Projections of cervical cancer mortality and incidence in New Zealand: the possible impact of screening

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Abstract

Study objective—The aim was to estimate the likely burden of cervical cancer in New Zealand over the next two decades, according to whether cervical screening services are made more effective.

Design—The study was based on national mortality and incidence data for the periods 1954–87 and 1954–86, respectively. An age-period-cohort model was used to estimate the contributions of age, time period, and birth cohort effects to the occurrence of cervical cancer. Using age specific estimates of the future female population of New Zealand, projections of cervical cancer mortality and incidence until the year 2008 were derived from the model. Projections were made assuming either that screening services will not be improved, or that an immediate improvement in the organisation of screening will lead to a decline in period effects for incidence of 15% per five year time period (with a slightly delayed effect on mortality). It was also assumed either that the risk in new birth cohorts will be similar to that in recent cohorts, or that their risk will be halved as a result of changes in sexual behaviour (due to education about AIDS or other factors). Combining these assumptions produced four sets of estimates, reflecting a range of possible scenarios.

Setting—Both the data used and the projections obtained related to the entire population of New Zealand women.

Main results—For both mortality and incidence, projections were made of age specific rates, cumulative rates, and absolute numbers of deaths or new cases. With the first assumption about new birth cohorts, it was estimated that both mortality and incidence rates will increase if screening services are are not improved. In absolute terms, the present 100 deaths per year could increase to about 148 deaths per year, while there could be a much larger increase in incidence from 235 per year to about 440 per year). With improved screening, there could be a reduction in age specific mortality rates and a modest decline in the number of deaths, while a reduction in incidence rates would be accompanied by about the same number of new cases as at present. In comparison with improvements in screening, changes in the underlying risk in new birth cohorts would have much smaller effects on the occurrence of cervical cancer over the next two decades.

Conclusions—Plausible improvements in cervical screening are likely to be accompanied by only small changes in the burden of cervical cancer over the next two decades. If screening services are not improved, however, there will be striking increases in both mortality and incidence.
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As in Britain and several other countries, cervical cancer rates have been increasing among young women in New Zealand.[1] The New Zealand government is committed to an improved cervical screening programme, and it has been suggested that one way of evaluating the effectiveness of such a programme would be to monitor incidence and mortality rates for cervical cancer. In order to assess the impact of cervical screening, however, it is necessary to estimate the future burden of disease that would have occurred in the absence of screening. Because of the pronounced changes in the risk of cervical cancer among different generations of women,[1] it is essential to allow for cohort effects when making projections of incidence and mortality rates. Apart from improvements in screening, one has to consider the possibility that behavioural changes (due to the AIDS epidemic or other factors) might also have an impact on the future occurrence of cervical cancer.

The amount of preinvasive disease (and particularly of carcinoma in situ, which is most likely to progress to invasive cancer) that is detected by screening can be used to estimate the reduction in cervical cancer expected.[2] If the screening service is organised and monitored, it is also possible to use estimates of the relative protection provided by organised screening and of the screening coverage[3 4] to estimate the prevented fraction.[5] Such a calculation of the prevented fraction uses current rather than future incidence rates of disease, however, so it will give an unreliable view of the future if age specific rates change with time. Because of the increased risk of cervical cancer among recent generations of women, a decline in the incidence of cervical cancer might not be observed even if screening services are improved.[6]

Statistical models that estimate age, birth cohort, and period effects can be used to predict the future burden of disease.[7–9] Knowledge of the prevalence of major risk factors can also be applied to modify projections of disease incidence.[9 10] We used this modelling approach to obtain estimates of the future occurrence of cervical cancer, according to whether screening services become more effective.

Methods

The numbers of deaths and registrations for cervical cancer in New Zealand were obtained from publications of the National Health Statistics Centre for the periods 1954–87 and 1954–86, respectively. Six five year time periods were used while the most recent period was truncated to 1984–87 for mortality and 1984–86 for incidence, so that in all seven time periods were used. Five year age groups from 25 to 85 or more years of age and 20 to 85 or more years of age were used for the projections of mortality and incidence rates, respectively. The effects of age, period, and birth cohort were estimated separately for mortality and incidence in successive time periods and each five year age group.[8] When separation of these effects occurs the age values are approximate age specific rates adjusted for period and birth cohort effects. The cohort values estimate the risk of cervical cancer for different generations relative to an average generation represented in the table of rates, while the period values estimate the risk of disease in successive time periods relative to an average period. The period values obtained from modelling the incidence and mortality rates (from the earliest to the most recent time periods: for incidence, 0·93, 1·02, 1·01, 0·94, 1·04, 1·07, and 0·96; for mortality, 0·98, 1·00, 1·02, 0·98, 1·03, 0·99, and 1·00) did not indicate the presence of any overall increasing or decreasing trend in period values.

