Forecasting vascular disease cases and associated mortality in India

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The mandate was to forecast cases with cardiovascular disease (CVD) and associated mortality in India through the year 2015 at 5-year intervals. A break-up of forecasts in age/gender/urban/rural categories was desirable and State-wise projections were expected. This exercise is based on the data gathered and supplied by Centre for Chronic Disease Control (CCDC), New Delhi. These voluminous data lack State-wise details, which rendered the ideal unattainable and even cross-classification by age, gender and area became difficult. Recent data were even more scanty. We made the best use of whatever data were supplied to us. Limitations of our estimates are stated at the end of this paper. However, we expect our estimates to be not far from reality.

Nobody doubts that cases of CVD would rapidly increase in India during the next few years. This increase is attributable to (i) sheer increase in the population size due to natural growth, (ii) ageing of the population which makes people more vulnerable to chronic diseases, and (iii) increased vulnerability due to lifestyle changes that promote CVD. The first would happen in any case, and the second would operate even if age–gender-specific prevalence rates remain the same. The third would manifest in terms of higher age–gender-specific rates if people tend to become more obese, consume more calories, eat more processed food, take more salt or a high carbohydrate diet which can increase cholesterol and blood pressure levels, adopt a more sedentary lifestyle, smoke more, etc. Many more would get diabetes (*see* Appendix 1) which in turn is a strong risk factor for CVD. One factor that is generally ignored is the stress level that acts as a twin-edged sword. Poverty and ignorance can make life difficult and stressful for the deprived, and development coupled with urbanization and vanishing family security can bring its own set of problems.

Methodology

The first approach to forecasting is to estimate the increase in risk due to apprehended changes in lifestyle and other factors, and impute this increase to forecast prevalence estimates. This requires a study of past trends in vulnerability factors. According to Singh and Sen (2003), the risk factors for coronary heart disease (CHD) are a formidable list: obesity, a sedentary lifestyle, smoking, hypertension, high low-density lipoprotein (LDL), low high-density lipoprotein (HDL), diabetes, insulin resistance, triglycerides, lipoprotein (a) (Lp[a]), homocysteine, fibrinogen, HbA1c, albumin, etc.

Although an equation linking the risk of CHD with some of its risk factors is available from the Framingham study (Wilson *et al.* 1998), this is for individuals and cannot be easily used for the present exercise. In fact, the risk factor approach to forecasting requires a study of past trends in various risk factors and an assumption that the same trend would continue. This also requires the presence of a relationship between disease prevalence and risk factors, which itself would be subject to much uncertainty. In addition, the data supplied to us on various risk factors were inadequate for this approach. Lack of data can be misleading and validity would suffer. Also, the foregoing list is restricted to the known factors. Many factors affecting the vulnerability to CHD are unknown. Therefore we adopted the second approach based on trends in prevalences to get more valid projections. This second approach is to use previous trends in age–gender–area-specific prevalence rates and project it to the future. This trend automatically takes care of the trend in the conglomerate of risk factors. This approach obviates the need to know the relationship between risk factors and prevalence. The projected age–gender–area-specific rates are used on the estimated age–gender–area-specific population to get the projected number of cases. This approach assumes that both vulnerability factors and preventive strategies would continue to rise in the same fashion as before. Thus, the decelerating effect of positive changes in lifestyle and other factors is also in-built. Boyle *et al.* (2001) used this approach to project cases of diabetes in the US through the year 2050.

Age–gender–area-wise population projection

India seems to be all set for a demographic transition. Life expectancy is increasing primarily due to a decline in infant mortality but the adult mortality is also declining as chronic

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Why the Framingham equation cannot be easily used in this work

Wilson *et al*. (1998) developed the following equation that links the risk for coronary heart disease (CHD) with its factors:

$$P = 1 - S(t)^{\exp[f(x,M)]},$$

where $f(x,M) = \beta_1(x_1 - M_1) + \beta_2(x_2 - M_2) + \ldots + \beta_p(x_p - M_p)$; $x_1, x_2, \ldots, x_p$ are scores for the presence of risk factors in the individual; $M_1, M_2, \ldots, M_p$ are mean values of the risk factors in the group; and S(t) is 10-year survival rate at these mean values. The equation estimates P which is 10-year risk for CHD. This equation has the following features:

1. The risk factors considered are age, smoking (yes/no), diabetes, blood pressure category, total cholesterol category, low density lipoprotein (LDL)-C category and high density lipoprotein (HDL)-C category. Many risk factors have not been incorporated.
2. The area under the curve is in the range of 0.75. Thus, there is an inherent uncertainty to the extent of 25%. This kind of uncertainty is a necessary component of any model but here it is rather high. This implies that the predictivity of the model is low.
3. The equation is useful for predicting the risk of CHD in *individual* subjects whose status with regard to the seven risk factors is known. The presence of various risk factors in individual subjects is assessed against the mean presence in the group to which the individual belongs (*see* f(x,M)). Although the equation can be used for say, each age group, it looks stretching it too much.
4. The equation cannot be directly used in other countries. It requires recalibration for local set-up. For this, data on the risk factors and 10-year survival rate are required for a large group of local subjects. These are not available.

For the reasons enumerated above, the equation is unsuitable in the present exercise on CHD projection at the national level.

diseases are replacing infectious diseases. The age–gender-wise projections for each year till 2016 are available in a report of the Registrar General of the Government of India (1996). The gross picture of the trend in population is shown in Fig. 1. Those in the age group of 60+ years will face the major onslaught of CVDs.

We could not locate the rural–urban break-up of the projected age-wise population anywhere. Since the prevalence of CVD is very different in rural areas compared with urban areas, this break-up is important for forecasting because urbanization is occurring rapidly. We captured the linear trend

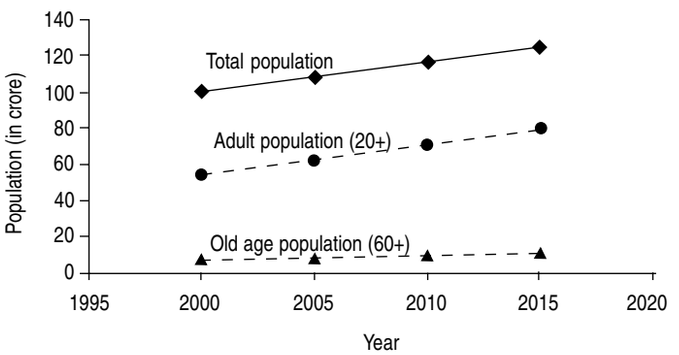

Fig. 1 Projected trends in population

Source: Report of the Registrar General of India 1996

in rural–urban ratio from the data of three censuses (1971, 1981 and 1991) and from the Sample Registration System (SRS) for the year 2000. We used this trend to forecast the ratio in the years 2005, 2010 and 2015. This was done separately for each age group and gender as shown in Fig. 2. The value of R^2 is more than 80% in 9 out of 10 age–gender groups, and the projections looked realistic. The projected rural–urban ratio so obtained was used on the projected population to get the rural–urban break-up of population in different age–gender groups. The population and the age–gender–area-wise break-up is given in Table 1.

Projection of cases

Trends in the prevalence of coronary heart disease

Coronary heart disease is the predominant CVD. CHD includes conditions such as cardiomyopathies, acute MI, angina pectoris, congestive heart failure and inflammatory heart disease (these are not necessarily mutually exclusive terms). Some useful data are available for CHD. Although longitudinal data from community-based studies from several places were desirable, they are not available. Hospital-based data were not useful in the present exercise because of their high selectivity. When the place is ignored, 4–5 points of data on prevalence rate were available for each of the age–gender groups in urban areas, and to a lesser degree in rural areas. The age groups we chose were 20–29, 30–39, …, 60–69 years. Wherever the reported age groups did not match exactly with these intervals, the data were put into the nearest group. When prevalence from some studies was available separately for 5-yearly intervals such as 30–34 and 35–39, the average was used for 30–39 years. These prevalences were used to fit a linear trend. Although a curvilinear trend is plausible, the data were inadequate to try this. Statistically, forecasting for 15 years on the basis of trend in the past 15 years is not a wise proposition. Yet, it is better to have something rather than nothing. Our experience suggests that forecasting on the basis of such scanty data may not be a worthless exercise although it has obvious limitations.

The CHD prevalence trends for various age–gender groups in urban areas are given in Fig. 3 and in rural areas in Fig. 4. For an exercise such as this, when the data are highly fluctuating and scanty, we did not consider it necessary to test the statistical significance of the trend (*Note*: The NCMH Expert Group was of the opinion that the exercise be redone after deleting one data point relating to the year 1974 that might be pushing the estimates upwards. This has been done and reported in Appendix 2, where we found that when that data point was deleted, the estimates of CHD caseload increased further).

