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Effect of Elimination of Leading Causes of Death in Rural Bangladesh: Potential Gains in Life Expectancies

Introduction

SEVERAL causes of death are competing with each other to take away the life of an individual; Some of them are independent and some are interrelated or difficult to differentiate. Others are preventive in nature, and a few are controllable, yet some others are beyond control. These causes may not be equally responsible/effective for all age groups. Some of the causes may be highly dominant in the lower age groups while some others may be dominant in the higher age groups. There may be sex and/or location biased causes of death. Elimination of a disease usually yield highest gain in life expectancy in the < 1 year age group, with a decreasing trend along to the higher age groups, but the percent gain in life expectancy may not follow this trend (Hossain, 1992).

Even in the recent past, the developing countries witnessed heavy loss of lives caused by infective, parasitic, respiratory and diarrhoeal diseases as such, coupled with lack of health and medical services. The situation started to improve after the Second World War with the advent of extended health and medical services and correspondingly an impressive gain in life expectancy was registered. Notwithstanding the remarkable decline in deaths, respiratory, infectious and other diseases in these countries are still predominant causes of death and take a sizable proportion of lives. However, there would be an ample scope for further gain in the

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expectation of life even though socio-economic status could not be changed significantly. Most of the infectious diseases and epidemics can be brought under control with the use and implementation of safe drinking water, hygienic sanitation and effective immunization technique (preventive technology).

Health system in Bangladesh is mainly divided into two broad strata viz., preventive and curative, while the latter has found more importance than the former. In any country to attain a sound health status, preventive measure is more effective since it has enough potentialities of reducing mortality rate significantly. Needless to mention that mortality rate is still very high in Bangladesh as in many other developing countries where infant mortality is at the top of the list. In a rural community of Bangladesh Chen *et al.* (1980) found that the most significant causes of death for the under-five years of age group were diarrhoea and dysentery, tetanus, measles, fever, respiratory and dropsy; and these causes accounted for 18.8, 9.9, 4.7, 9.2, 8.1 and 6.9 per cent of the total deaths respectively.

Tetanus, measles, whooping cough and tuberculosis can be subsided by preventive measures of immunization. This has been reflected in the ongoing expanded programme of immunization (EPI) commenced partially in 1982 (Report of the Task Forces, 1990; UNICEF, 1987). The preventive measures make a marked contribution in reducing the deaths from infectious and diarrhoea! diseases and thus help in gaining the expectation of life (Hossian, 1992). Presumably expectation of life will be increased if we are able to eradicate the infectious as well as the diarrhoea! diseases through proper preventive measures. To evaluate the impact of these diseases on human longevity, we may compare the mortality and survival experience of a population where infectious and diarrhoeal diseases are to be removed as cause of death. A number of works have been done in India and some other advanced countries investigating the effect on the expectation of life if some causes of death were eliminated from the population (Gupta and Rao, 1973; Gupta, 1975; Hemminki *etal.*, 1976;Tsai(?/a/., 1983). Following the existing methodology, it is observed that traditional multiple decrement approach is too weak to analyze data in the competing risk setup. Entrophy method of Keyfitz (1977) underestimates the gain in expectation of life when mortality rate is high and linear approximation method of Tsai (1983) overestimates the gain in expectation of life while rate of mortality is high. The life table and the theory of competing risks provide the most convenient methods for the analysis of the problems as such. In this paper an attempt has been made to observe the effect of the elimination of infectious and diarrhoeal diseases on the expectation of life at different age groups by sex during 1984 and 1995. The data corresponding to the year 1995 were taken as the average figure for the period 1994 to 1996 in order to reduce the sampling variability.