After estimating the age, period, and birth cohort values the likely changes in mortality and incidence due to improved treatment or secondary prevention by screening (future period effects) and changes in the exposure to risk factors among future generations were estimated. Multiplication of the appropriate age, period and cohort values produced the estimates of future age specific mortality and incidence rates of cervical cancer in New Zealand.

To predict the risk of cervical cancer in future generations, two sets of estimates were used. First (labelled C1), the estimates of the risk of cervical cancer in the most recent three birth cohorts were weighted by the number of deaths or registrations that had occurred in each birth cohort to estimate the risk in future birth cohorts or generations. The numbers of deaths or registrations in each birth cohort were used as weights as they are inversely proportional to the variance of the estimates of risk for each birth cohort. Second (labelled C2), the risk among women born about 1964, 1969, 1974, and 1979 for mortality, and birth cohorts 1969 to 1984 for incidence, was set at one half of the first estimate used in C1, to reflect the possible effects of health education about risk factors. Two sets of estimates were also used to estimate future period effects. First (labelled P1), since the period values obtained from statistical models of past mortality and incidence rates showed no clear trend and did not vary greatly from unity, all future period effects were given the value of unity representing no overall improvement in survival or effectiveness of cervical screening. Second (labelled P2), future period effects for incidence were set at declining values of 15% per five year time period, to represent immediate improvement in the organisation of cervical screening in New Zealand. Since

improvements in mortality from a better screening service occur later than reductions in the incidence of cervical cancer, the period value for the first future time period in estimating mortality rates, 1989–93, was assumed to be only 7·5% lower than unity (with successive 15% reductions thereafter). These future period values represent a 43% reduction in mortality and a 48% reduction in incidence from improvements in screening over a 20 year period. Such reductions in mortality and incidence from screening are similar to those observed in Finland and Sweden but not as great as those observed in Iceland.[11-12] The age values obtained from the statistical models of past incidence and mortality rates remained the same for future time periods. Combinations of the two future time period values and the two future birth cohort values produced four projections for both mortality and incidence.

Recombining the age values with estimated future birth cohort values and time period values produced estimates of future mortality and incidence rates of cervical cancer in New Zealand. Using projections of the population that assume low fertility, medium short term migration and zero long term migration,[13] future numbers of deaths and women developing cervical cancer were estimated. For the 1984–88 time period the mortality and incidence rates used were those observed for the 1984–87 and 1984–86 periods, respectively. The cumulative mortality and incidence rates up to age 75 years were calculated for previous years and compared with those predicted for the future.

Results

PROJECTIONS OF MORTALITY

The estimates of future cervical cancer mortality based on the two assumptions about the effectiveness of cervical screening services, P1C1 and P2C1, are shown in table I.

Without improved screening (projection P1C1) the present 100 deaths per year could increase to about 148 deaths per year by next century. Improved cervical screening could be expected to reduce this mortality by 64 deaths per year to about 84 deaths per year by next century (projection P2C1). Thus the observed reduction in the annual number of deaths from cervical cancer with improved screening is likely to be small (only about 16 deaths per year), because of the increased numbers of deaths expected due to the aging of generations with increased risks of cervical cancer and the greater than average number of women in these generations (as a result of the increase in fertility after the second world war).

Table II shows mortality projections based on the assumption that future generations will have a lower risk of developing cervical cancer. Cervical cancer mortality next century might be as low as 73 deaths per year if protection is obtained from organised cervical screening (projection P2C2). The effect of a reduction in underlying risk in emerging generations without any improvement in cervical screening would be much smaller (projection P1C2). In each of the four projections shown in tables I and II, 80% or more of all deaths from cervical cancer can be expected to occur among women aged 40 years or older.