Whereas the trend apparently looked fine for all age–gender groups in urban areas, there was only one data point for the 20–29 years age group (males as well as females) in rural areas (Fig. 4). We assume that the prevalence in

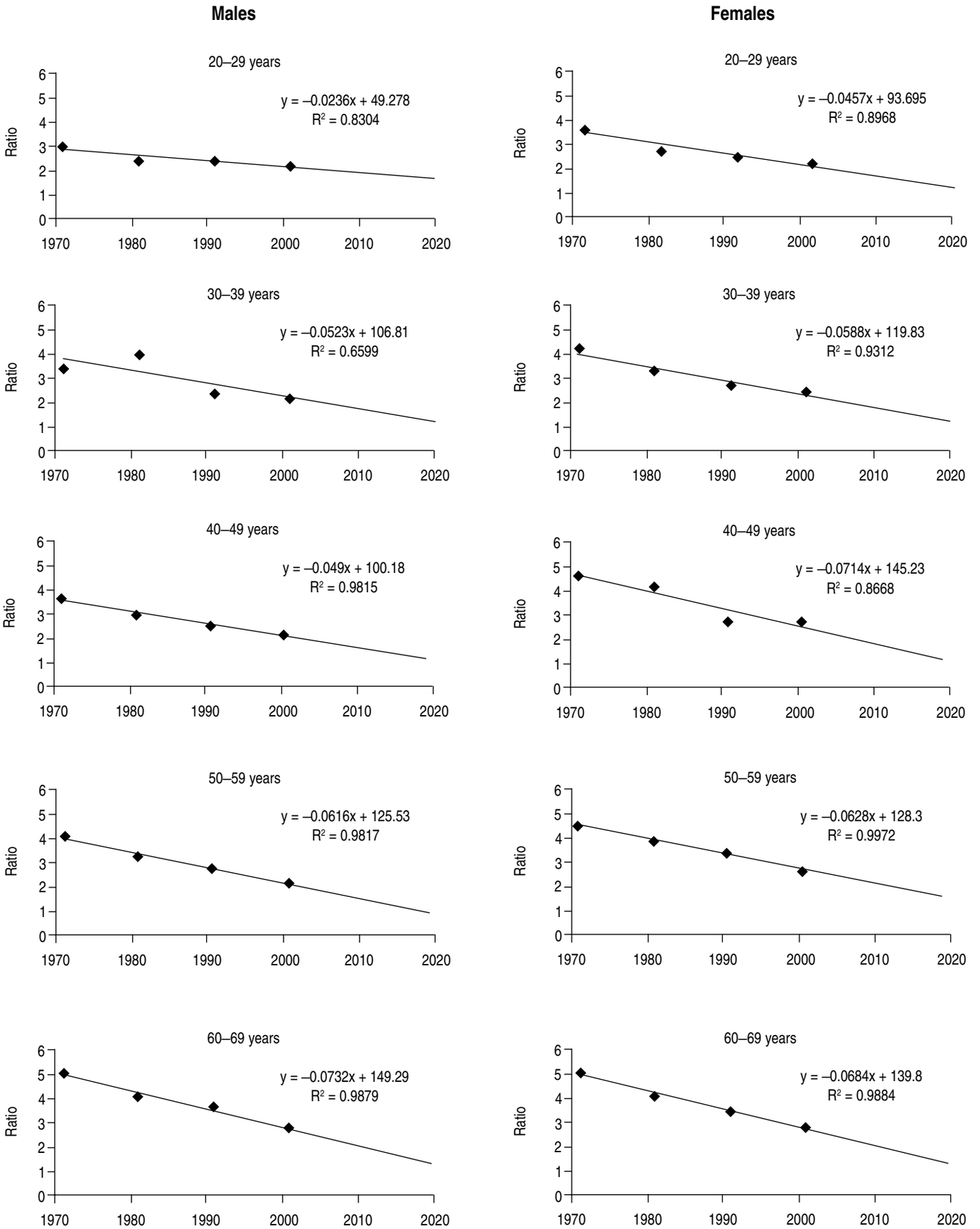

Fig. 2 Trends in rural–urban ratio in male and female populations

Sources of data: Indian Census 1971, 1981, 1991 and Sample Registration System (SRS) Survey 2000