Materials and Methods

The data analyzed here were collected and primarily reported by Demographic Surveillance system (DSS)-Matlab of the International Centre for Diarrhoeal Disease Research, Bangladesh (ICDDR,B). Details of the Matlab programme are available elsewhere (Bhatiae/ *al.*, 1980; Philips *et al.*, 1984; Hossain, 1992); however a brief description is given here. Beginning in 1963, the ICDDR.B initiated a Demographic Surveillance System in selected villages within

expectation of life even though socio-economic status could not be changed significantly. Most of the infectious diseases and epidemics can be brought under control with the use and implementation of safe drinking water, hygienic sanitation and effective immunization technique (preventive technology).

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Tetanus, measles, whooping cough and tuberculosis can be subsided by preventive measures of immunization. This has been reflected in the ongoing expanded programme of immunization (EPI) commenced partially in 1982 (Report of the Task Forces, 1990; UNICEF, 1987). The preventive measures make a marked contribution in reducing the deaths from infectious and diarrhoeal diseases and thus help in gaining the expectation of life (Hossian, 1992). Presumably expectation of life will be increased if we are able to eradicate the infectious as well as the diarrhoea! diseases through proper preventive measures. To evaluate the impact of these diseases on human longevity, we may compare the mortality and survival experience of a population where infectious and diarrhoeal diseases are to be removed as cause of death. A number of works have been done in India and some other advanced countries investigating the effect on the expectation of life if some causes of death were eliminated from the population (Guptaand Rao, 1973; Gupta, 1975; Hemminki *etal.*, 1976;Tsaie/a/., 1983). Following the existing methodology, it is observed that traditional multiple decrement approach is too weak to analyze data in the competing risk setup. Entrophy method ofKeyfitz(1977) underestimates the gain in expectation of life when mortality rate is high and linear approximation method of Tsai(1983) overestimates the gain in expectation of life while rate of mortality is high. The life table and the theory of competing risks provide the most convenient methods for the analysis of the problems as such. In this paper an attempt has been made to observe the effect of the elimination of infectious and diarrhoeal diseases on the expectation of life at different age groups by sex during 1984 and 1995. The data corresponding to the year 1995 were taken as the average figure for the period 1994 to 1996 in order to reduce the sampling variability.

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an area adjacent to Matlab Thana, Greater Comilla district, Bangladesh. The DSS combined periodic censuses of the study population with continuous registration of vital events; births, deaths and migrations. In 1977 an MCH-FP programme was installed in almost half of the DSS area which is known as the *Treatment* area. The remaining half of the area, known as *Comparison* area receives only government usual facilities. Initially, in *Treatment* area only family planning services and treatment of minor ailments for women and children were offered; but as the programme got underway a selected package of immunization, oral therapy and nutrition education was introduced. On the other hand, in the *Comparison* area no extra offer other than the government facilities was given.

The DSS report has identified 21 major causes of death including tuberculosis, tetanus, other infectious diseases, ARI, diarrhoea and dysentery. In this study we reclassify the causes of death into three major disease groups, viz., infectious diseases, diarrhoeal diseases and other diseases. Tetanus, tuberculosis, measles and respiratory ailments have been categorized as the infectious diseases; the diarrhoeal diseases consist of acute diarrhoea, chronic diarrhoea, acute dysentery, chronic dysentery and cholera (proved) and rest of the causes belong to the other disease group. Most of the causes belonging to the infectious disease group can be eradicated by some preventive measure such as immunization programme. The causes falling in the diarrhoeal disease group can be prevented through using safe water, sound sanitation, usual hygienic health behaviour, and the deaths from diarrhoeal diseases can be averted by using oral rehydration therapy. The causes belonging to the other disease group are assumed here not to be prevented by immunization or improved hygienic behaviour.

In Bangladesh, no investigation is done on competing risks to study the impact of different diseases on life expectancy. Expanded Programme of Immunization (EPI) and preventive measure of diarrhoeal diseases such as oral rehydration therapy (ORT) are being carried on in Bangladesh. The study investigates the gain in expectation of life if infectious and diarrhoeal diseases are completely eradicated from the population. Individual gain and joint gain are investigated by different factors affecting the mortality using classical model of Chiang (1968). The justification of using classical method lies in the fact that mortality rate is comparatively higher in Bangladesh.