Without improvements in the organisation of cervical screening, the cumulative mortality rate (up to 75 years of age) may increase (projection P1C1) or, if future generations have a reduced risk compared to recent generations (projection P1C2), may remain at about 0·55 per cent (fig 1). With improved screening (projections P2C1 and P2C2) the cumulative mortality rate of cervical cancer may continue the substantial decline that has been apparent from at least the mid-1950s. Projections P2C1 and P2C2 represent a 35–40% reduction in cervical cancer mortality by next century from improvements in the organisation of cervical screening.

PROJECTIONS OF INCIDENCE

If future generations have high risks of cervical cancer and screening in New Zealand is not very effective (table III, projection P1C1), the number of women developing cervical cancer each year may reach 440 by next century, with an annual age specific incidence rate of about 60 per 100 000 for women aged 40 to 54 years. If the risk of cervical cancer remains high for future generations but screening is made more effective, about 220

women may still develop cervical cancer each year next century (projection P2C1).

If future generations have a lower risk of cervical cancer than recent generations (table IV) the annual number of women developing cervical cancer can be expected to increase to about 400 per year if screening does not become more effective (projection P1C2) and to remain at the current level of about 200 per year if screening improves significantly (projection P2C2). In every projection of the incidence of cervical cancer, 80% or more of invasive cancers are expected to develop in women over 35 years of age.

Without improved screening (projections P1C1 and P1C2) the cumulative incidence rate of cervical cancer up to 75 years of age is projected to increase dramatically during the 1990s (fig 2). With improvements in the cervical screening service, the cumulative incidence rate can be expected to decline by 20–25% by next century (projections P2C1 and P2C2).

Comparison of projections P1C1 with P1C2 or P2C1 with P2C2, for both cumulative mortality and incidence rates, suggests that the influence of

Table I   Projected mortality rates (per 100 000) and numbers of deaths from cervical cancer in New Zealand using methods of projection P1C1 and P2C1 (see text).

Time periods	Age group (years)													Total
	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85+	
1979–83	2·6	4·5	7·1	5·2	10·4	13·1	14·0	15·7	18·7	16·0	20·9	27·5	19·6	
	16	27	35	22	38	49	51	52	56	39	36	29	15	465
1984–88	2·0	3·6	8·0	8·5	15·3	10·1	11·7	13·4	14·2	18·7	23·3	23·0	19·3	
	14	25	48	41	63	36	43	48	44	50	46	29	18	505
P1C1 projection														
1989–93	1·9	4·8	9·0	10·9	13·2	12·6	11·3	12·2	15·1	17·1	19·8	17·8	18·1	
	13	31	55	53	56	45	42	45	48	48	41	23	16	516
1994–98	1·9	4·4	9·7	11·2	16·4	14·8	12·6	11·4	12·9	15·3	17·4	19·6	15·2	
	14	32	62	69	80	62	44	41	45	45	41	30	17	582
1999–2003	1·9	4·4	8·9	12·0	16·8	18·3	14·8	12·7	12·1	13·1	15·5	17·2	16·7	
	14	34	65	77	103	88	60	43	41	41	38	31	24	659
2004–08	1·9	4·4	8·9	11·1	18·0	18·8	18·3	14·9	13·4	12·3	13·3	15·3	14·7	
	13	33	69	80	116	114	86	59	43	38	35	29	24	739
P2C1 projection														
1989–93	1·7	4·4	8·3	10·1	12·2	11·6	10·4	11·3	13·9	15·8	18·3	16·4	16·7	
	12	28	51	49	52	42	39	41	45	44	37	21	15	476
1994–98	1·5	3·5	7·6	8·8	12·9	11·6	9·8	9·0	10·1	12·0	13·6	15·3	11·9	
	11	25	49	54	63	48	35	32	35	35	32	24	14	457
1999–2003	1·3	2·9	6·0	8·0	11·2	12·2	9·8	8·5	8·1	8·7	10·3	11·4	11·1	
	9	23	43	52	69	59	40	29	28	27	25	20	16	440
2004–08	1·1	2·5	5·1	6·3	10·2	10·6	10·4	8·4	7·6	6·9	7·5	8·7	8·3	
	7	19	39	45	66	64	49	33	25	22	20	16	14	419

Table II   Projected mortality rates (per 100 000) and numbers of deaths from cervical cancer in New Zealand using methods of projection P1C2 and P2C2 (see text).