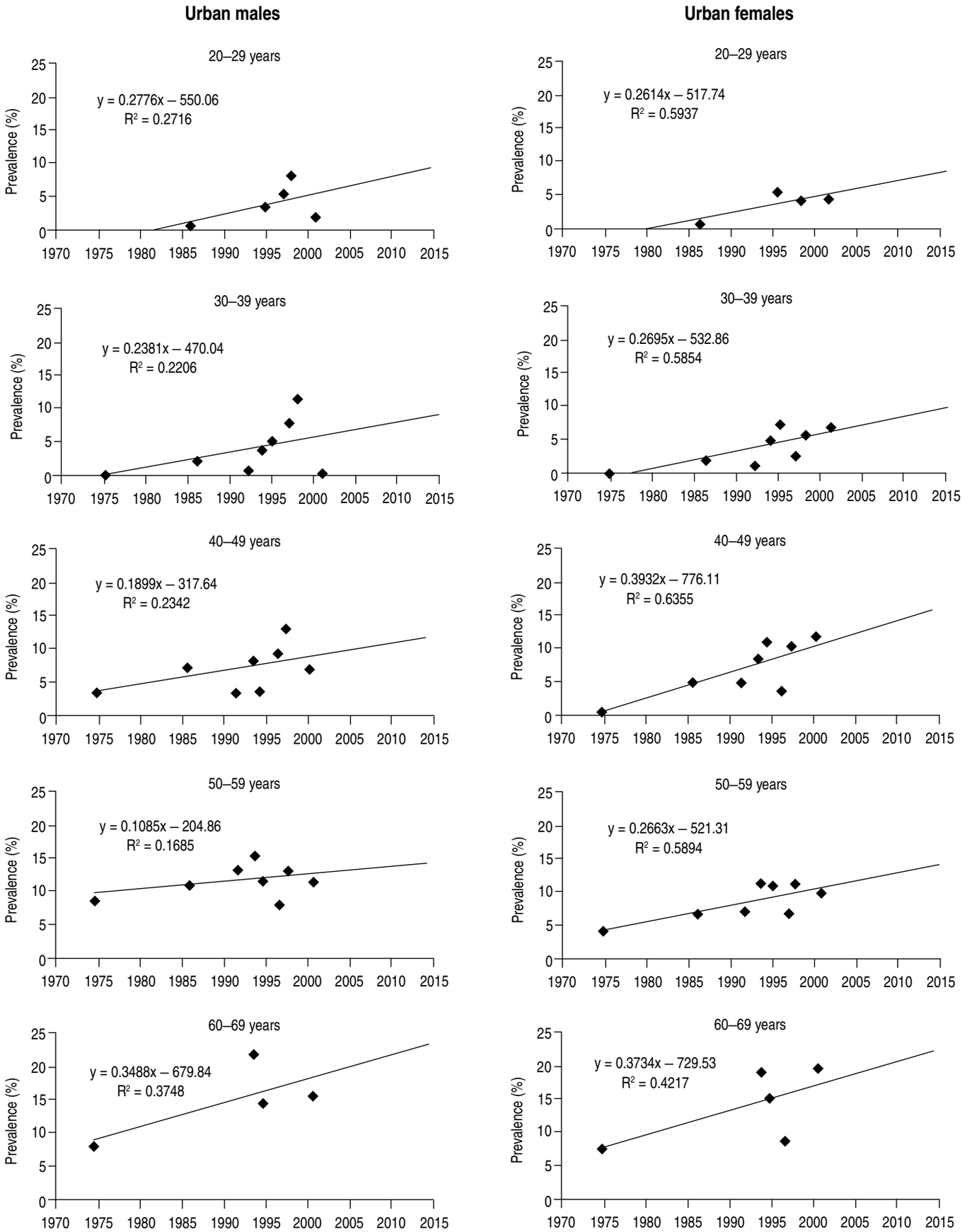

Fig. 3 Trends in CHD prevalence—Urban

Source of data: Centre for Chronic Disease Control

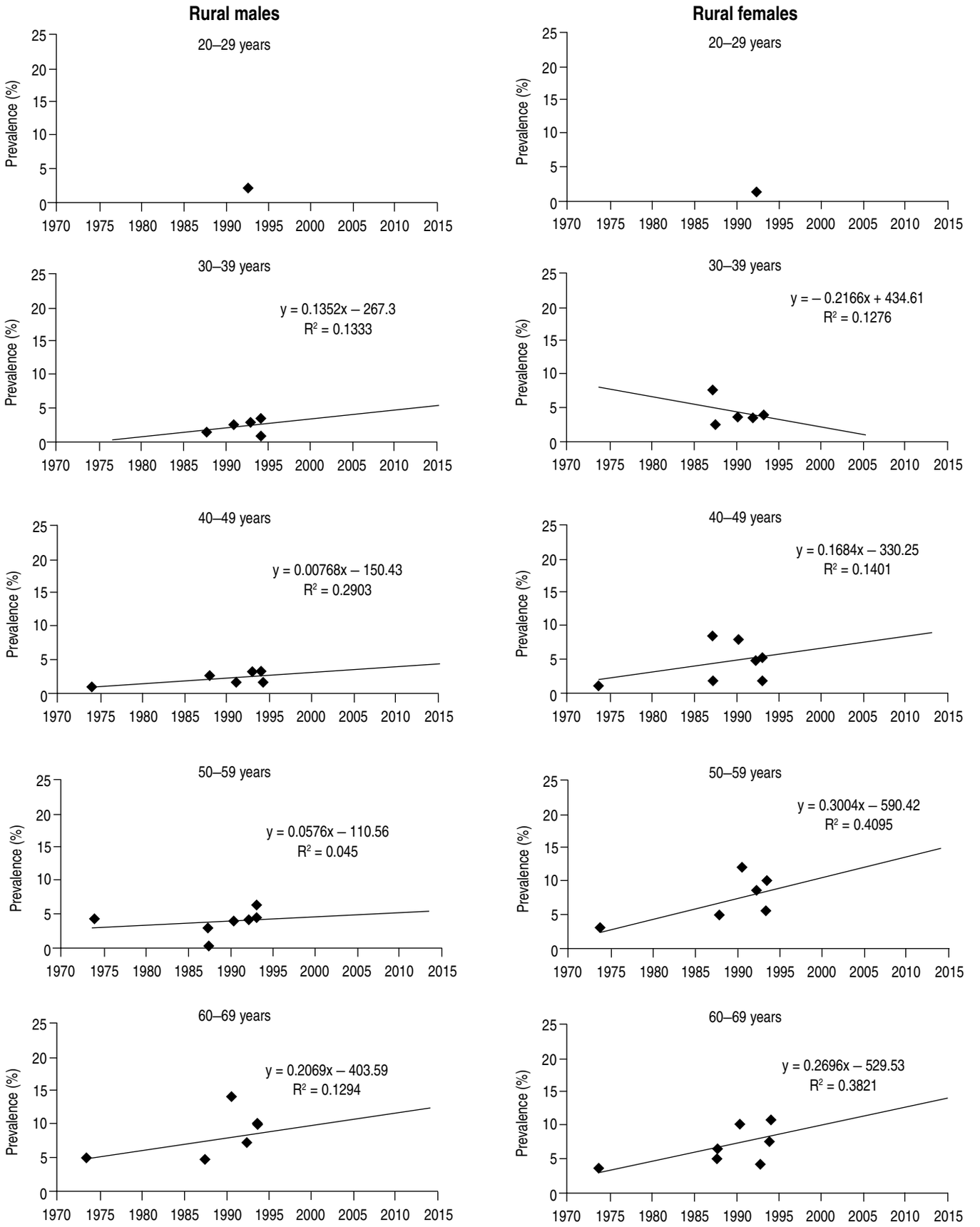

Fig. 4 Trends in CHD prevalence—Rural

Source of data: Centre for Chronic Disease Control

Table 1. Projected population of India by age, sex and area

Year/age	Population			Projected population			Rural–urban ratio (calculation from census)		By multiplication			
									Rural		Urban	
group	Both sexes	Male	Female	Age	Male	Female	Male	Female	Male	Female	Male	Female
2000												
0–4	110,298,000	56,527,000	53,771,000	20–29	87,138,000	81,813,000	2.078	2.295	58,828,058	56,983,561	28,309,942	24,829,439
5–9	119,711,000	61,155,000	58,557,000	30–39	69,778,000	68,176,000	2.210	2.230	48,040,305	47,068,879	21,737,695	21,107,121
10–14	122,401,000	63,574,000	58,827,000	40–49	53,059,000	47,182,000	2.180	2.430	36,373,780	33,426,315	16,685,220	13,755,685
15–19	105,816,000	56,107,000	49,709,000	50–59	36,011,000	31,972,000	2.330	2.700	25,196,886	23,330,919	10,814,114	8,641,081
20–24	88,178,000	46,387,000	41,792,000	60–69	21,785,000	20,697,000	2.890	3.000	16,184,743	15,522,750	5,600,257	5,174,250
25–29	80,772,000	40,751,000	40,021,000	70+	13,471,000	12,835,000						
30–34	73,997,000	36,944,000	37,053,000	Others	237,363,000	220,864,000						
35–39	63,957,000	32,834,000	31,123,000	Total	518,605,000	483,539,000						
40–44	54,712,000	28,865,000	25,847,000									
45–49	45,528,000	24,194,000	21,335,000									
50–54	37,839,000	20,069,000	17,769,000									
55–59	30,144,000	15,942,000	14,203,000									
60–64	23,594,000	12,179,000	11,415,000									
65–69	18,888,000	9,606,000	9,282,000									
70–74	12,576,000	6,411,000	6,165,000									
75–79	7,653,000	3,892,000	3,760,000									
80+	6,078,000	3,168,000	2,910,000									
Total	1,002,142,000	518,604,000	483,538,000									
2005												
0–4	112,341,000	57,821,000	54,519,000	20–29	101,923,000	91,038,000	1.960	2.067	67,489,554	61,350,082	34,433,446	29,687,918
5–9	107,964,000	55,275,000	52,688,000	30–39	76,996,000	76,480,000	1.949	1.936	50,882,383	50,430,954	26,113,617	26,049,046
10–14	118,498,000	60,492,000	58,007,000	40–49	60,491,000	56,148,000	1.935	2.073	39,880,779	37,876,604	20,610,221	18,271,396
15–19	121,992,000	63,340,000	58,652,000	50–59	42,067,000	37,716,000	2.022	2.386	28,146,749	26,577,193	13,920,251	11,138,807
20–24	105,300,000	55,822,000	49,478,000	60–69	24,745,000	23,191,000	2.524	2.658	17,723,150	16,851,197	7,021,850	6,339,803
25–29	87,661,000	46,101,000	41,560,000	70+	15,708,000	15,471,000						
30–34	80,187,000	40,437,000	39,750,000	Others	236,928,000	223,866,000						
35–39	73,289,000	36,559,000	36,730,000	Total	558,858,000	523,910,000						
40–44	63,074,000	32,325,000	30,750,000									
45–49	53,565,000	28,166,000	25,398,000									
50–54	43,996,000	23,247,000	20,749,000									
55–59	35,787,000	18,820,000	16,967,000									
60–64	27,532,000	14,387,000	13,145,000									
65–69	20,404,000	10,358,000	10,046,000									
70–74	15,212,000	7,580,000	7,632,000									
75–79	8,735,000	4,373,000	4,361,000									
80+	7,232,000	3,755,000	3,478,000									
Total	1,082,768,000	558,857,000	523,911,000									
2010												
0–4	120,292,000	61,741,000	58,551,000	20–29	118,496,000	107,566,000	1.842	1.838	76,801,419	72,488,224	41,694,581	35,077,776
5–9	109,763,000	56,381,000	53,383,000	30–39	85,786,000	80,684,000	1.687	1.642	53,859,688	53,203,074	31,926,312	27,480,926
10–14	106,819,000	54,715,000	52,104,000	40–49	67,596,000	66,530,000	1.690	1.716	42,467,375	44,880,146	25,128,625	21,649,854
15–19	117,994,000	60,217,000	57,776,000	50–59	48,972,000	44,577,000	1.714	2.072	30,927,785	31,411,908	18,044,215	13,165,092
20–24	121,384,000	63,016,000	58,368,000	60–69	29,364,000	27,395,000	2.158	2.316	20,065,710	19,133,540	9,298,290	8,261,460
25–29	104,678,000	55,480,000	49,198,000	70+	18,026,000	18,203,000						
30–34	87,032,000	45,755,000	41,278,000	Others	351,550,000	329,380,000						
35–39	79,437,000	40,031,000	39,406,000	Total	601,294,000	566,769,000						
40–44	72,318,000	36,019,000	36,299,000									
45–49	61,808,000	31,577,000	30,231,000									
50–54	51,844,000	27,116,000	24,729,000									
55–59	41,704,000	21,856,000	19,848,000									
60–64	32,800,000	17,045,000	15,755,000									
65–69	23,959,000	12,319,000	11,640,000									

(*Cont.*)

Table 1 (*cont.*) Projected population of India by age, sex and area

Year/age group	Population			Projected population			Rural/urban ratio (calculation from census)		By multiplication			
									Rural		Urban	
	Both sexes	Male	Female	Age	Male	Female	Male	Female	Male	Female	Male	Female
70–74	16,363,000	8,133,000	8,230,000									
75–79	11,046,000	5,414,000	5,632,000									
80+	8,820,000	4,479,000	4,341,000									
Total	1,168,062,000	601,293,000	566,769,000									
2015												
0–4	122,690,000	63,068,000	59,622,000	20–29	122,622,000	115,633,000	1.724	1.610	77,606,581	71,320,680	45,015,419	44,312,320
5–9	116,840,000	60,002,000	56,838,000	30–39	100,449,000	89,877,000	1.426	1.348	59,035,271	51,598,891	41,413,729	38,278,109
10–14	109,478,000	56,193,000	53,286,000	40–49	74,738,000	74,734,000	1.445	1.359	44,170,311	43,053,627	30,567,689	31,680,373
15–19	106,349,000	54,467,000	51,882,000	50–59	56,044,000	53,216,000	1.406	1.758	32,750,567	33,920,859	23,293,433	19,295,141
20–24	117,490,000	59,947,000	57,543,000	60–69	34,547,000	32,535,000	1.792	1.974	22,173,433	21,595,188	12,373,567	10,939,812
25–29	120,766,000	62,675,000	58,090,000	70+	20,909,000	21,181,000						
30–34	104,021,000	55,108,000	48,913,000	Others	233,730,000	221,628,000						
35–39	86,305,000	45,341,000	40,964,000	Total	643,039,000	608,804,000						
40–44	78,482,000	39,489,000	38,993,000									
45–49	70,990,000	35,249,000	35,741,000									
50–54	59,960,000	30,468,000	29,492,000									
55–59	49,299,000	25,576,000	23,724,000									
60–64	38,379,000	19,875,000	18,504,000									
65–69	28,703,000	14,672,000	14,031,000									
70–74	19,446,000	9,807,000	9,639,000									
75–79	11,948,000	5,801,000	6,147,000									
80+	10,696,000	5,301,000	5,395,000									
Total	1,251,841,000	643,037,000	608,804,000									

Note: Differences in some totals are due to rounding off

Source: Registrar General of India 1996

this age group will remain unchanged from this value till the year 2015 in rural areas.

In rural females, in the 30–39 years age group, the trend shows a decline and approaching zero prevalence. Since this does not seem plausible, we assume that the rate last seen would remain constant till the year 2015.

The projected prevalence rates of CHD in India in different age–gender groups in urban and rural areas are given in Table 2. The assumption is that they too follow the past trends. The prevalence in rural areas is much lower than that in urban areas, and is not much different among males and females.