The basic methodology is based on the construction of life tables. While several different techniques have been proposed in the literature, this study uses Chiang's (1968) technique which is operationally more convenient in converting age specific death rates to the probability of dying. The construction of multiple decrement life table is discussed briefly in the Appendix. These life tables serve the basis on which the potential gains of life expectancies are evaluated when a certain cause or a group of causes are thought to be completely or partially eliminated. The data were averaged for each age group, for each sex and for both the areas for the consecutive years 1994, 1995 and 1996. However, data for the year 1984 were taken for single year since the data of consecutive years are not available for that period.

Results and Discussions

The absolute gain and per cent gain in the life expectancy have been calculated for each age group by taking different causes of death into consideration. Tables 1-3 show the

TABLE 1 : EFFECTS OF ELIMINATION OF INFECTIOUS, DIARRHOEAL AND BOTH DISEASES ON EXPECTATION OF LIFE (BOTH SEX), TREATMENT AREA, MATLAB, BANGLADESH

Age	*Life Expectancy*	*Life Expectancy and gain after elimination of Disease Group*					
		Infectious	*% Gain*	*Diarrhoeal*	*% Gain*	*Both diseases*	*%Gain*
			For the Year 1995*				
<1	65.11	67.16	3.14	66.73	2.48	68.88	5.79
1-4	68.21	69.42	1.78	69.32	1.63	70.61	3.53
5-9	65.81	66.85	1.59	66.62	1.23	67.73	2.92
15-44	56.51	57.48	1.71	57.21	1.24	58.25	3.07
45-64	29.02	29.68	2.27	29.65	2.18	30.37	4.67
65-84	13.63	13.98	2.25	14.15	3.77	14.55	6.76
85+	4.60	4.80	4.44	5.02	9.30	5.27	14.63
			For the Year 1984				
<1	53.33	57.24	7.33	58.73	10.11	63.49	19.04
1-4	58.86	61.01	3.66	63.97	8.68	66.79	13.48
5-9	60.40	62.17	2.93	62.78	3.94	65.11	7.80
15-44	51.62	53.23	3.11	53.67	3.97	55.83	8.14
45-64	24.50	25.91	5.75	26.29	7.32	28.24	15.30
65-84	10.76	11.32	5.21	11.80	9.64	12.86	19.46
85+	3.25	3.91	20.45	3.58	10.42	4.41	35.90

*The data corresponding to the year 1995 were taken as the average figure for the period 1994 to 1996

TABLE 2 : EFFECTS OF ELIMINATION OF INFECTIOUS, DIARRHOEAL AND BOTH DISEASES ON EXPECTATION OF LIFE (MALE), TREATMENT AREA, MATLAB, BANGLADESH

Age	*Life Expectancy*	*Life Expectancy and Gain after elimination of Disease Groups*					
		Infectious	*% Gain Diarrhoea! % Gain*			*Both diseases %*	*Gain*
For the Year 1995*							
<1	64.18	66.20	3.14	65.64	2.27	67.79	5.63
1-4	67.27	68.70	2.13	68.22	1.42	69.77	3.72
5-9	64.69	65.94	1.93	65.45	1.18	66.81	3.28
15-44	55.34	56.52	2.12	55.98	1.15	57.26	3.46
45-64	27.79	28.64	3.06	28.41	2.23	29.36	5.67
65-84	13.32	13.79	3.53	13.92	4.48	14.50	8.81
85+	4.50	4.85	7.69	5.04	12.00	5.48	21.74
			For the Year 1984				
<	54.34	58.71	8.04	58.82	8.24	63.91	17.61
1-4	60.27	62.68	3.99	64.44	6.91	67.39	11.81
5-9	60.37	62.33	3.25	62.62	3.73	65.04	7.74
15-44	51.36	53.27	3.72	53.39	3.96	55.75	8.56
45-64	23.93	25.55	6.79	25.80	7.82	27.87	16.45
65-84	11.47	11.95	4.11	12.37	7.79	13.15	14.61
85+	3.41	4.19	23.08	3.63	6.67	4.54	33.33