| Time periods	Age group (years)													Total
	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85+	
1979–83	2·6	4·5	7·1	5·2	10·4	13·1	14·0	15·7	18·7	16·0	20·9	27·5	19·6	
	16	27	35	22	38	49	51	52	56	39	36	29	15	465
1984–88	2·0	3·6	8·0	8·5	15·3	10·1	11·7	13·4	14·2	18·7	23·3	23·0	19·3	
	14	25	48	41	63	36	43	48	44	50	46	29	18	505
P1C2 projection														
1989–93	0·9	4·8	9·0	10·9	13·2	12·6	11·3	12·2	15·1	17·1	19·8	17·8	18·1	
	7	31	55	53	56	45	42	45	48	48	41	23	16	510
1994–98	0·9	2·2	9·7	11·2	16·4	14·8	12·6	11·4	12·9	15·3	17·4	19·6	15·2	
	7	16	62	69	80	62	44	41	45	45	41	30	17	559
1999–2003	0·9	2·2	4·5	12·0	16·8	18·3	14·8	12·7	12·1	13·1	15·5	17·2	16·7	
	7	17	32	77	103	88	60	43	41	41	38	31	24	602
2004–08	0·9	2·2	4·5	5·5	18·0	18·8	18·3	14·9	13·4	12·3	13·3	15·3	14·7	
	6	16	34	40	116	114	86	59	43	38	35	29	24	640
P2C2 projection														
1989–93	0·9	4·4	8·3	10·1	12·2	11·6	10·4	11·3	13·9	15·8	18·3	16·4	16·7	
	6	28	51	49	52	42	39	41	45	44	37	21	15	470
1994–98	0·7	1·7	7·6	8·8	12·9	11·6	9·8	9·0	10·1	12·0	13·6	15·3	11·9	
	6	12	49	54	63	48	35	32	35	35	32	24	14	439
1999–2003	0·6	1·5	3·0	8·0	11·2	12·2	9·8	8·5	8·1	8·7	10·3	11·4	11·1	
	5	11	21	52	69	59	40	29	28	27	25	20	16	402
2004–08	0·5	1·3	2·5	3·1	10·2	10·6	10·4	8·4	7·6	6·9	7·5	8·7	8·3	
	4	9	19	23	66	64	49	33	25	22	20	16	14	364
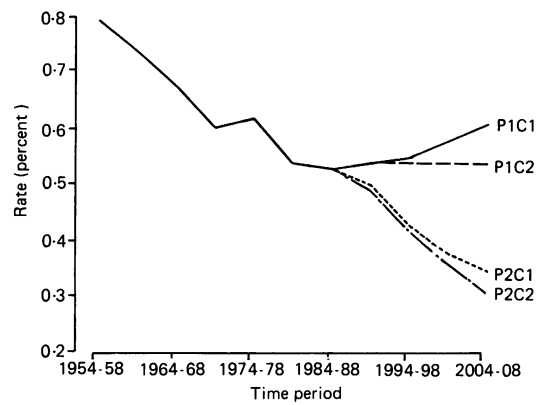
Figure 1 The trend and projections of the cumulative mortality rate, 0–74 years of age, for cervical cancer in New Zealand.
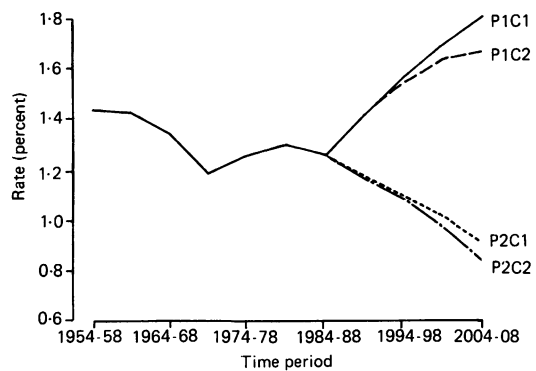

Figure 2 The trend and projections of the cumulative incidence rate, 0–74 years of age, for cervical cancer in New Zealand.

changes in the risk of death or disease in emerging generations of women (as might be expected from health promotion activity) would have a much smaller impact than improved screening of most women at risk.