The ICMR Task Force project reported for 1991–94 a prevalence of 23.2% in urban males in Delhi in the 60–64 years age group based on the history and ECG evidence, which is unusually high. This could be because CHD includes angina pectoris, which is quite common, and also includes CHD arising from conditions such as diabetes and hypertension. Another explanation of such a high projection could be the indiscriminate eating and exercise habits of the younger generation. A recent study in Delhi found that 1 in 4 adolescents and young adults suffers from insulin intolerance, which predisposes to diabetes and subsequent coronary conditions, and 1 in 8 has a high level of C-reactive

Table 2. Forecasting the prevalence rate (%) of coronary heart disease (CHD) in India

Year	Area	20–29 years		30–39 years		40–49 years		50–59 years		60–69 years	
		Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
2000	Urban	5.14	5.06	6.16	6.14	8.16	10.29	12.14	11.29	17.76	17.27
	Rural	1.80	1.30	3.10	2.90	3.17	6.55	4.64	10.38	10.21	9.67
2005	Urban	6.53	6.37	7.35	7.49	9.11	12.26	12.68	12.62	19.50	19.14
	Rural	1.80	1.30	3.78	2.90	3.55	7.39	4.93	11.88	11.24	11.02
2010	Urban	7.92	7.67	8.54	8.84	10.06	14.22	13.23	13.95	21.25	21.00
	Rural	1.80	1.30	4.45	2.90	3.94	8.23	5.22	13.38	12.28	12.37
2015	Urban	9.30	8.98	9.73	10.18	11.01	16.19	13.77	15.28	22.99	22.87
	Rural	1.80	1.30	5.13	2.90	4.32	9.08	5.50	14.89	13.31	13.71

Table 3a. Forecasting the number of male and female cases of coronary heart disease (CHD) in India

	20–29 years		30–39 years		40–49 years		50–59 years		60–69 years		Total	
Year/area	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
2000												
Urban	1,455,131	1,256,370	1,339,042	1,295,977	1,361,514	1,415,460	1,312,833	975,578	994,606	893,593	6,463,126	5,836,978
Rural	1,058,905	740,786	1,489,249	1,364,997	1,153,049	2,189,424	1,169,136	2,421,749	1,652,462	1,501,050	6,522,801	8,218,007
Total	2,514,036	1,997,156	2,828,291	2,660,975	2,514,563	3,604,884	2,481,969	3,397,327	2,647,068	2,394,643	12,985,927	14,054,985
2005												
Urban	2,247,815	1,890,230	1,919,481	1,950,422	1,877,488	2,239,342	1,765,436	1,405,885	1,369,542	1,213,248	9,179,762	8,699,127
Rural	1,214,812	797,551	1,921,319	1,462,498	1,417,363	2,799,839	1,387,072	3,157,902	1,992,880	1,856,665	7,933,445	10,074,454
Total	3,462,627	2,687,781	3,840,800	3,412,920	3,294,851	5,039,181	3,152,508	4,563,787	3,362,421	3,069,913	17,113,207	18,773,581
2010												
Urban	3,300,543	2,691,869	2,726,826	2,427,940	2,527,688	3,079,042	2,386,347	1,836,925	1,975,701	1,735,237	12,917,106	11,771,013
Rural	1,382,426	942,347	2,397,833	1,542,889	1,672,365	3,695,431	1,613,193	4,204,170	2,463,869	2,366,054	9,529,686	12,750,891
Total	4,682,969	3,634,215	5,124,660	3,970,829	4,200,054	6,774,473	3,999,541	6,041,095	4,439,569	4,101,291	22,446,792	24,521,903
2015												
Urban	4,188,235	3,979,689	4,030,177	3,897,668	3,365,044	5,128,419	3,206,923	2,949,166	2,844,931	2,502,044	17,635,310	18,456,987
Rural	1,396,918	927,169	3,027,329	1,496,368	1,909,041	3,907,547	1,802,591	5,049,459	2,952,060	2,961,564	11,087,939	14,342,107
Total	5,585,153	4,906,858	7,057,506	5,394,036	5,274,085	9,035,966	5,009,515	7,998,625	5,796,991	5,463,608	28,723,249	32,799,094

protein that increases the risk of heart disease later in life (HT 2004). Our projections based on trends in prevalences have an inbuilt provision to take care of such changes.

Using these projected prevalence rates onto the projected population gives the number of cases as shown in Tables 3a and b. The estimate for the year 2000 is nearly 2.7 crore cases of CHD which more than doubles to nearly 6.1 crore cases in the year 2015. The pattern across age groups is nearly the same (Fig. 5). More than half of this rise can be ascribed to demographic changes but the contribution of increased prevalence of risk factors is also substantial.

Trends in the prevalence of other cardiovascular diseases

Appropriate area–gender-wise data are not available for stroke, rheumatic heart disease (RHD) and congenital heart disease. Age group-wise information is available only for stroke. Since RHD is primarily a disease of childhood and congenital heart disease is seen in infants, some workable projections could still be obtained. In the absence of any worthwhile information, it would be statistically incorrect to interpolate to males–females and rural–urban areas, and to younger age groups.

Trends in the prevalence of stroke revealed by various

Table 3b. Forecasting the number of cases (males and females) of coronary heart disease (CHD) in India

Year/area	20–29 years	30–39 years	40–49 years	50–59 years	60–69 years	Total
2000						
Urban	2,711,501	2,635,019	2,776,974	2,288,412	1,888,199	12,300,104
Rural	1,799,691	2,854,247	3,342,472	3,590,885	3,153,512	14,740,808
Total	4,511,192	5,489,266	6,119,446	5,879,296	5,041,711	27,040,912
2005						
Urban	4,138,045	3,869,904	4,116,830	3,171,320	2,582,790	17,878,889
Rural	2,012,363	3,383,816	4,217,201	4,544,974	3,849,544	18,007,899
Total	6,150,408	7,253,720	8,334,032	7,716,294	6,432,334	35,886,789
2010						
Urban	5,992,412	5,154,766	5,606,731	4,223,273	3,710,938	24,688,119
Rural	2,324,772	3,940,722	5,367,797	5,817,363	4,829,922	22,280,577
Total	8,317,184	9,095,489	10,974,527	10,040,636	8,540,860	46,968,695
2015						
Urban	8,167,924	7,927,846	8,493,463	6,156,089	5,346,975	36,092,297
Rural	2,324,087	4,523,697	5,816,588	6,852,050	5,913,624	25,430,046
Total	10,492,011	12,451,542	14,310,051	13,008,140	11,260,599	61,522,343

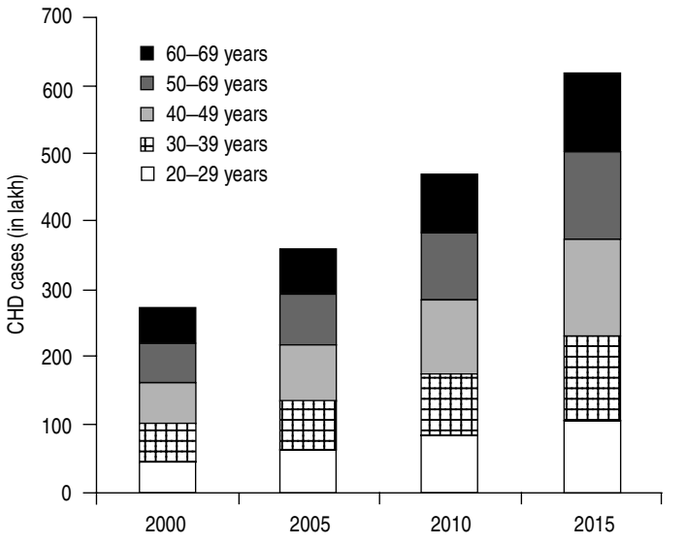

Fig. 5 Estimates and trends of coronary heart disease (CHD) cases in various age groups

studies in different areas in different years are shown in Fig. 6. The value of R^2 is too small and the trends are weird: decreasing and reaching to zero by the year 2015 in the 20–39 and 40–59 years age groups but increasing to 11.5 per 1000 in the 60–69 years age group. Because of these highly unstable features, we ignored the time trend and instead depended only on the age group-specific averages. Available data did not allow study of the 10-year age intervals. These average prevalences were used on the projected population of different ages to forecast the number of cases (Table 4). The total number of stroke cases estimated for the year 2000 are 1,081,000 and projected for the years 2005, 2010 and 2015 are 1,248,000, 1,451,000 and 1,667,000, respectively.

According to the data supplied to us, the average prevalence of RHD in the assumed age group of 6–16 years is 2.935 per 1000 children (Table 5). This age group does not conform to the standard age groups for which population data are readily available—thus the size was worked out by additional calculations for relevant proportions. The fewer cases in the year 2010 reflect a slight decrease in population of those 6–16 years of age by that year because of the ongoing demographic transition.

Congenital heart disease afflicts newborns and the number of cases can be easily projected on the basis of expected live-births in the next 10–15 years. For this we studied the trend in the birth rate over the past 30 years (1971–2000) for which we relied on data from SRS reports. Since 30 data points were available it was possible to examine the adequacy of fit of various curves. Figure 7 shows the results of linear, quadratic and cubic fit to the birth rate data. Cubic fit projected a birth rate of nearly 2 per 1000 population for the year 2015, and quadratic fit a rate of nearly 16. Both are absurd and were discarded. The linear fit forecast for birth rate is 24.99 for the year 2005, 23.29 for the year 2010, and 21.58 for the year 2015. These estimates seem

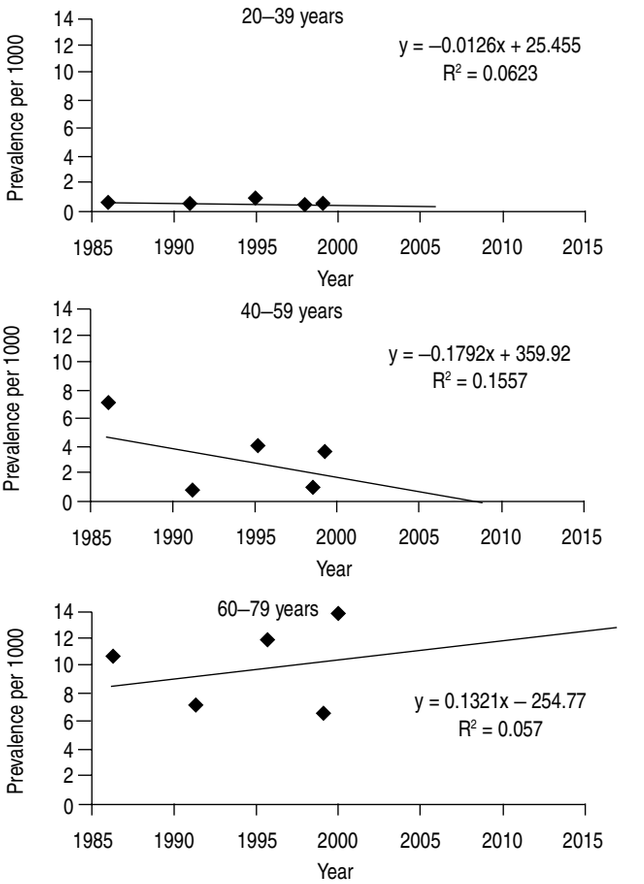

Fig. 6 Linear trend in the prevalence of stroke

Source of data: Centre for Chronic Disease Control

Table 4. Forecasting of cases of stroke

Year/ age	Estimated prevalence of stroke per 1000	Estimated population	Estimated cases
2000			
20–39	0.3022	306,904,000	92,746
40–59	2.7188	168,223,000	457,365
60–79	8.4733	62,711,000	531,369
Others		464,304,000	
Total		1,002,142,000	1,081,480
2005			
20–39	0.3022	346,437,000	104,693
40–59	2.7188	196,422,000	534,032
60–79	8.4733	71,883,000	609,086
Others		468,027,000	
Total		1,082,769,000	1,247,812
2010			
20–39	0.3022	392,531,000	118,623
40–59	2.7188	227,674,000	619,000
60–79	8.4733	84,168,000	713,181
Others		463,688,000	
Total		1,168,061,000	1,450,804
2015			
20–39	0.3022	428,582,000	129,517
40–59	2.7188	258,731,000	703,438
60–79	8.4733	98,476,000	834,417
Others		466,053,000	
Total		1,251,842,000	1,667,372

