THE AGE-SPECIFIC DEATH-RATES IN ENGLAND AND WALES

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(With 1 Figure in the Text)

The continuous fall in the birth-rate and the prospect of a declining population aroused considerable public interest during the interval between the two wars. Parliamentary debates, books and numerous articles were devoted to various aspects of the problem. Family allowances and the Population (Statistics) Act of 1938 were two measures which resulted from the concern expressed over the probability of a declining population. Various estimates were made of the maximum size of the population and of the year when it would start to decline. Most of the short-term estimates of the future population have been invalidated because the births and deaths followed an unpredicted trend. The forecasting of the size of the future population is necessary from many aspects of administration and for planning future policy. The Statistical Basis of the Pensions Bill (Editorial, 1925) may be used as an example of the necessity and difficulties of population forecasting. The Government Actuary, who based his prediction largely on the 1921 census, estimated that the population in the United Kingdom at ages 65 and over in 1951 would be 4,942,000 persons but actually there were 5,628,200 persons, i.e. the observed number was 13·9 % more than the expected number. Greenwood (1925), discussing in 1925 the growth of the population in England and Wales, thought 'That the general death-rate is now very close to its minimum value and that in a few years, probably within six or seven years, it will increase and by 1941 will have regained the height of the last years before the war. It will then continue to increase until the population is stationary.' In fact, the large falls in the death-rates, particularly in the very young age groups, have counteracted the ageing of the population and the crude death-rate has fluctuated around a low level and indeed the rate for 1952, 11·3 per 1000, was below any value recorded prior to Greenwood's paper. Although Greenwood placed the start of the increase in the crude death-rate much too early his main argument holds, and with the continuous ageing of the population an increase in the crude death-rate must occur in the future. The population must also decline in size unless the births increase in numbers and remain at or above the level necessary to replace the population into which they are born. The chief reason why most of the population estimates have been in error is that the authors did not predict a continuous fall in the death-rate. In the light of medical knowledge at the time it was reasonable to expect that the death-rates at ages would improve more slowly as time advanced until the irreducible core of mortality was reached.

https://doi.org/10.1017/S0022172400027613 Published online by Cambridge University Press

The discovery and the general use of antibiotics in the last few years has caused a remarkable fall in the death-rates at the younger ages, much greater than any optimist in the 1930's would have dared to predict. The older age groups have not

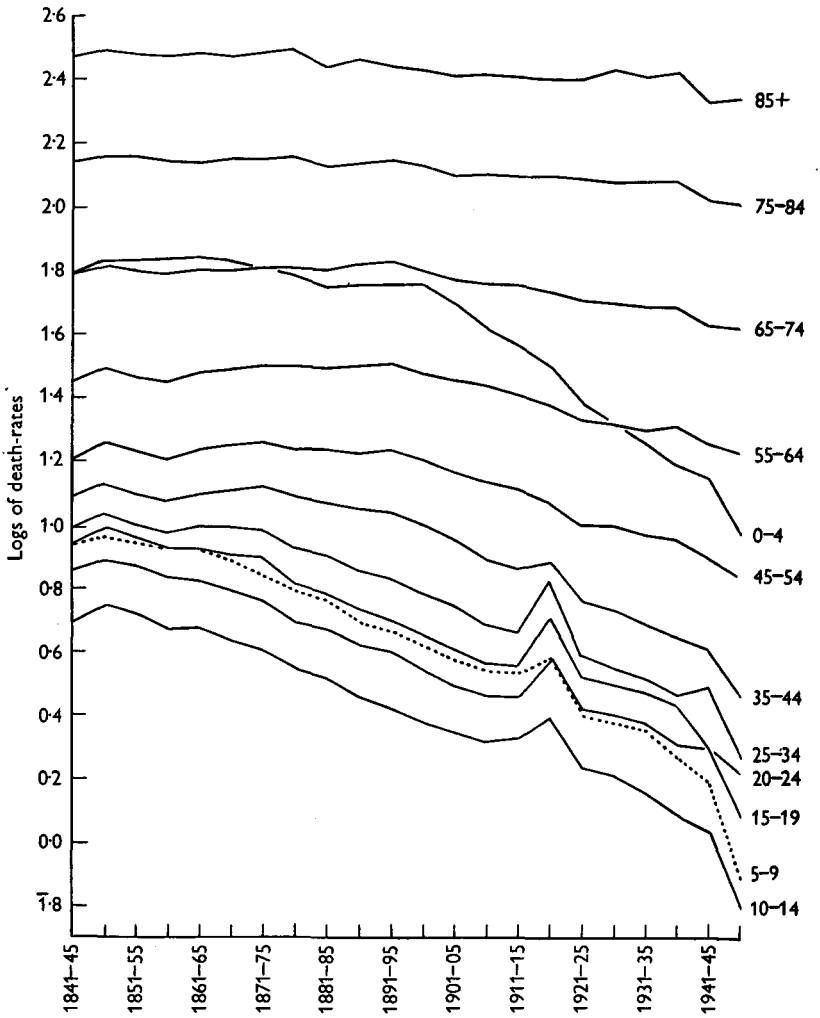

Fig. 1.

