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A Mortality Analysis of a Developing Country in the Demographic Transition — Sri Lanka after the Eradication of Malaria

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Abstract : The demographic transition in Sri Lanka was brought about quite dramatically through drastic reductions in mortality due to malaria. Life table methods are used to analyze mortality in the midst of this transition and to compare mortality patterns with that of a population used as a standard, that of the United States. The major causes of death are examined to determine which causes of mortality, if reduced, would raise the life expectancy to that of the standard population.

1. Introduction

In one single year, 1947, the deaths due to malaria were cut by two thirds in Sri Lanka. This resulted in a dramatic drop in the crude death rate as can be seen in Figure 1, after which the death rate continued to fall gradually. The crude birth rates also fell a little later but more slowly after a slight rise soon after the war. The expectation of life at birth rose sharply in 1947, as would be expected, and then continued to rise more gradually. In 1964 we find the crude birth and death rates falling and the life expectancy rising. The female life expectancy had just overtaken that of the males. The population rose from 6.7 million in 1946 to 10.9 million in 1964. In the same period, the percentage urban of the population rose from 15.5 to about 20, but largely as a result of a change in definition of "urban" in 1963. Figure 1 gives some idea of the stage of the demographic transition in Sri Lanka at this point in time.

We shall analyze mortality by cause, age and sex in Sri Lanka during this period using life table methods and examining what effects the removal of certain causes of mortality will have on the expectation of life at various ages. In order to obtain a tangible measure of these effects, we shall compare this population with that of the United States (Life tables for 1973 - White), which will be used as a standard.

2. Constructing the Life Tables

The theory of the method followed here is given by Chiang[4] (Chapter 9). The corrected mid-year populations from the Annual Report of the Registrar General (ARRG)[1,2,3] were used for all age groups except for the first two, which were not available. The under 1 year group was calculated directly from the detailed records of births and deaths of infants of all categories (e.g., under 1 week, 1 week to 1 month, etc.) under 1 year, assuming a uniform distribution of deaths in each sub-interval of time available. The 1 to 4 years group was then taken as the difference of the under 5 years population, which was available, and the calculated under 1 year population. Detailed records on death by cause, age and sex were available.[1,2,3]

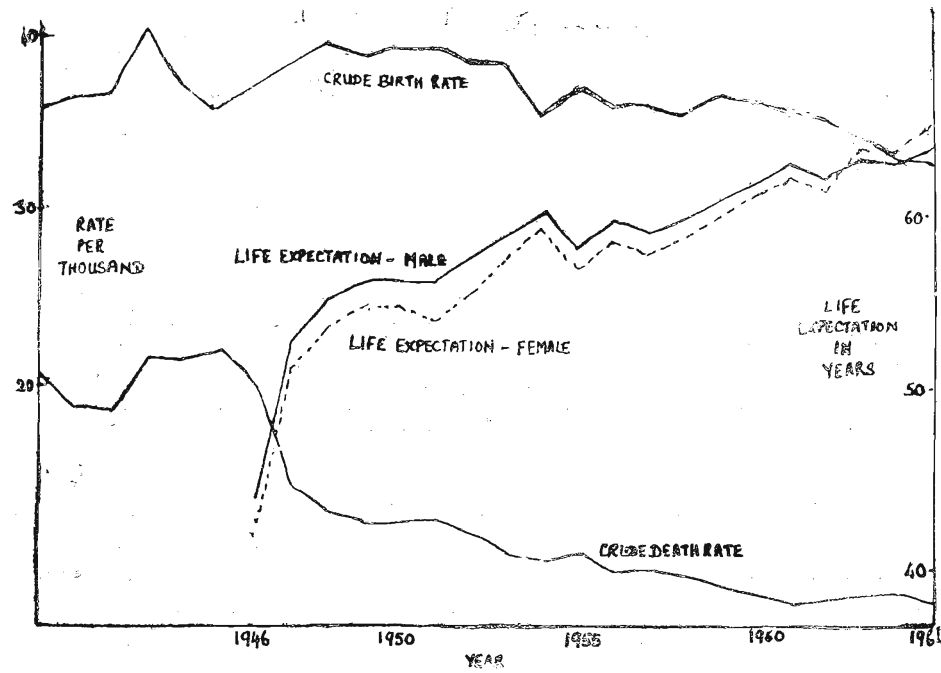

Figure 1. Crude Birth and Death rates and Life expectation — Sri Lanka.