Discussion

Attempts to predict the future burden of cervical cancer are subject to major uncertainties and possible errors. In order to assess whether preventive actions such as improvements in cervical screening are succeeding, however, it is essential to estimate the mortality and incidence rates that would occur in the absence of such activity. When predicting the future number of women developing or dying from cervical cancer, accurate estimation of the future population structure is also required. Because the risk of cervical cancer differs between generations, linear exrapolation of age standardised rates is inappropriate and it is necessary to allow for the influence of generation or cohort effects on future rates.[7] As age specific survival over the past 30 years was unavailable, and the methods of collection of mortality and incidence data differed, mortality rates were projected separately from incidence rates. In this

Table III Projected incidence rates (per 100 000) and numbers of women developing cervical cancer in New Zealand using methods of projection P1C1 and P2C1 (see text).

Time periods	Age group (years)														Total
	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85+	
1979–83	2·1	11·6	23·6	26·1	28·7	29·1	22·5	28·8	30·6	33·1	23·4	26·1	24·6	13·1	
	14	71	140	129	122	106	84	105	101	99	57	45	26	10	1109
1984–88	1·4	9·5	20·5	29·6	28·4	30·7	29·3	24·3	25·7	26·2	25·1	32·4	21·7	22·5	
	10	63	128	175	135	123	105	88	92	80	67	63	27	20	1176
P1C1 projection															
1989–93	1·0	10·0	27·5	43·8	46·1	36·2	29·0	23·5	21·7	24·2	21·9	22·9	17·9	14·1	
	8	70	176	269	226	153	104	88	79	78	61	47	23	13	1395
1994–98	1·0	7·0	25·9	48·3	56·1	50·4	35·0	27·4	22·7	20·1	19·5	20·3	18·5	13·5	
	7	53	186	311	347	246	146	96	82	69	57	47	29	15	1691
1999–2003	1·0	7·0	18·2	45·5	61·9	61·4	48·7	33·1	26·5	21·0	16·1	18·1	16·4	14·0	
	7	51	139	328	401	376	234	135	90	72	51	45	29	20	1978
2004–08	1·0	7·0	18·2	32·0	58·4	67·7	59·3	46·0	32·0	24·4	16·9	15·0	14·6	12·4	
	6	48	135	246	422	435	358	216	126	79	52	40	27	20	2210
P2C1 projection															
1989–93	0·8	8·2	22·5	35·8	37·7	29·9	23·7	19·3	17·8	19·8	17·9	18·8	14·6	11·5	
	6	57	144	220	185	125	85	72	65	64	50	39	19	10	1141
1994–98	0·7	4·9	18·0	33·6	39·1	35·1	24·4	19·1	15·8	14·0	13·5	14·1	12·9	9·4	
	5	37	129	217	241	171	102	67	57	48	39	33	20	11	1177
1999–2003	0·6	4·2	10·8	26·9	36·6	36·3	28·8	19·6	15·7	12·4	9·5	10·7	9·7	8·3	
	4	30	82	194	237	223	138	80	53	42	30	26	17	12	1168
2004–08	0·5	3·5	9·1	16·1	29·4	34·1	29·8	23·1	16·1	12·3	8·5	7·5	7·3	6·2	
	3	24	68	124	212	219	180	109	64	40	26	20	14	10	1113

Table IV Projected incidence rates (per 100 000) and numbers of women developing cervical cancer in New Zealand using methods of projection P1C2 and P2C2 (see text).