Table 5. Forecasting of cases of rheumatic heart disease

Year/age	Prevalence of RHD per 1000	Estimated population	Estimated cases
2000			
6–16	2.935	260,496,200	764,556
Others		741,645,800	
Total		1,002,142,000	
2005			
6–16	2.935	253,666,000	744,510
Others		829,103,000	
Total		1,082,769,000	
2010			
6–16	2.935	241,827,000	709,762
Others		926,234,000	
Total		1,168,061,000	
2015			
6–16	2.935	245,489,600	720,512
Others		1,006,352,400	
Total		1,251,842,000	

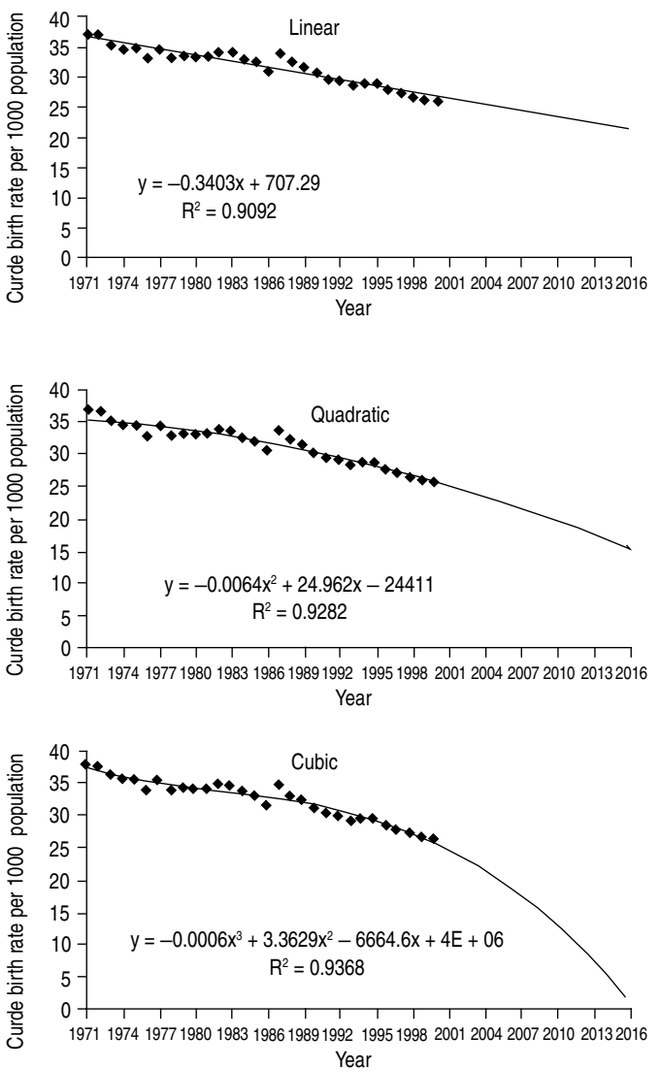

Fig. 7 Linear, quadratic and cubic fit to the birth rate data

Table 6. Forecasting of cases of congenital heart disease

Year	Estimated population	Birth rate per 1000	Number of live-births	Estimated prevalence per 1000 live-births	Estimated cases
2000	1,002,142,000	25.8*	25,855,264	5.98667	154,787
2005	1,082,768,000	24.9885	27,056,748	5.98667	161,980
2010	1,168,062,000	23.2870	27,200,660	5.98667	162,841
2015	1,251,841,000	21.5835	27,019,110	5.98667	161,754

*From Sample Registration System Survey 2000

plausible. R^2 for linear fit also exceeded 90%.

The estimated average prevalence of congenital heart disease as revealed by the data supplied to us is nearly 6 per 1000 live-births. No data were available to project the trend. Thus this rate was used on the projected births to get the projection of cases. The estimates for the years 2000, 2005, 2010, 2015 are given in Table 6.

A summary of the estimated prevalence rates of stroke, RHD and congenital heart disease is given Table 7.

Table 7. Prevalence rate per 1000 for stroke, rheumatic heart disease (RHD) and congenital heart disease

	Stroke (age in years)			RHD (age in years)	Congenital heart disease per
Year	20–39	40–59	60–79	6–16	1000 live-births
2000–2015	0.302	2.719	8.473	2.935	5.987

Note: No time trend could be detected from the available data. Thus their revalence rates have neither decreased nor increased.

Estimates of mortality

Death is the only certainty in life. It can only be postponed, not denied. If I do not die of tuberculosis, I may die of cancer. Various causes of death compete with one another, and one replaces the other. This has raised the question of what causes should be prevented and what should be promoted for death in old age (Indrayan 2001), while efforts are made to prevent all deaths in young age.

CVDs are extremely important in the context of epidemiological transition. Chronic diseases of old age are the major causes of death as the life expectancy increases and as communicable and undernutrition-based diseases respond to control efforts. Khor (2001) projected that non-communicable diseases including CVDs are expected to account for 7 out of 10 deaths in developing countries in the year 2020 compared to less than half in the year 2001. This is a likely scenario for India too.

Mortality due to coronary heart disease

Data on CVD mortality are even more scanty. A hospital-based study in Ahmedabad found a mortality rate of

Table 8. Estimated mortality from coronary heart disease (CHD)

	Deaths in age group (years) (4%)			Deaths in age group (years) (6%)		
Year	20–29	30–39	40–49	50–59	60–69	Total deaths
2000	180,448	219,571	244,778	352,758	302,503	1,300,057
2005	246,016	290,149	333,361	462,978	385,940	1,718,444
2010	332,687	363,820	438,981	602,438	512,452	2,250,378
2015	419,680	498,062	572,402	780,488	675,636	2,946,268

5.39% among cases of MI and 1.83% among cases of angina pectoris in the year 1996–97. One study in Karnataka reported a case-fatality rate of only 0.96% in a 3-year follow-up whereas it was 12.35% within 6 weeks of hospital stay in Chennai in the year 1970. Yearwise information is not available to evaluate the trend. However, it is exponentially declining in the UK (www.dh.gov.uk/PolicyAndGuidance/HealthAndSocialCareTopics CoronaryHeartDisease/fs/en), and also in the USA (www.khi.org/transfers/Marks.ppt). In the long run, the decline in India may be steeper because the technology is already available. The present evidence, through weak, suggests an average mortality of 4% in the age group of 20–49 years and 6% in those 50+ years due to CHD. This may remain so till the year 2015 if the current situation continues for the next 10–15 years. Based on this premise, the estimated mortality due to CHD is given in Table 8. This estimate is 1,300,000 for the year 2000, and the projection for the year 2015 is 2,946,000 deaths (Table 8).

Mortality due to other cardiovascular diseases

The case-fatality rate due to stroke varies from 11.7% to 32.4%. Stroke is a serious condition and the mortality is high. A case-fatality rate of 25% could be the average (Table 9). The case-fatality rate of RHD was supplied to us from two studies. In Haryana, this was 16% in 1999, and in Cuttack, 11.2% in 1981–90 and 8.3% in 1991–2000. This decline could be real because of the advanced technology now available in hospitals to save lives. Further reduction in case fatality seems highly unlikely. If a mortality of 8% is estimated for RHD cases, the number of deaths due to this cause are estimated as 61,000 for the year 2000; 60,000 for the year 2005; 57,000 for the year 2010; and 58,000 for the year 2015 (Table 10). No data were available on mortality from congenital heart disease.

The mortality estimates are derived from hospital-based studies and these may not be truly representative of community conditions. This is because health care services are not available to a large percentage of cases; as a result, the statistics provide a higher estimate compared to other cases. On the other hand, higher estimates will be obtained if hospitals get only severe cases. Although hard data are not available, we expect that the two would nearly balance and case-fatality rate seen in hospitals would be nearly the same as in the general population.