The proportion of a time-interval lived on the average by those who died in that interval, a_x, was calculated by Professor C. L. Chiang for Sri Lanka (population of 1952) for all intervals except the first two. These two, being more likely to have changed, were calculated directly for the 1964 population.

The six highest causes of death in 1964 were:

		number	*percent*
1.	Diseases peculiar to early infancy (B. 42-44) birth injuries, post-natal asphyxia and atelectasis, infections and haemolytic diseases of the newborn, etc.	11,364	12
2.	Gastritis, duodenitis, enteritis and colitis except diarrhoea of the newborn (B.36)	6,368	7
3.	Influenza and pneumonia except pneumonia of the newborn (B.30-31)	6,181	6
4.	Heart disease (B.25-28)	5,963	6
5.	Accidents (E. 47-48)	3,032	3
6.	Cancer (B. 18)	2,784	3

For the WHO International Classification of Diseases, Mortality Code, and source see ARRG.[1,2,3]

Life tables were constructed using all these causes except "Accidents" which was not thought particularly useful. Causes 1,2 and 3 were combined to form another life table.

For each cause the probability of dying in each age interval, by that cause in the presence of all other causes, was calculated and these probabilities were used to obtain the number of life table deaths due to that cause. Then the probability of death with each cause eliminated, in the presence of all other causes, was calculated and used to construct life tables with that particular cause eliminated.

3. Method of Comparison with a Standard Population

It was thought that a deeper insight into the structure of mortality could be obtained by comparing this population with a standard population from a developed country. For this, the U.S. (White) population of 1973, males and females separately, was used. Hence all comparisons with the U.S. given here are with the U.S. (White) life tables of 1973. The basic units of all life-tables being the age-specific probabilities of death, we shall compare these and also the life expectancies derived from them. The technical details involved could be found.[4]

4. Results

The life tables for 1964 are given in Table 1. For each age interval, thega e specific death rate, the mid-year population, the number of actual deaths, the average fraction of the age interval lived by those dying in that interval, and the age specific probability of death were obtained from the data and used to calculate the number of life table survivors at the beginning of each interval, the number of deaths during it, and the expectation of life at its commencement.

The detailed results for each cause alone, in the presence of all other causes, were calculated. A summary of these results for specific causes of death is given in Tables 2 and 3. Table 2 compares the number of life table deaths by each cause, while Table 3 gives the percentage each cause contributed to the total number of deaths in each age group.

Finally, the life tables with particular causes eliminated as risks of death were calculated. These results are summarized in Table 4, which gives the expectations of life when various causes are eliminated as risks of death.

TABLE 1. Life Tables for Sri Lanka 1964 Males (Females)

