted black line indicates 1-time per capita GDP for 2018–19 India. The curves depict estimated probabilities, based on probabilistic sensitivity analysis, for various frequencies of screening to be cost-effective against willingness to pay thresholds. GDP=gross domestic product.

Our findings indicate that with current patterns of health-care use, population level screening of diabetes and hypertension is not cost-effective. However, increasing the share of use for the treatment of diabetes and hypertension at HWCs is a potential strategy to make population-based screening cost-effective. Population-based screening combined with greater use of HWCs for treatment could also reduce out-of-pocket expenditure and improves financial risk protection. Evidence suggests that the inequalities in use of health services are lowest at primary health-care facilities, which are mostly located in rural and relatively remote areas.[44–46] Secondly, the extent of unmet need for both diagnosis and treatment of diabetes or hypertension is higher in the poorest and most rural populations in India.[19,47] Hence, linking the screening and treatment of diabetes or hypertension with comprehensive primary health care at HWCs, is likely to improve the equity of service use and, consequently, health outcomes. A well organised primary health-care system also offsets the unmet need for care and reduces out-of-pocket expenditures.[33]

Contributors

The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

SP, GK, and ASC verified the underlying data and that all authors had access to the underlying data. SP, GK, YT, ASC, GJ, MM, AB, SJ, and AG conceptualised the study. GK, ASC, SP, GJ, MM, and KN curated the data. GK, SP, ASC, YT, GJ, MM, KN, AR, AB, and SJ formally analysed the data. SP, MM, and KN were responsible for acquiring the funding, resources, and project administration. SP, GK, ASC, MM, and KN were involved in the data collection of the study. All authors contributed equally to designing the methodology of the study and visualisation (ie, the graphs and figures) of findings. GK, ASC, and GJ were involved in the software used in the study. SP, YT, PVML, AB, and SJ were responsible for supervision of data collection and analysis. GK, ASC, SP, AR, YT, AB, SJ, JMS, and AG were involved in validating the study. GK, SP, and YT wrote the original draft. All authors contributed equally to writing, reviewing, and editing the manuscript.

Declaration of interests

We declare no competing interests.

Data sharing

The relevant data are available in the manuscript and the appendix. Data that are not presented in the article or appendix are available upon reasonable request from the corresponding author.

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