Table 9. Estimated mortality from stroke

Year	Age (years)	Case-fatality rate (%)	Estimated cases	Estimated deaths
2000	20–79	25	1,081,480	270,370
2005	20–79	25	1,247,812	311,953
2010	20–79	25	1,450,804	362,701
2015	20–79	25	1,667,372	416,843

Table 10. Estimated mortality from rheumatic heart disease (RHD)

Year	Age (years)	Case-fatality rate (%)	Estimated cases	Estimated deaths
2000	6–16	8	764,556	61,165
2005	6–16	8	744,510	59,561
2010	6–16	8	709,762	56,781
2015	6–16	8	720,512	57,641

Summary

A summary of our projections is given in Table 11. A total of nearly 6.4 crore cases of CVD are likely in the year

Table 11. Summary of projections of cardiovascular disease (CVD) cases and deaths

Year	CHD	Stroke	RHD	Congenital heart disease	Total cases
2000	27,040,912	1,081,480	764,556	154,787	29,041,735
2005	35,886,789	1,247,812	744,510	161,980	38,041,090
2010	46,968,695	1,450,804	709,762	162,841	49,292,102
2015	61,522,343	1,667,372	720,512	161,754	64,071,981
			Deaths		
Year	CHD	Stroke	RHD	Congenital heart disease	Total deaths (CHD+stroke +RHD)
2000	1,300,057	270,370	61,165	No data available	1,631,591
2005	1,718,444	311,953	59,561	No data available	2,089,958
2010	2,250,378	362,701	56,781	No data available	2,669,860
2015	2,946,268	416,843	57,641	No data available	3,420,752

CHD: coronary heart disease, RHD: rheumatic heart disease

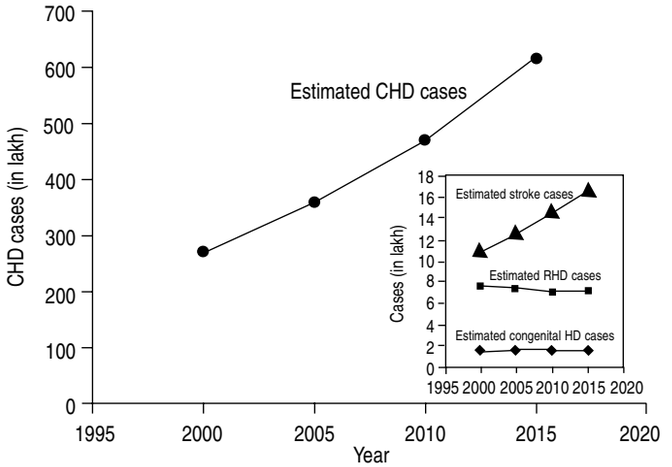

Fig. 8 Estimated trends of cases due to cardiovascular disease (CVD)
CHD: coronary heart disease; RHD: rheumatic heart disease

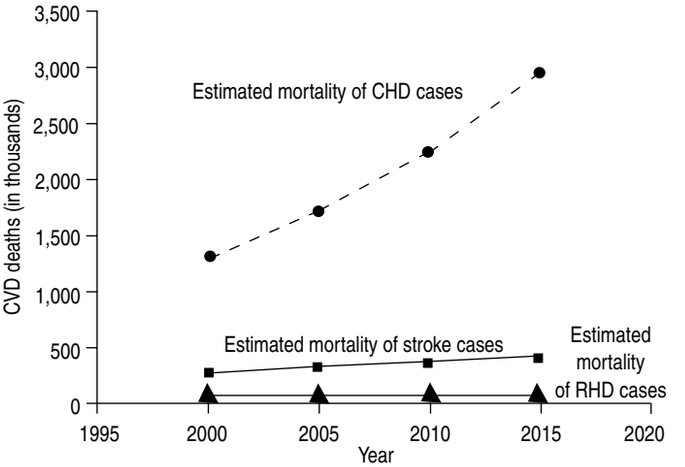

Fig. 9 Estimated trends in mortality due to cardiovascular disease (CVD)

2015, of which nearly 96% would be CHD cases (Fig. 8). Deaths from this group of diseases are likely to amount to be a staggering 34 lakh (Fig. 9).

Since the crude death rate is 8 per 1000 population even in many developed countries, it would not be wrong to assume that India has also reached its limit, and this rate would continue to be static in the near future. If so, nearly 1 crore deaths would occur in the year 2015. Thus, CVD is expected to contribute to nearly one-third of the mortality pie if the previous trend continues (Table 12).

The economic cost of CVD per case may not be staggering at present but future technology would be expensive. Given the finite resources, the management of CVD at the macro level will pose a tougher challenge.

Table 12. Deaths due to cardiovascular disease (CVD) as a percentage of total deaths

Year	Population	Crude death rate per 1000	Total deaths by all causes	Total CVD deaths	Percentage of CVD to total deaths
2000	1,002,142,000	8	8,017,136	1,631,591	20.35
2005	1,082,768,000	8	8,662,144	2,089,958	24.13
2010	1,168,062,000	8	9,344,496	2,669,860	28.57
2015	1,251,841,000	8	10,014,728	3,420,752	34.16

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Limitations of this exercise in forecasting mortality due to CVD

- Since all diseases are not considered in this exercise, there is a possibility of over-counting. The total mortality from all causes put together should not exceed the deaths calculated from the crude death rate. In the absence of other diseases from this exercise, such epidemiological consistency could not be ensured. It is possible that a case of diabetes dying of MI is counted twice—once in diabetes and again in CHD.
- Different studies use different criteria for identifying or labelling a patient of CVD. For example, one study has used only ECG whereas another has used clinical history. We have ignored this distinction because of lack of data with uniform criteria.
- This exercise does not include the population in the age group of 70+ years for CHD because of lack of data for this age group in whom the prevalence and death rates may be high. However, only 3% of the population in India is in this age group, and the total cases or deaths in terms of absolute numbers may not be much affected.
- Our projections are based on very few data points, which could affect their reliability.
- Only linear trends could be explored because of lack of data.
- Some CVDs such as arrhythmias and inflammatory heart disease (carditis and cardiomyopathy) may be excluded from this exercise. No data were supplied to us on these conditions.

Appendix 1

Projections for the prevalence of diabetes

Since diabetes is a risk factor for CVD, the information supplied to us contained data points on the prevalence of diabetes in various age–gender groups for various years since 1990. These are plotted in Fig. A1.1 for males and females of various age groups. No time trend could be detected. The value of R^2 is very small except for males 50–59 years of age.

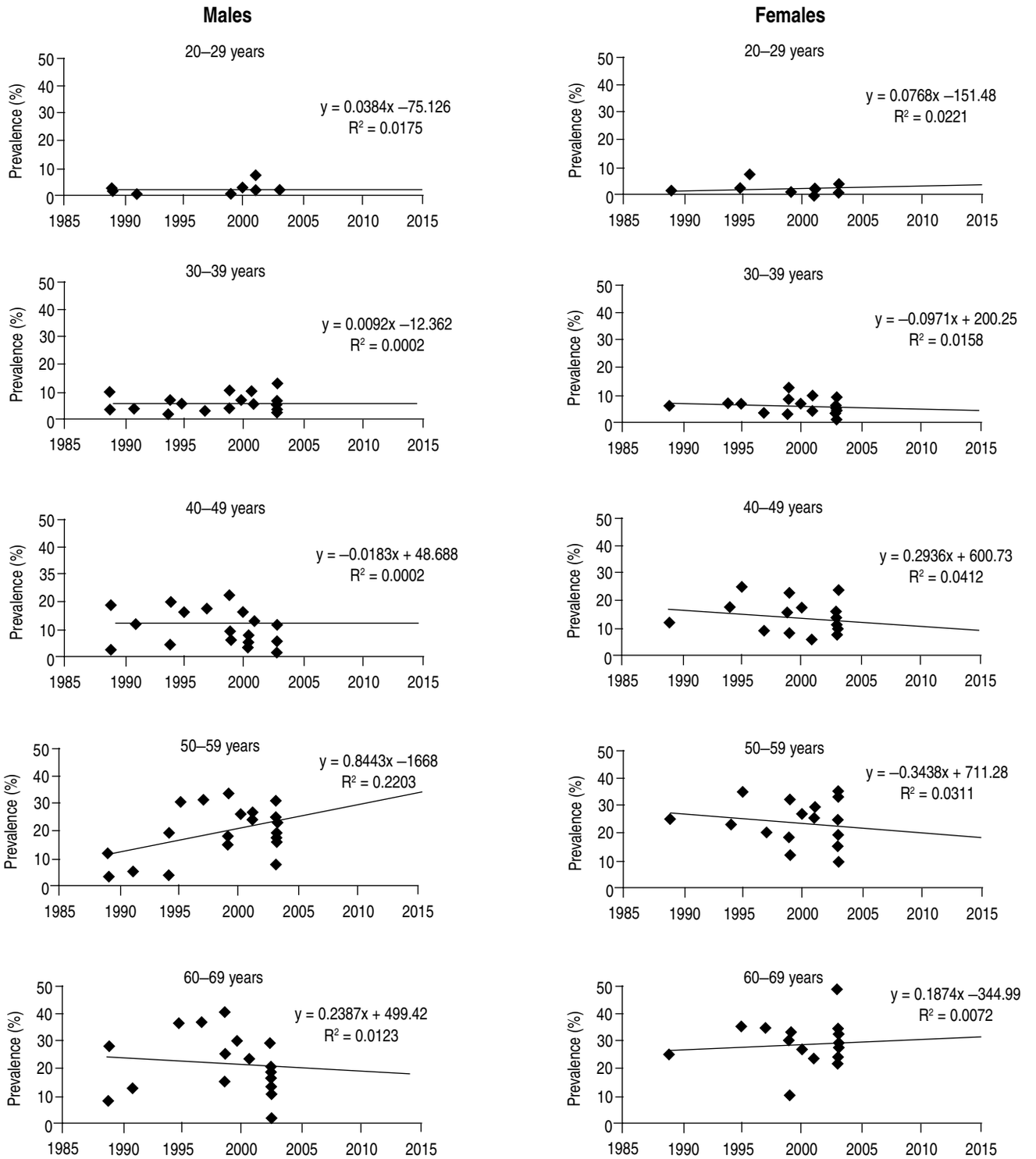

Fig. A1.1 Absence of a trend in the prevalence of diabetes

Source of data: Centre for Chronic Disease Control

Table A1.1 Prevalence of diabetes in rural and urban areas of India

State	Year	Age group	Prevalence (%) Male Urban	Male Rural	Female Urban	Female Rural	References
Delhi	1991–94	35–44	8.1	1.7	7.0	2.5	ICMR Task Force Project on
		45–54	19.6	3.7	17.5	1.6	Collaborative Study of Coronary
		55–64	18.8	3.9	23.3	4.9	Heart Study
Tamil Nadu	1989	20–24	—	—	2.0	—	
		25–34	1.1	1.9	0.6	—	Ramachandran A, Snehalatha C,
		35–44	10.5	3.8	5.7	0.9	Dharmaraj D, Viswanathan M.
		45–54	18.5	1.6	12.2	3.7	*Diabetes Care* 1992;**15:**1348–55
		55–64	11.8	3.6	25.0	1.7	

Under these circumstances the only plausible hypothesis is that the age–gender rates of diabetes have neither increased nor decreased in our population over the past 15 years or so, although diabetes might have increased due to ageing and urbanization of the population. This may remain so till the year 2015.