Beginning of Age Interval	Age Specific Death Rate	Mid-year Population	Deaths	Avg. Frac. Lived	Probability of Death	Life Table Survivors	Life Table Deaths	Expectation of Life
0	0.0654	174,116	11,394	0.176	.0621	100,000	6,209	63.01
	(0.0538)	(170,419)	(9,170)	(0.207)	(.0516)	(100,000)	(5,161)	(63.60)
1	0.0079	698,526	5,521	0.419	.0310	93,791	2,912	66.17
	(0.0092)	(676,954)	(6,196)	(.425)	(.0359)	(94,839)	(3,401)	(66.05)
5	0.0021	748,060	1,586	.53	.0105	90,879	959	64.24
	(0.0024)	(733,567)	(1,746)	(.53)	(.0118)	(91,439)	(1,082)	(64.44)
10	0.0012	696,792	804	.55	.0058	89,920	517	59.90
	(0.0011)	(665,591)	(737)	(.42)	(.0055)	(90,357)	(499)	(60.18)
15	0.0018	535,928	983	.49	.0091	89,403	816	55.23
	(0.0016)	(521,516)	(827)	(.55)	(.0079)	(89,858)	(710)	(55.51)
20	0.0017	459,973	784	.51	.0085	88,587	752	50.71
	(.0026)	(457,193)	(1,177)	(.54)	(.0128)	(89,148)	(1,141)	(50.93)
25	.0023	388,912	877	.52	.0112	87,835	985	46.12
	(.0031)	(381,599)	(1,170)	(.53)	(.0152)	(88,007)	(1,340)	(46.55)
30	.0024	365,691	883	.53	.0120	86,850	1,043	41.62
	(.0032)	(325,819)	(1,028)	(.54)	(.0157)	(86,668)	(1,357)	(42.23)
35	.0036	355,439	1,282	.53	.0179	85,807	1,534	37.09
	(.0041)	(321,194)	(1,316)	(.54)	(.0203)	(85,310)	(1,731)	(37.86)
40	.0044	267,783	1,178	.54	.0218	84,273	1,835	32.72
	(.0042)	(220,228)	(920)	(.53)	(.0207)	(83,579)	(1,729)	(33.59)
45	.0067	255,495	1,706	.54	.0329	82,438	2,711	28.39
	(.0054)	(204,001)	(1,110)	(.53)	(.0269)	(81,850)	(2,199)	(29.24)
50	.0090	200,668	1,804	.53	.0440	79,727	3,510	24.26
	(.0068)	(157,529)	(1,068)	(.53)	(.0334)	(79,652)	(2,658)	(24.98)
55	.0137	160,445	2,205	.53	.0666	76,218	5,073	20.26
	(.0114)	(117,118)	(1,338)	(.53)	(.0556)	(76,994)	(4,283)	(20.75)
60	.0198	143,562	2,837	.53	.0944	71,144	6,718	16.51
	(.0168)	(106,539)	(1,788)	(.53)	(.0807)	(72,711)	(5,870)	(16.81)
65	.0367	87,420	3,206	.53	.1688	64,427	10,876	12.96
	(.0334)	(67,739)	(2,261)	(.53)	(.1548)	(66,841)	(10,344)	(13.06)
70	.0560	58,230	3,259	.52	.2467	53,550	13,211	10.05
	(.0552)	(48,554)	(2,679)	(.52)	(.2436)	(56,497)	(13,764)	(9.96)
75	.0844	32,199	2,719	.5	.3486	40,339	14,063	7.49
	(.0809)	(28,167)	(2,278)	(.45)	(.3308)	(42,733)	(14,136)	(7.33)
80	.1415	21,131	2,991	.42	.5018	26,276	13.184	5.16
	(.1482)	(18,107)	(2,684)	(.35)	(.5002)	(28,597)	14,304)	(4.84)
85 & over	.3088	16,099	4,971	—	—	13,092	13,092	3.24
	(.3403)	(15,090)	(5,135)	—	—	(14,293)	(14,293)	(2.94)

TABLE 2. Sri Lanka 1964. Life Table Deaths by Specific Causes, In the Presence of All Other Causes, Male (Female)

Beginning of Age Interval	Survivors at Beginning	Infant Diseases	Gastritis etc.	Influenza Pneumonia	Heart	Cancer	First Three Combined
0	100,000 (100,000)	3,541 (2,739)	447 (393)	480 (441)	2 (7)	9 (6)	4,467 (3,573)
1	93,791 (94,839)	— (—)	449 (454)	457 (554)	21 (9)	12 (9)	906 (1,008)
5	90,879 (91,439)	— (—)	96 (117)	92 (121)	15 (20)	14 (15)	188 (237)
10	89,920 (90,357)	— (—)	42 (49)	34 (49)	17 (24)	15 (11)	76 (98)
15	89,403 (89,858)	— (—)	34 (35)	46 (48)	33 (43)	22 (15)	80 (83)
20	88,587 (89,148)	— (—)	46 (72)	35 (77)	58 (79)	22 (15)	81 (148)
25	87,835 (88,007)	— (—)	49 (89)	45 (89)	83 (94)	31 (37)	94 (179)
30	86,850 (86,668)	— (—)	63 (106)	53 (83)	98 (87)	33 (62)	116 (189)
35	85,807 (85,310)	— (—)	79 (128)	71 (97)	199 (138)	67 (142)	150 (225)
40	84,273 (83,579)	— (—)	79 (126)	83 (111)	279 (184)	151 (195)	162 (237)
45	82,438 (81,850)	— (—)	103 (119)	95 (115)	483 (248)	222 (325)	199 (234)
50	79,727 (79,652)	— (—)	189 (139)	121 (152)	632 (306)	319 (343)	309 (291)
55	76,218 (76,994)	— (—)	269 (243)	177 (224)	1,031 (586)	416 (525)	446 (467)
60	71,144 (72,711)	— (—)	384 (391)	313 (325)	1,177 (781)	398 (492)	696 (716)
65	64,427 (66,841)	— (—)	533 (558)	431 (476)	1,601 (1,075)	600 (618)	963 (1,034)
70	53,550 (56,497)	— (—)	649 (601)	470 (555)	1,561 (1,115)	482 (498)	1,119 (1,156)
75	40,339 (42,733)	— (—)	605 (490)	336 (478)	1,309 (980)	326 (329)	941 (968)
80	26,276 (28,597)	— (—)	410 (458)	278 (293)	868 (815)	203 (197)	688 (751)
85 & Over	13,092 (14,293)	— (—)	319 (395)	161 (220)	527 (482)	92 (53)	479 (615)