Time periods	Age group (years)														Total
	20–24	25–29	30–34	35–39	40–44	45–49	50–54	55–59	60–64	65–69	70–74	75–79	80–84	85+	
1979–83	2·1	11·6	23·6	26·1	28·7	29·1	22·5	28·8	30·6	33·1	23·4	26·1	24·6	13·1	
	14	71	140	129	122	106	84	105	101	99	57	45	26	10	1109
1984–88	1·4	9·5	20·5	29·6	28·4	30·7	29·3	24·3	25·7	26·2	25·1	32·4	21·7	22·5	
	10	63	128	175	135	123	105	88	92	80	67	63	27	20	1176
P1C2 projection															
1989–93	0·5	10·0	27·5	43·8	46·1	36·2	29·0	23·5	21·7	24·2	21·9	22·9	17·9	14·1	
	4	70	176	269	226	153	104	88	79	78	61	47	23	13	1391
1994–98	0·5	3.5	25·9	48·3	56·1	50·4	35·0	27·4	22·7	20·1	19·5	20·3	18·5	13·5	
	4	26	186	311	347	246	146	96	82	69	57	47	29	54	1661
1999–2003	0·5	3·5	9·1	45·5	61·9	61·4	48·7	33·1	26·5	21·0	16·1	18·1	16·4	14·0	
	3	25	70	328	401	376	234	135	90	72	51	45	29	20	1879
2004–08	0·5	3·5	9·1	16·0	58·4	67·7	59·3	46·0	32·0	24·4	16·9	15·0	14·6	12·4	
	3	24	67	123	422	435	358	216	126	79	52	40	27	20	1992
P2C2 projection															
1989–93	0·4	8·2	22·5	35·8	37·7	29·7	23·7	19·3	17·8	19·8	17·9	18·8	14·6	11·5	
	3	57	144	220	185	125	85	72	65	64	50	39	19	10	1138
1994–98	0·4	2·4	18·0	33·6	39·1	35·1	24·4	19·1	15·8	14·0	13·5	14·1	12·9	9·4	
	3	18	129	217	241	171	102	67	57	48	39	33	20	11	1156
1999–2003	0·3	2·1	5·4	26·9	36·6	36·3	28·8	19·6	15·7	12·4	9·5	10·7	9·7	8·3	
	2	15	41	194	237	223	138	80	53	42	30	26	17	12	1110
2004–08	0·3	1·8	4·6	8·0	29·4	34·1	29·8	23·1	16·1	12·3	8·5	7·5	7·3	6·2	
	1	12	34	62	212	219	180	109	64	40	26	20	14	10	1003

study the choice of future period values for mortality and incidence rate projections allowed for the more delayed impact of screening on mortality than on the incidence of cervical cancer. Since the relative protection from screening does not alter greatly with age,[4] changes in screening practice to meet current screening recommendations should result in similar age specific reductions for all but the very oldest women.[14] Although the choices of future period values and cohort values for future generations were arbitrary, they might be considered as extremes of a spectrum of possible scenarios.

The projected incidence rates were somewhat higher than would be expected from the projected mortality rates. If the incidence of cervical cancer was proportionally greater than mortality among recent generations, due to screen detected tumours, compared to less screened older generations, then higher estimates of risk for recent birth cohorts when modelling incidence rates would occur. Also, if some women with carcinoma in situ have been registered as having invasive disease, some overestimation of the incidence of invasive cervical cancer among the more intensely screened younger women would have occurred.[15] Both possibilities would lead to an overestimation of the future risk of developing cervical cancer among recent generations, producing proportionally greater projected incidence rates than projected mortality rates as these generations age (fig 1 and 2).

Despite such uncertainties, several conclusions are apparent from our analysis. Improvements in the organisation of cervical screening may not produce any dramatic reduction in the cumulative incidence rate of cervical cancer in New Zealand over the next two decades. Without substantial improvements, however, the increased number of women at risk due to changes in the age structure of the population and aging of generations at increased risk of the disease could result in a 100% increase in the number of women developing cervical cancer. Even if the risk of cervical cancer did not vary between generations, the relatively large number of women currently between 35 and 45 years of age would produce a greater number of women developing or dying from cervical cancer because of the higher rates of disease at older ages in the absence of improved screening. The aging of these generations will increase the absolute burden of many diseases in the future, so this is not a special feature of cervical cancer. In the case of cervical cancer, however, these generations also have an increased risk of disease.[1]

Despite the uncertainties in the projections, it is noteworthy that improvements in the organisation of cervical screening could be expected to produce greater reductions in the mortality and incidence of cervical cancer in the next 15 years than any measures to reduce the sexual transmission of the causal agent. On the other hand, reducing exposure to established risk factors through health education among unexposed generations could reduce the burden of pre-invasive disease.[6] Changes in sexual behaviour associated with the AIDS epidemic will not reduce the risk of cancer for generations who have already been exposed to the causal agent and cannot be expected to have any marked effect on the burden of cervical cancer over the next 15 years. Health education and organisational changes aimed at improving participation in effective screening programmes are required to reduce the mortality and incidence of cervical cancer among the generations of women who have already been exposed to the causal agent.

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