Table A1.2 Estimated prevalence rate of diabetes per 1000 in India

	20–29		30–39		40–49		50–59		60–69		70+	
Area	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Urban	17.29	20.70	60.13	59.74	121.04	135.39	198.50	236.26	222.26	297.31	215.20	221.33
Rural	4.32	5.18	15.03	14.93	30.26	33.85	49.63	59.07	55.57	74.33	53.80	55.33

Since not many studies have been reported from rural areas, the best strategy in such data-deficient situations is to obtain the rural prevalence as a percentage of the urban prevalence. Comparable data from a few studies are given in Table A1.1. The data in Table A1.1 suggest that the rural prevalence could be nearly one-fourth of the urban prevalence. With this assumption, the age–gender-wise prevalence rates are as shown in Table A1.2. Females are probably affected more than males. Using these rates on the projected population gives the projected caseload of diabetes (Table A1.3). These projections take into account factors such as population growth, ageing and urbanization.

Diabetes mortality

No data on diabetes mortality were supplied to us.

Table A1.3a Forecasting the total number of male and female cases of diabetes in India

Year and area	Age groups 20–29	30–39	40–49	50–59	60–69	70+	Total
2000							
Urban	1,003,310	2,567,970	3,882,005	4,188,171	2,783,100	1,401,300	15,825,855
Rural	549,102	1,425,108	2,232,090	2,628,455	2,053,095	1,100,412	9,988,262
Total	1,552,412	3,993,077	6,114,095	6,816,626	4,836,195	2,501,712	25,814,117
2005							
Urban	1,209,725	3,126,311	4,968,478	5,394,860	3,445,602	1,807,951	19,952,927
Rural	609,128	1,518,041	2,488,845	2,966,586	2,237,319	1,267,086	11,087,005
Total	1,818,853	4,644,352	7,457,323	8,361,446	5,682,920	3,075,038	31,039,932
2010							
Urban	1,505,267	3,744,045	6,358,087	7,010,131	4,522,903	2,304,049	25,444,482
Rural	692,391	1,558,528	2,707,848	3,310,679	2,537,127	1,420,910	12,227,483
Total	2,197,658	5,302,573	9,065,935	10,320,810	7,060,030	3,724,959	37,671,965
2015							
Urban	1,695,361	4,776,839	7,989,191	9,182,478	6,002,731	2,961,490	32,608,091
Rural	704,444	1,658,043	2,793,878	3,628,810	2,837,214	1,578,669	13,201,058
Total	2,399,805	6,434,881	10,783,069	12,811,288	8,839,946	4,540,160	45,809,149

Table A1.3b Forecasting the total number of cases of diabetes in India

	Age groups													
	20–29		30–39		40–49		50–59		60–69		70+		Total	
Year/area	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
2000														
Urban	489,340	513,969	1,307,097	1,260,873	2,019,637	1,862,367	2,146,602	2,041,569	1,244,731	1,538,369	682,108	719,192	7,889,515	7,936,340
Rural	254,212	294,890	722,171	702,937	1,100,702	1,131,388	1,250,395	1,378,059	899,318	1,153,777	570,007	530,404	4,796,807	5,191,455
Total	743,552	808,859	2,029,268	1,963,809	3,120,340	2,993,755	3,396,997	3,419,629	2,144,049	2,692,146	1,252,115	1,249,596	12,686,322	13,127,795
2005														
Urban	595,186	614,540	1,570,223	1,556,088	2,494,733	2,473,744	2,763,170	2,631,690	1,560,699	1,884,903	864,764	943,188	9,848,775	10,104,152
Rural	291,641	317,487	764,895	753,146	1,206,827	1,282,018	1,396,782	1,569,803	984,801	1,252,518	646,823	620,264	5,291,769	5,795,236
Total	886,826	932,027	2,335,118	2,309,234	3,701,561	3,755,762	4,159,952	4,201,493	2,545,500	3,137,421	1,511,586	1,563,451	15,140,543	15,899,388
2010														
Urban	720,695	784,572	1,919,743	1,824,302	3,041,657	3,316,430	3,581,777	3,428,354	2,066,668	2,456,235	1,087,218	1,216,830	12,417,757	13,026,724
Rural	331,880	360,511	809,652	748,876	1,285,100	1,422,748	1,534,791	1,775,888	1,114,967	1,422,160	717,886	703,024	5,794,276	6,433,207
Total	1,052,575	1,145,083	2,729,394	2,573,179	4,326,757	4,739,178	5,116,568	5,204,242	3,181,635	3,878,395	1,805,105	1,919,854	18,212,034	19,459,931
2015														
Urban	778,096	917,265	2,490,225	2,286,613	3,700,020	4,289,171	4,623,746	4,558,732	2,750,189	3,252,543	1,394,365	1,567,125	15,736,642	16,871,449
Rural	335,359	369,085	887,454	770,589	1,336,632	1,457,246	1,625,247	2,003,563	1,232,085	1,605,130	798,437	780,232	6,215,214	6,985,844
Total	1,113,455	1,286,350	3,377,679	3,057,202	5,036,652	5,746,417	6,248,993	6,562,295	3,982,273	4,857,673	2,192,802	2,347,357	21,951,856	23,857,293

Appendix 2

Revision following the suggestion of the experts

The NCMH called a meeting of experts to review the draft report we had submitted earlier. Primarily, two revisions were suggested. We were asked to

—use population projection of the Registrar-General (R-G) instead of the US Census Bureau that we had used earlier. This revision has been done and is reflected in this final report. Due to the higher population estimates of the R-G, the corresponding estimates of CVD caseload and deaths have increased.

—remove the 1974 data point that is suspected to cause a steep rise in the regression line used for projecting the prevalence of CHD. It was expected that the estimates would come down when this point is deleted. The experts were of the view that the estimates seemed to be on the higher side.

The new graphs obtained after deleting the 1974 data point are shown in Figs A2.1 and A2.2 for urban and rural areas,

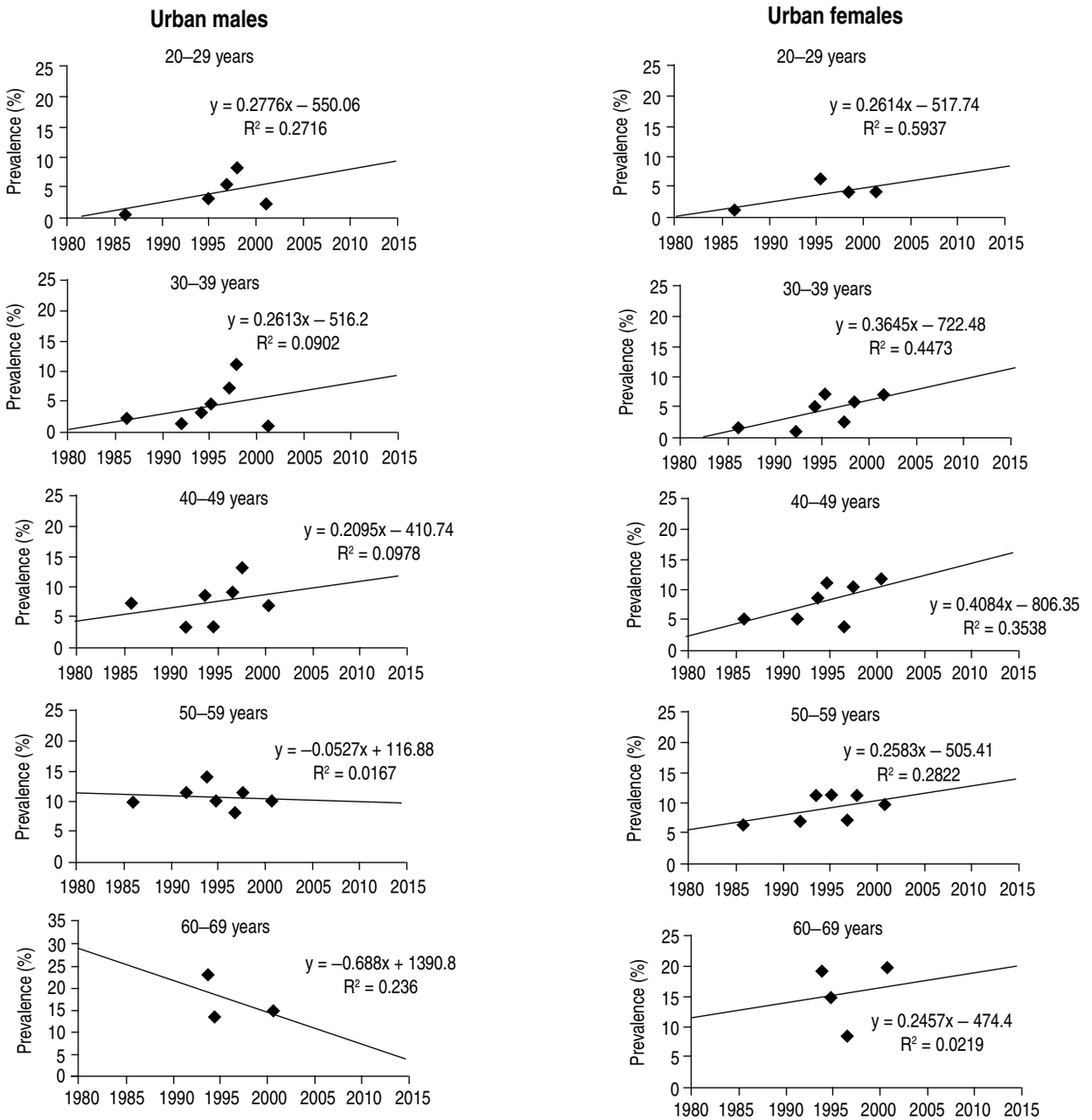

Fig. A2.1 Trends in the prevalence of coronary heart disease (CHD)—Urban (after excluding 1974 data point)

Source of data: Centre for Chronic Disease Control

respectively. Comparison of these with the previous graphs (Figs 3 and 4 in the main paper) show that this deletion had the reverse effect, particularly for rural areas. Table A2.1 has these estimates for each age group. When such 'revised' prevalence estimates were used on the estimated population, the projected CHD caseload for the year 2015 rose from nearly 6.15 crore estimated earlier to more than 6.60 crore (Table A2.2). Thus, deletion of the 1974 data point had a reverse effect of what was anticipated. We would like to stick to the estimates of 6.15 crore for the year 2015 provided in the main paper.