TABLE 3. Sri Lanka 1964. Percentages Contributed to the Age Specific Death Rates by Each Cause.

Beginning of Age Interval	Infant Diseases		Gastritis etc.		Influenza Pneumonia		Heart		Cancer		First Three Combined	
	M	F	M	F	M	F	M	F	M	F	M	F
0	57%	53%	7%	8%	8%	9%	0.04%	0.1%	0.1%	0.1%	72%	69%
1	—	—	15	13	16	16	1	0.3	0.4	0.3	31	30
5	—	—	10	11	10	11	2	2	1	1	20	22
10	—	—	8	10	7	10	3	5	3	2	15	20
15	—	—	4	5	6	7	4	6	3	2	10	12
20	—	—	6	6	5	7	8	7	3	1	11	13
25	—	—	5	7	5	7	8	7	3	3	10	13
30	—	—	6	8	5	6	9	6	3	5	11	14
35	—	—	5	7	5	6	13	8	4	8	10	13
40	—	—	4	7	4	6	15	11	8	11	9	14
45	—	—	4	5	4	5	18	11	8	15	8	11
50	—	—	5	5	3	6	18	12	9	13	9	11
55	—	—	5	6	3	5	20	14	8	12	9	11
60	—	—	6	7	4	6	18	13	6	8	10	12
65	—	—	5	5	4	5	15	10	6	6	9	10
70	—	—	5	4	4	4	12	8	4	4	8	8
75	—	—	4	3	2	3	9	7	2	2	7	7
80	—	—	3	3	2	2	7	6	2	1	5	5
85 & Over	—	—	2	3	1	2	4	3	0.7	0.4	4	4
All ages	12%		7%		6%		6%		3%		25%	

TABLE 4. Sri Lanka 1964. Expectation of Life with Certain Causes Eliminated. (The eliminated cause heads each column.)