*The data corresponding to the year 1995 were taken as the average figure for the period 1994 to 1996.

expectation of life and the absolute gain and per cent gain after the elimination of infectious, diarrhoeal and both diseases separately and combined for different age groups, for both sex, for male and for female in the *Treatment* area for the year 1984 and 1995. Tables 4-6 represent the *Comparison* area for the same. It is observed from Tables 1 and 4 that the life expectancy at birth was 53.3 and 65.1 years in the *Treatment* area compared to 48.7 and 62.8 years in the *Comparison* area in the years 1984 and 1995. In the *Treatment* area, the life expectancy at birth was 54.3 years for males compared to 52.4 years for females in 1984, while the corresponding figures were 64.2 and 66.0 years respectively for males and females in 1995 (Tables 2 and 3). Tables 5 and 6 show that the life expectancy at birth was 50.7 years for males compared to 46.8 years for females in the *Comparison* area in 1984, while the corresponding figures for male and females were 61.7 and 63.7 years respectively in 1995.

TABLE 3 : EFFECTS OF ELIMINATION OF INFECTIOUS, DIARRHOEAL AND BOTH DISEASES ON EXPECTATION OF LIFE (FEMALE), TREATMENT AREA, MATLAB, BANGLADESH

Age	*Life Expectancy*	*Life Expectancy and Gain after elimination of Disease Groups*					
		Infectious	*% Gain*	*Diarrhoeal*	*% Gain*	*Both diseases*	*%Gain*
				For the Year 1995*			
< 1	66.02	67.96	2.94	67.80	2.69	69.81	5.74
1-4	69.13	70.03	1.30	70.41	1.85	71.34	3.20
5-9	66.92	67.67	1.12	67.77	1.27	68.55	2.44
15-44	57.68	58.39	1.23	58.44	1.32	59.18	2.61
45-64	30.24	30.66	1.38	30.88	2.12	31.33	3.60
65-84	14.00	14.17	1.27	14.43	3.14	14.63	4.54
85+	4.68	4.68	0.00	4.94	5.56	4.94	5.56
				For the Year 1984			
<1	52,44	55.84	6.48	58.57	11.70	62.59	19.37
1-4	57.58	59.42	3.20	63.42	10.16	65.68	14.07
5-9	60.73	61.93	1.99	62.94	3.64	64.42	6.08
15-44	52,21	53.13	1.75	53.96	3.35	55.13	5.59
45-64	25.41	26.17	2.99	26.78	5.40	27.79	9.39
65-84	10.40	10.53	1.19	11.15	7.22	11.51	10.62
85+	3.00	3.00	0.00	3.50	16.67	3.50	16.67

*The data corresponding to the year 1995 were taken as the average figure for the period 1994 to 1996.

An examination of the tables revealed that the life expectancy at birth has increased by 11.8 years in the *Treatment* area compared to 14.1 years in the *Comparison* area during the period 1984 to 1995. The increment of life expectancy was higher for females (16.9 years in *Comparison* area and 13.6 years in *Treatment* area) compared to males (11.0 years in *Comparison* area and 9.8 years in *Treatment* area) during the period 1984to 1995. It suggests that the MCH-FP programme helped female much more than male in gaining life expectancy.