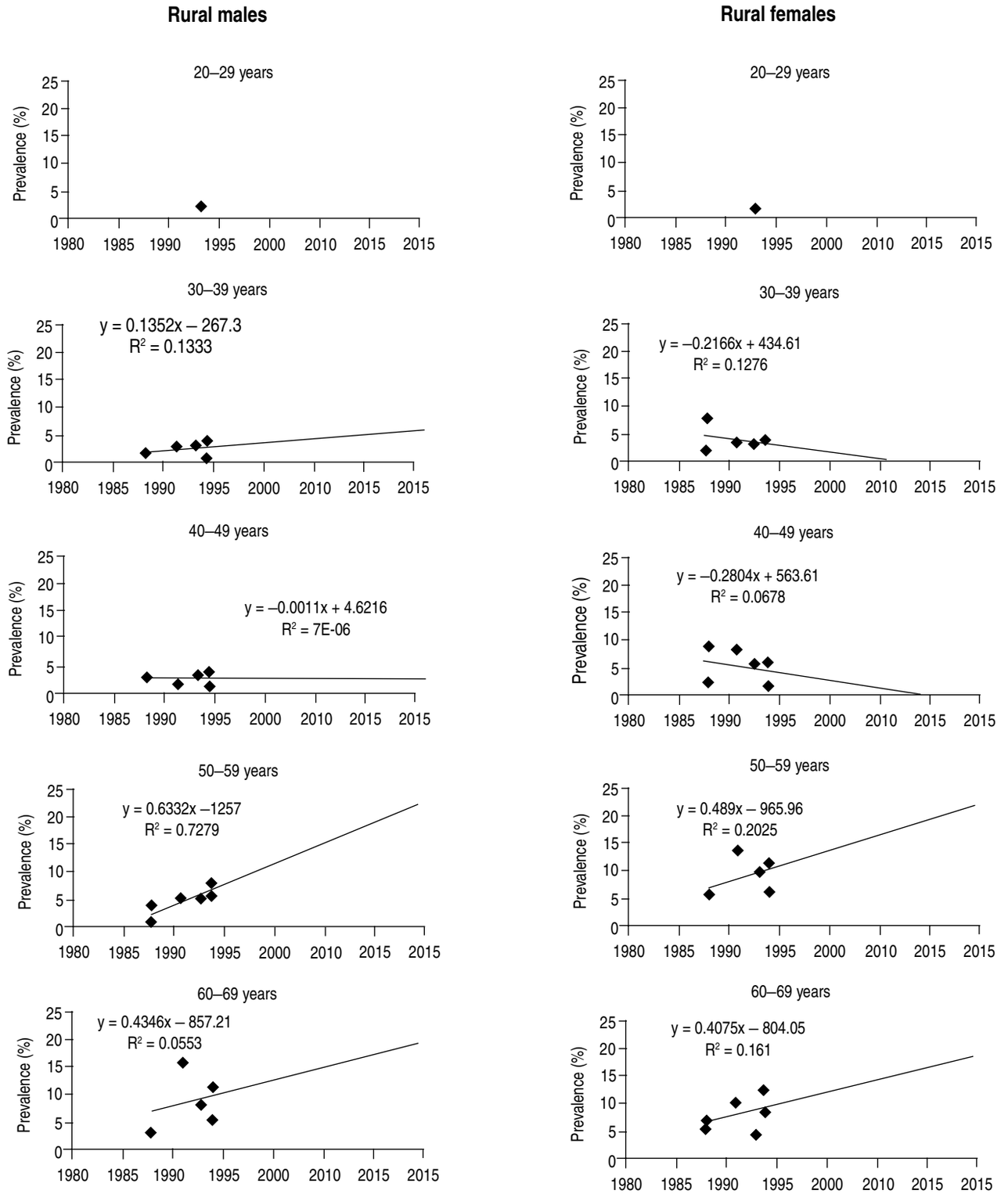

Fig. A2.2 Trends in the prevalence of coronary heart disease (CHD)—Rural (after excluding 1974 data point)

Source of data: Centre for Chronic Disease Control

Table A2.1 Forecasting the prevalence rate (%) of coronary heart disease (CHD) in India (after excluding 1974 data point)

Year and area	Age groups									
	20–29		30–39		40–49		50–59		60–69	
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
2000										
Urban	5.14	5.06	6.39	6.52	8.26	10.45	11.00	11.19	14.81	17.00
Rural	1.80	1.30	3.10	2.90	3.45	5.50	9.40	12.04	11.99	10.95
2005										
Urban	6.53	6.37	7.70	8.34	9.31	12.49	11.00	12.48	14.81	18.23
Rural	1.80	1.30	3.78	2.90	3.45	5.50	12.57	14.48	14.16	12.99
2010										
Urban	7.92	7.67	9.00	10.17	10.36	14.53	11.00	13.77	14.81	19.46
Rural	1.80	1.30	4.45	2.90	3.45	5.50	15.73	16.93	16.34	15.03
2015										
Urban	9.30	8.98	10.31	11.99	11.40	16.58	11.00	15.06	14.81	20.69
Rural	1.80	1.30	5.13	2.90	3.45	5.50	18.90	19.38	18.51	17.06

Table A2.2a Forecasting the number of male and female cases of coronary heart disease (CHD) in India (after excluding 1974 data point)

Year/area	Age groups										Total	
	20–29		30–39		40–49		50–59		60–69			
	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males	Females
2000												
Urban	1,455,131	1,256,370	1,389,039	1,376,184	1,378,199	1,437,469	1,189,553	966,937	829,398	879,623	6,241,319	5,916,582
Rural	1,058,905	740,786	1,489,249	1,364,997	1,254,895	1,838,447	2,368,507	2,809,043	1,940,551	1,699,741	8,112,108	8,453,015
Total	2,514,036	1,997,156	2,878,288	2,741,182	2,633,095	3,275,916	3,558,060	3,775,980	2,769,949	2,579,364	14,353,427	14,369,597
2005												
Urban	2,247,815	1,890,230	2,009,835	2,173,142	1,918,296	2,282,463	1,531,228	1,390,290	1,039,936	1,155,651	8,747,110	8,891,775
Rural	1,214,812	797,551	1,921,319	1,462,498	1,375,887	2,083,213	3,536,920	3,849,706	2,510,130	2,188,549	10,559,068	10,381,518
Total	3,462,627	2,687,781	3,931,153	3,635,639	3,294,183	4,365,676	5,068,148	5,239,997	3,550,066	3,344,200	19,306,178	19,273,293
2010												
Urban	3,300,543	2,691,869	2,874,326	2,793,436	2,602,069	3,146,590	1,984,864	1,813,228	1,377,077	1,607,432	12,138,878	12,052,555
Rural	1,382,426	942,347	2,397,833	1,542,889	1,465,124	2,468,408	4,865,559	5,318,036	3,277,934	2,874,814	13,388,877	13,146,495
Total	4,682,969	3,634,215	5,272,159	4,336,325	4,067,194	5,614,998	6,850,423	7,131,264	4,655,011	4,482,247	25,527,755	25,199,049
2015												
Urban	4,188,235	3,979,689	4,269,548	4,588,588	3,485,481	5,251,339	2,562,278	2,906,717	1,832,525	2,262,955	16,338,067	18,989,288
Rural	1,396,918	927,169	3,027,329	1,248,555	1,523,876	2,367,949	6,189,202	6,572,166	4,104,081	3,684,679	16,241,406	14,800,519
Total	5,585,153	4,906,858	7,296,877	5,837,144	5,009,356	7,619,288	8,751,480	9,478,883	5,936,606	5,947,634	32,579,472	33,789,807

Table A2.2b Forecasting the total number of coronary heart disease (CHD) cases in India (after excluding 1974 data point)

	Age groups					
Year and area	20–29	30–39	40–49	50–59	60–69	Total
2000						
Urban	2,711,501	2,765,223	2,815,668	2,156,490	1,709,021	12,157,902
Rural	1,799,691	2,854,247	3,093,343	5,177,550	3,640,292	16,565,123
Total	4,511,192	5,619,470	5,909,011	7,334,039	5,349,312	28,723,025
2005						
Urban	4,138,045	4,182,976	4,200,759	2,921,518	2,195,587	17,638,885
Rural	2,012,363	3,383,816	3,459,100	7,386,627	4,698,679	20,940,585
Total	6,150,408	7,566,793	7,659,859	10,308,145	6,894,266	38,579,471
2010						
Urban	5,992,412	5,667,762	5,748,659	3,798,092	2,984,509	24,191,433
Rural	2,324,772	3,940,722	3,933,533	10,183,595	6,152,749	26,535,371
Total	8,317,184	9,608,484	9,682,191	13,981,687	9,137,258	50,726,805
2015						
Urban	8,167,924	8,858,137	8,736,819	5,468,994	4,095,480	35,327,354
Rural	2,324,087	4,275,884	3,891,825	12,761,368	7,788,760	31,041,925
Total	10,492,011	13,134,021	12,628,645	18,230,363	11,884,240	66,369,279