Beginning of Age Interval	None		Infant Diseases		Gastritis Etc.		Influenza Pneumonia		Heart		Cancer		First Three Combined	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
0	63.0	63.6	65.4	65.4	64.2	64.8	64.1	64.9	64.5	64.6	63.6	64.3	67.7	68.0
1	66.2	66.1	66.2	66.1	67.1	67.1	67.0	67.1	67.7	67.1	66.8	66.8	68.0	68.2
5	64.2	64.4	64.2	64.4	64.9	65.2	64.8	65.1	65.8	65.5	64.8	65.2	65.4	65.9
10	59.9	60.2	59.9	60.2	60.5	60.8	60.4	60.8	61.5	61.3	60.5	60.9	61.0	61.5
15	55.2	55.5	55.2	55.5	55.8	56.1	55.7	56.1	56.8	56.6	55.8	56.2	56.2	56.7
20	50.7	50.9	50.7	50.9	51.3	51.5	51.1	51.5	52.3	52.0	51.3	51.7	51.7	52.1
25	46.1	46.6	46.1	46.6	46.6	47.1	46.5	47.1	47.7	47.6	46.7	47.3	47.1	47.7
30	41.6	42.2	41.6	42.2	42.1	42.8	42.0	42.7	43.2	43.2	42.2	43.0	42.5	43.3
35	37.1	37.9	37.1	37.9	37.6	38.4	37.5	38.3	38.6	38.8	37.7	38.6	37.9	38.8
40	32.7	33.6	32.7	33.6	33.2	34.1	33.1	34.0	34.2	34.5	33.3	34.2	33.5	34.5
45	28.4	29.2	28.4	29.2	28.8	29.7	28.7	29.6	29.8	30.1	28.9	29.8	29.2	30.1
50	24.3	25.0	24.3	25.0	24.7	25.4	24.6	25.3	25.5	25.8	24.7	25.5	25.0	25.7
55	20.3	20.7	20.3	20.7	20.6	21.1	20.5	21.1	21.4	21.5	20.6	21.2	20.9	21.4
60	16.5	16.8	16.5	16.8	16.9	17.1	16.8	17.1	17.4	17.4	16.8	17.1	17.1	17.4
65	13.0	13.1	13.0	13.1	13.2	13.3	13.2	13.3	13.7	13.6	13.2	13.3	13.5	13.6
70	10.0	10.0	10.0	10.0	10.3	10.2	10.2	10.1	10.6	10.3	10.2	10.1	10.4	10.3
75	7.5	7.3	7.5	7.3	7.7	7.5	7.6	7.4	7.8	7.6	7.6	7.4	7.8	7.6
80	5.2	4.8	5.2	4.8	5.3	5.0	5.2	4.9	5.4	5.0	5.2	4.9	5.3	5.0
85 & Over	3.2	2.9	3.2	2.9	3.3	3.0	3.3	3.0	3.4	3.0	3.3	2.9	3.4	3.1

5. Discussion

We see that the largest number of deaths per year among both the males and the females is in the first year of life (Table 1), which is different from the United States (Life tables for 1973-White) population which had the largest number in the intervals over 75 years. Although the greatest values of the probability of dying are in the last two intervals of life for both populations, the value in the first year of life of Sri Lanka is about four times as great as that of the United States. After the first year, life expectancy increases by 3.2 years for males and 2.5 for females, again reflecting high infant mortality, whilst for the U.S. it remained almost constant. However, the life expectation itself is fairly high for a developing country. From 1963 onwards the life expectation at birth for females began exceeding that of males, though by a small margin (Figure 1), but as we see (Table 1), past the age of 70 years the males still appear to have a longer life expectation. Among the diseases of older ages we notice that heart diseases seem to affect the males more than the females, while cancer appears to have an opposite effect.

The greatest increase in life expectation at birth with a single cause eliminated occurs with the elimination of "diseases of early infancy" (Table 4) —which was to be expected from our examination of the life tables (Table 1) and the fact that this was the highest cause of death (12 percent), nearly double its nearest competitor (7 percent). However, this increase is only about two years. The next three highest causes, amounting to 7 percent, 6 percent and 6 percent respectively, of the crude death rate, when eliminated increase the life expectation by about equal amounts, none being higher than 1.5 years. The fourth highest, heart diseases, when eliminated, causes a greater increase than any of the higher causes in the years 35 to 75; the reason for which is clear if one examines the percentage contribution to the age specific death rates from each cause (Table 3) and the number of life table deaths due to each cause (Table 2). Heart diseases account for 10 to 20 percent of the deaths in these age intervals while accounting for only 6 percent over all ages.

The highest increase in life expectancy, when a cause was removed, was only 2.4 years. Even if we eliminate the three highest causes of death, a total of 25 percent of the crude death rate, the increase is only 4.7 for males and 4.4 for females. This is not surprising when one considers the fact that 25 percent of the crude death rate is a mere 2 per 1,000. This raises a question : how is it that the death rate is only 8 per 1,000 when in more developed countries with longer life expectations, like the United States and Sweden, the crude death rate is greater? The answer lies in the fact that the sudden rise of the natural increase since 1946 has made the population very young compared to the developed countries—the mean age being 23 for females and 25, for males, with the median between 15 and 19 years. With a large proportion of the

population being quite young, and consequently not exposed to the risk of death as much as the older populations of the U.S. and Sweden are, quite naturally we find a smaller proportion of the total population succumbing to death, which is what affects the crude death rate.