When infectious diseases were eliminated as risk of death, the expectation of life at birth rises to as high as 57.2 years in the *Treatment* area and 54.7 years in the *Comparison* area for the year 1984. The corresponding life expectancy for the year 1995 were 67.2 and 65.4

years for *Treatment* and *Comparison* area respectively (Tables 1 and 4). The gain in life expectancy was observed to be higher for males compared to females in both the areas and in both the

TABLE 4 : EFFECTS OF ELIMINATION OF INFECTIOUS, DIARRHOEAL AND BOTH DISEASES ON EXPECTATION OF LIFE (BOTH SEX), COMPARISON AREA, MATLAB, BANGLADESH

Age	*Life Expectancy*	*Life Expectancy and Gain after elimination of Disease Groups*					
		Infectious	*% Gain*	*Diarrhoeal*	*% Gain*	*Both diseases*	*% Gain*
				For the Year 1995*			
<1	62.75	65.37	4.18	65.25	3.98	68.09	8.51
1-4	67.18	68.45	1.89	69.25	3.07	70.68	5.20
5-9	65.25	66.21	1.48	66.56	2.01	67.67	3.71
15-44	55.94	56.84	1.60	57.12	2.10	58.15	3.95
45-64	28.34	28.95	2.15	29.49	4.07	30.23	6.69
65-84	13.34	13.68	2.53	14.29	7.07	14.75	10.58
85+	5.00	5.30	6.06	6.03	20.69	6.48	29.63
				For the Year 1984			
<1	48.66	54.65	12.29	55.20	13.44	62.58	28.59
1-4	54.43	57.83	6.25	61.08	12.21	65.51	20.34
5-9	59.32	60.98	2.80	61.92	4.39	64.28	8.35
15-44	51.12	52.49	2.68	53.20	4.07	55.24	8.06
45-64	23.71	24.78	4.53	25.53	7.70	27.28	15.06
65-84	9.68	9.83	1.62	10.38	7.24	11.19	15.63
85+	5.88	6.67	13.33	7.14	21.43	8.33	41.67

*The data corresponding to the year 1995 were taken as the average figure for the period 1994 to 1996

period 1984 and 1995. Further, the gain was observed to be higher in lower and upper age groups compared to middle age groups in both the periods in both the *Treatment* and *Comparison* areas. Clearly, in the study areas the maximum gain in life expectancy for the year 1984 was 23.1% which is observed for male at 85+ age group in the *Treatment* area, while the maximum gain in 1995 was 7.7% for the same old age group of males in the *Comparison* area (Tables 2, 3, 5 and 6). From the above discussion, it transpires that the infant and the aged persons benefited more due to the elimination of infectious diseases. So emphasis should given to the male child than female child in reducing the infectious diseases. Moreover, the gain in life expectancy was slightly higher in the *Comparison* area compared to *Treatment* area for both the time period 1984 and 1995 which reflects the success of the MCH-FP programme

When diarrhoeal diseases were eliminated as risk of death, the expectation of life at birth increased to 58.7 years in the *Treatment* area and 55.2 years in *Comparison* area for the year 1984. Whereas, the corresponding figures for the year 1995 raised 66.7 for the *Treatment* area and 65.3 in the *Comparison* area. The gain in life expectancy was observed to be higher in all the ages in the *Comparison* area compared with *Treatment* area in both the period 1984 and 1995. Further, the gain was observed to be higher in the higher age groups (45 and above) and lower age groups (less than 5 years) compared with middle age groups in both the

TABLE 5 : EFFECTS OF ELIMINATION OF INFECTIOUS. D1ARRHOEAL AND BOTH DISEASES ON EXPECTATION OF LIFE (MALE). COMPARISON AREA, MATLAB, BANGLADESH

Age	*Life Expectancy*	*Life Expectancy and Gain after elimination of Disease Groups*					
		Infectious	*% Gain*	*Diarrhoeal*	*% Gain*	*Both diseases*	*% Gain*
				For the Year 1995*			
< 1	61.74	64.70	4.79	64.14	3.88	67.33	9.05
1-4	66.47	67.89	2.14	68.33	2.81	69.92	5.20
5-9	64.36	65.59	1.90	65.61	1.94	66.99	4.08
15-44	55,13	56.29	2.10	56.27	2.07	57.58	4.43
45-64	27.42	28.27	3.10	28.57	4.16	29.56	7.80
65-84	13.31	13.73	3.16	14.11	6.00	14.66	10.12
85+	5.00	5.26	5.26	5.88	17.65	6.25	25.00
				For the Year 1984			
< 1	50.73	56.90	12.16	55.91	10.21	62.81	23.82
1-4	57.01	60.32	5.81	62.10	8.92	65.81	15.43
5-9	60.19	61.80	2.67	62.34	3.57	64.10	6.49
15-44	51.73	53.16	2.77	53.49	3.40	55.06	6.43
45-64	23.86	24.99	4.77	25.15	5.42	26.39	10.63
65-84	10.00	10.00	0.00	10.00	0.00	10.00	0.00
85+	8.38	9.57	14.29	11.17	33.33	13.40	60.00

*The data corresponding to the year 1995 were taken as the average figure for the period 1994 to 1996.

TABLE 6 : EFFECTS OF ELIMINATION OF INFECTIOUS. D1ARRHOEAL AND BOTH DISEASES ON EXPECTATION OF LIFE (FEMALE). COMPARISON AREA, MATLAB, BANGLADESH

Age	*Life Expectancy*	*Life Expectancy and Gain after elimination of Disease Groups*					
		Infectious	*% Gain*	*Diarrhoeal*	*% Gain*	*Both diseases*	*% Gain*
For the				Year 1995*			
< 1	63.70	65.94	3.51	66.34	4.14	68.78	7.97
1-4	67.81	68.89	1.59	70.07	3.33	71.30	5.14
5-9	66.05	66.76	1.09	67.42	2.08	68.26	3.35
15-44	56.66	57.30	1.12	57.87	2.12	58.63	3.46
45-64	29.15	29.52	1.27	30.31	3.95	30.80	5.64
65-84	13.36	13.61	1.87	14.42	7.91	14.80	10.76
85+	4.93	5.29	7.14	6.17	25.00	6.73	36.36
				For the Year 1984			
< l	46.81	52.49	12.14	54.05	15.47	60.70	29.68
1-4	52.10	55.45	6.43	59.55	14.31	63.46	21.82
5-9	58.86	60.41	2.63	61.01	3.65	62.68	6.49
15-44	50.95	52.08	2.21	52.40	2.84	53.62	5.23
45-64	24,01	24.81	3.35	25.34	5.54	26.22	9.21
65-84	10.00	10.00	0.00	10.00	0.00	10.00	0.00
85+	3.67	4.13	12.50	4.13	12.50	4.71	28.57

*The data corresponding to the year 1995 were taken as the average figure fore the period 1994 to 1996.

periods (Tables 1 and 4). It was found that the gain in life expectancy was higher for the females than males in the *Treatment* area for the year 1984 (Tables 2 and 3), whereas in the same area the gain was slightly higher for males than females for the year 1995. In the *Comparison* area the gain in life expectancy was slightly higher for females than males with a negligible exceptions subject to elimination of diseases in both the periods (Tables 5 and 6),

When both infectious and diarrhoeal diseases were eliminated as independent risks of death the expectation of life rises to as high as 63.5 in the *Treatment* area and 62.6 years in the *Comparison* area for the year 1984. In 1995, the life expectancy rises to 68.9 years in the *Treatment* area and 68.1 years in the *Comparison* area. In 1984, the gain in expectation of life due to the elimination of both of the diseases were significantly higher (more than 14%) in higher (45 and above) and lower (under 5) age groups in both the areas. However, in 1995 the gain in life expectancy was more pronounced in higher age groups compared to lower age groups subject to the elimination of both the diseases. It was observed that the gain was more pronounced in the *Comparison* area than *Treatment* area in both the time periods.