Another imbalance in this crude death rate is seen when we examine how the 25 percent contributed by the three highest causes is spread among the age groups (Table 5).

TABLE 5. The Percentage Distribution Among the Age Intervals of the Deaths due to the Three Highest Causes of Death

Beginning of Age Interval	Male	Female
0	64.1	57.1
1	13.4	16.5
5	2.4	3.4
10	0.9	1.3
15	0.8	0.9
20	0.7	1.4
25	0.7	1.4
30	0.8	1.3
35	1.0	1.5
40	0.8	1.1
45	1.0	1.1
50	1.2	1.1
55	1.5	1.3
60	2.3	2.0
65	2.2	2.0
70	2.2	2.0
75	1.4	1.4
80	1.2	1.3
85 & Over	1.4	2.0
All Ages	100.0	100.0

Three quarters of the deaths from the three highest causes of mortality are concentrated on the first five years of life. Let us examine the consequences of this. Is the main difference between the populations of Sri Lanka and the developed countries solely in the mortality of the group under 5 years of age? Again turning to the United States (Life tables for 1973 - White) population we find the life expectation at birth to be 68.4 for males and 76.1 for females. With the three highest causes of death eliminated the corresponding figures for Sri Lanka were 67.7 and 68.0, respectively. The male life expectation is near the U.S. figure, but that is not the case for the females. To compare the childhood mortality alone, we could substitute the U.S.values of the age specific probabilities of death in the earlier intervals of the Sri Lanka life table (Table 6).

TABLE 6. Comparison of the Age Specific Probabilities (A.S.P.) of Death in the First Two Intervals of Age, and the Life Expectation at Birth (Exp.) when the Probabilities are the same as the U.S. Values for These Two Intervals.

	U.S.		Sri Lanka	
	Male	Female	Male	Female
A.S.P. 0 to 1 year	0.0175	0.0133	0.062	0.052
A.S.P. 1 to 4 years	9.0032	0.0025	0.031	0.035
Exp. with U.S. A.S.P. in 0 - 4 years	68.4	76.1	67.8	68.35

We see that the difference in the two male populations is almost fully accounted for by childhood mortality. Among the females, however, there is still a gap of almost eight years. If the 5 to 10 year old Sri Lankan females also had the age specific probabilities of the corresponding American population, then the life expectancy would increase to 69.0, which is hardly an improvement. Hence, we look at the ratios of the age specific probabilities of death for females in each interval (Table 7).

TABLE 7. The Ratios of the Female Age Specific Probabilities of Death, Sri Lanka Divided by United States.

Beginning of Age Interval	Ratio
0	3.9
1	14.3
5	7.4
10	3.9
15	2.7
20	4.1
25	4.5
30	3.4
35	2.9
40	1.9
45	1.5
50	1.3
55	1.4
60	1.4
65	1.8
70	1.7
75	1.4
80	1.4
85 & over is 1 for all populations.	

Since the probability in Sri Lanka is more than treble that of the United States in almost every age interval until the age of 40, this leads one to suspect maternal mortality. We examine this by eliminating maternal mortality; the resulting life expectations at birth for females are presented in Table 8.

TABLE 8. Life Expectations for Females Eliminating Maternal Mortality

	Expectations	Added Years
Eliminating maternal mortality (B. 40) only	64.1	0.5
Eliminating maternal mortality and with U. S. A.S.P. 0 to 4	68.9	5.3
Eliminating maternal mortality and with U. S. A.S.P. 0 to 9	69.5	5.9

Though there is an improvement it is still far behind the U.S. value of 76.1 years. Here it should be noted that we eliminated only those deaths which were attributed directly to maternal mortality. Some of the others could possibly be related indirectly to the problems of the child-bearing years. Looking at it another way, especially since we can account for the difference in the male mortality and since the male and female life expectations at birth for Sri Lanka are similar, the more pertinent question to pose would be : What makes the American female live so long? But that is another question, which we shall not try to answer, because it does not deal with the population under study.