The above results reflects that the gain in life expectancy has increased in a great deal during the period 1984 to 1995. This may be due to the ongoing EPI and ORT programmes commenced partially in the early eighties in Bangladesh.

Conclusions

The obtained results reflect that the gain in the expectation of life was affected more by diarrhoeal diseases than infectious diseases for all age groups and for both the sexes in both *Comparison* and *Treatment* area in both 1984 and 1995 periods with a few negligible exceptions. The elimination of diseases would benefited the *Comparison* area more than the *Treatment* area in all age groups for both the sexes. Since the expectation of life at birth is affected by all age groups, it is difficult to explain the effect of elimination of certain group and groups of diseases or causes, for any particular age group. However, the results of this investigation showed that the gain in expectation of life was higher for males compared to females in both the areas and in both the periods subject to the elimination of infectious diseases. Further, the gain in life expectancy was found to be higher in lower and higher age groups as compared to middle age groups due to elimination of both infectious and diarrhoeal diseases separately. It was noted that the reduction of deaths in the < 1 year age group contributed more in raising the life expectancy than the corresponding reduction in higher age groups. Elimination of infectious diseases showed a slightly higher gain in life expectancy in the < 1 year age group than elimination of diarrhoeal diseases. So, attention of remedial measures should be concentrated more to the elimination of infectious diseases than the diarrhoeal diseases.

The comparative picture crops up as the result of investigation is that the expectation of life in the *Treatment* area was higher in all the age groups than the *Comparison* area. This gain is, perhaps, achieved due to preventive measures and it implies that if the infectious and diarrhoeal diseases are eradicated from Bangladesh the expectation of life will increase at a significant rate. Therefore health planning of Bangladesh needs to include a more effective and separate strategy to combat these epidemic diseases. Allocation of resources should be

periods (Tables 1 and 4). It was found that the gain in life expectancy was higher for the females than males in the *Treatment* area for the year 1984 (Tables 2 and 3), whereas in the same area the gain was slightly higher for males than females for the year 1995. In the *Comparison* area the gain in life expectancy was slightly higher for females than males with a negligible exceptions subject to elimination of diseases in both the periods (Tables 5 and 6),

When both infectious and diarrhoeal diseases were eliminated as independent risks of death the expectation of life rises to as high as 63.5 in the *Treatment* area and 62.6 years in the *Comparison* area for the year 1984. In 1995, the life expectancy rises to 68.9 years in the *Treatment* area and 68.1 years in the *Comparison* area. In 1984, the gain in expectation of life due to the elimination of both of the diseases were significantly higher (more than 14%) in higher (45 and above) and lower (under 5) age groups in both the areas. However, in 1995 the gain in life expectancy was more pronounced in higher age groups compared to lower age groups subject to the elimination of both the diseases. It was observed that the gain was more pronounced in the *Comparison* area than *Treatment* area in both the time periods.

The above results reflects that the gain in life expectancy has increased in a great deal during the period 1984 to 1995. This may be due to the ongoing EPI and ORT programmes commenced partially in the early eighties in Bangladesh.

Conclusions

The obtained results reflect that the gain in the expectation of life was affected more by diarrhoeal diseases than infectious diseases for all age groups and for both the sexes in both *Comparison* and *Treatment* area in both 1984 and 1995 periods with a few negligible exceptions. The elimination of diseases would benefited the *Comparison* area more than the *Treatment* area in all age groups for both the sexes. Since the expectation of life at birth is affected by all age groups, it is difficult to explain the effect of elimination of certain group and groups of diseases or causes, for any particular age group. However, the results of this investigation showed that the gain in expectation of life was higher for males compared to females in both the areas and in both the periods subject to the elimination of infectious diseases. Further, the gain in life expectancy was found to be higher in lower and higher age groups as compared to middle age groups due to elimination of both infectious and diarrhoeal diseases separately. It was noted that the reduction of deaths in the < 1 year age group contributed more in raising the life expectancy than the corresponding reduction in higher age groups. Elimination of infectious diseases showed a slightly higher gain in life expectancy in the < 1 year age group than elimination of diarrhoeal diseases. So, attention of remedial measures should be concentrated more to the elimination of infectious diseases than the diarrhoeal diseases.