Conclusions

The crude death rate in Sri Lanka is unusually low for any country in the world partly because of the sudden drop in death rates around 1946. This caused the natural increase to become very high, giving rise to a younger population. It also postponed many deaths (Figure 2): the sudden drop in 1946 benefited the older age groups as well — even the over 55 death rate was almost halved. Thus we could expect, as those who got a new lease on life begin to reach the end of their extended life span, that the deaths in the later intervals would begin to rise. As the birth rates fall and the age structure becomes more stabilized and older, one would expect the crude death rate to rise a little.

As a result of the low crude death rate, causes of death accounting for large proportions of the crude death rate do not amount to large proportions of the total population except in the younger ages where the population is concentrated. A rise in life expectation, which among males would bring it up to the standard of the U.S. population, could be achieved by lowering childhood mortality. In the older working ages the cause, which if eliminated would raise life expectancy most, is heart disease. As the population becomes older one would expect heart disease and cancer (cancer accounted for only 3 percent in 1964) to become more formidable threats as major causes of death.

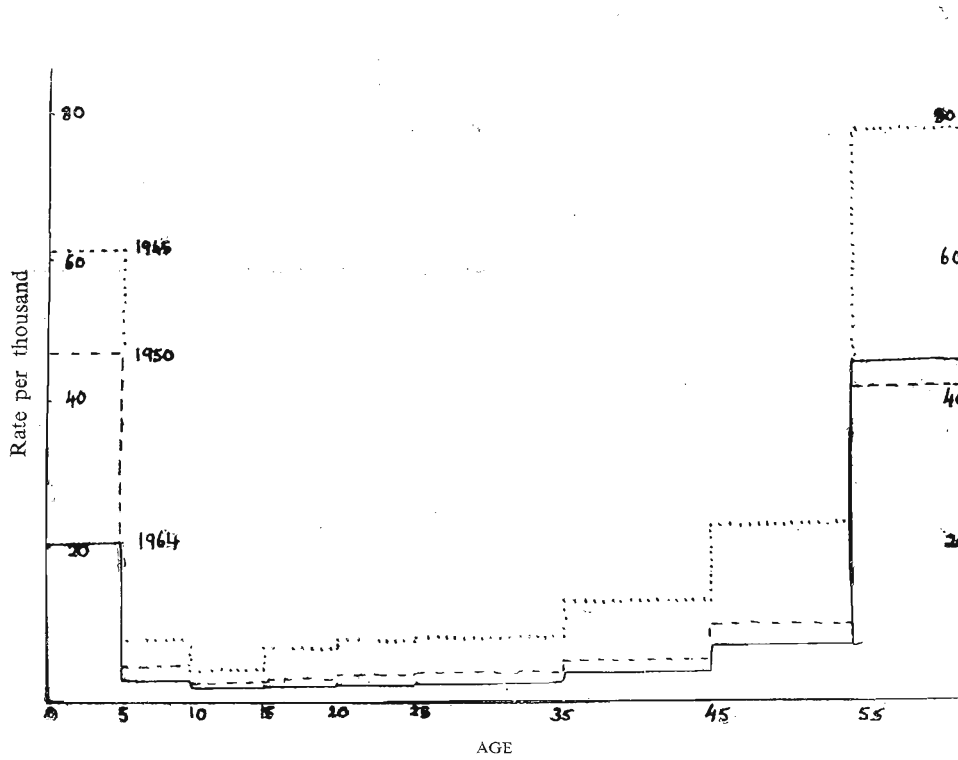

Figure 2. Age Specific Death rate per 1,000 — Sri Lanka.

By cutting down childhood mortality alone the male population could achieve a life expectation comparable to the U.S. (Life tables for 1973 - White) population. The absolute gain among females would be as great, although far short of the unusually high expectation of the corresponding U.S. female population. It is likely that the life expectancies should keep rising although at a slower rate than before.

Judging from mortality, life expectation and life tables, the 1964 population of Sri Lanka seems to have quite a good state of health for a developing country. The problem would be to maintain this level. It is heartening to note that steps have already been taken to cut down the birth rate rapidly enough to achieve a stable population and thus guard against the manifold problems of overpopulation.

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