The comparative picture crops up as the result of investigation is that the expectation of life in the *Treatment* area was higher in all the age groups than the *Comparison* area. This gain is, perhaps, achieved due to preventive measures and it implies that if the infectious and diarrhoeal diseases are eradicated from Bangladesh the expectation of life will increase at a significant rate. Therefore health planning of Bangladesh needs to include a more effective and separate strategy to combat these epidemic diseases. Allocation of resources should be

earmarked so as to enhance health and hygiene awareness. The present efforts of spreading oral rehydration therapy practice and ongoing immunization programme seem to be better means so far introduced to fight out these evils. The effort is now needed to be concerted through integration of health education with these innovative preventive practices.

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Appendix

The probability that an individual alive at x_i will die in the interval (x_i, x_{i+1}) is

$$q_i = 1 - p_i = 1 - \exp\left(- \int_{x_i}^{x_{i+1}} \mu(t)dt \right)$$

where $\mu(t) = \sum_{\delta} \mu(t;\delta)$

is an additive function of the cause specific mortality intensity function $\mu(t; \delta)$ for $\delta = 1, 2, 3, \ldots, r$. The net probability of dying when the risk $R\delta$ is eliminated is

$$q_{i\delta} = 1 - \exp\{- \int_{x_i}^{x_{i+1}} [\mu(r) - \mu(t;\delta)]dt\}$$

$$= 1 - \exp\{- \int_{x_i}^{x_{i+1}} [\mu(t) - C_{i\delta}\mu(t)]dt\} \text{ where } C_{i\delta} = \frac{\mu(t;\delta)}{\mu(t)} \text{ is independent of time } i.$$

$$= 1 - \exp\{- \int_{x_i}^{x_{i+1}} (1 - C_{i\delta})\mu(t)dt\} = 1 - p_i^{C_{i\delta}} = 1 - p_i^{[\mu(t)-\mu(t;\delta)]/\mu(t)}$$

or $q_{i\delta} = 1 - p_i^{(q_i - Q_{i\delta})/q_i}$ where $q_i = D_i / N_i$ and $Q_{i\delta} = D_{i\delta} / N_i$

where N_i is the number of individuals alive at exact age x_i among whom D_i deaths occur in the interval (x_i, x_{i+1}).

So $\hat{q}_{i\delta} = 1 - \hat{p}_i^{(D_i - D_{i\delta})/D_i}$

When risks R_1 and R_2 is eliminated from the population the net probability of dying is given by

$$\hat{q}_{i\,12} = 1 - \hat{p}_i^{(D_i - D_{i1} - D_{i2})/D_i}$$

Therefore we can compute the life expectancy by using $\hat{q}_{i\,1}$ instead of $\hat{q}_i$ when risk R_1 is eliminated from the population. When risks R_1 and R_2 is eliminated from the population the life expectancy is computed by using $\hat{q}_{1\,12}$ instead of $\hat{q}_i$.

$$e_0 = \int_0^{\infty} S(t)dt \text{ where } S(\tau) = \exp\{-\int_0^{t} \mu(\tau)d\tau\}$$

The expectation of life at birth can be written as the integral of the survivor function as, if risk R_δ is eliminated completely, then

$$e_{0\delta} = \int_0^{\infty} \exp\{-\int_0^{t} [\mu(\tau) - \mu(\tau;\delta)]d\delta\}dt$$

The gain in life expectancy can be expressed in the integral form

$$e_{0\delta} - e_0 = \int_0^{\infty} S(t)\{\exp[\mu(t;\delta)] - 1\}dt.$$