shown the same improvement in mortality. To obtain a picture of the trend since 1841 the logarithms of the death-rates in age groups for each quinquennium are shown in Fig. 1. The death rates for the single years of the last part of the period are shown in Table 1. The decrease in the death-rate is closely associated with age, the rate of fall diminishing with increasing age until, apparently, after age 55 the death-rate has reached its minimum value and there is no suggestion that the rate at the older ages will decline. In the last 7 years there has been a great improvement in the mortality of the younger ages; at ages under 25 the death-rate has been almost halved and a substantial fall has been recorded at ages 25–54. The

departure of these recent death-rates from the preceding trend can be illustrated by comparing the actual rates with those which might have been expected if no change had occurred in the rate of decline. To obtain the expected values a straight line was fitted to the logarithm of the actual values for the period 1921–45 and the expected values for 1946–52 found by extrapolation. The results obtained are shown in Table 2.

Table 1. *Death-rates per* 1000 *in England and Wales*

Year	0–	5–	10–	15–	20–	25–	35–	45–	55–	65–	75–	85+
1946	11·9	0·86	0·76	1·33	2·07	2·10	3·15	7·25	17·4	41·3	102·4	214·5
1947	12·1	0·90	0·70	1·39	1·92	2·03	3·08	7·24	17·5	42·8	108·3	234·4
1948	8·70	0·75	0·60	1·20	1·55	1·82	2·79	6·70	16·4	39·4	94·1	191·9
1949	7·71	0·69	0·56	1·10	1·51	1·70	2·80	6·81	17·2	43·1	105·7	227·5
1950	6·69	0·64	0·48	0·90	1·24	1·57	2·62	6·72	17·0	42·7	106·9	227·6
1951	6·54	0·56	0·47	0·76	1·13	1·46	2·62	6·89	18·0	46·3	117·9	280·9
1952	6·25	0·50	0·42	0·70	1·04	1·27	2·41	6·34	16·4	41·1	102·6	242·0

Table 2. *Deaths per* 1000 *population in England and Wales*

	Ages											
	0–		5–		10–		15–		20–		25–	
	E	A	E	A	E	A	E	A	E	A	E	A
1946	12·5	11·9	1·44	0·86	1·01	0·76	1·80	1·33	2·79	2·07	2·74	2·10
1947	12·2	12·1	1·41	0·90	0·98	0·70	1·77	1·39	2·78	1·92	2·70	2·03
1948	11·8	8·7	1·37	0·75	0·96	0·60	1·73	1·20	2·76	1·55	2·66	1·82
1949	11·5	7·7	1·34	0·69	0·94	0·56	1·70	1·10	2·74	1·51	2·63	1·70
1950	11·2	6·7	1·30	0·64	0·91	0·48	1·68	0·90	2·73	1·24	2·59	1·57
1951	10·8	6·5	1·27	0·56	0·89	0·47	1·65	0·76	2·71	1·13	2·56	1·46
1952	10·5	6·3	1·24	0·50	0·87	0·42	1·62	0·70	2·69	1·04	2·53	1·27

	Ages											
	35–		45–		55–		65–		75–		85+	
	E	A	E	A	E	A	E	A	E	A	E	A
1946	3·73	3·15	8·00	7·25	18·3	17·4	43·8	41·3	108·0	102·4	228·0	214·5
1947	3·66	3·08	7·91	7·24	18·2	17·5	43·5	42·8	107·4	108·3	226·5	234·4
1948	3·59	2·79	7·83	6·70	18·0	16·4	43·1	39·4	106·7	94·1	224·9	191·9
1949	3·52	2·80	7·74	6·81	17·9	17·2	42·8	43·1	106·0	105·7	223·4	227·5
1950	3·45	2·62	7·65	6·72	17·7	17·0	42·5	42·7	105·4	106·9	221·8	227·6
1951	3·39	2·62	7·56	6·89	17·6	18·0	42·2	46·3	104·8	117·9	220·2	280·9
1952	3·32	2·41	7·48	6·34	17·5	16·4	41·8	41·1	104·1	104·6	218·7	242·0

E = expected death-rate on basis of 1921–45 experience. A = actual death-rate.

The greatest reductions have occurred between ages 5–24, the actual rate being less than half the expected rate in each of the four quinquennial age groups. In the oldest age groups the actual rates are slightly in excess of the expected. The large improvement in the young ages and lack of improvement in the older age groups is in contradiction to the general predictions of the future trend of the death-rates made 20–30 years ago. Derrick (1927) suggested 'that the extent of the fall decreases with decreasing age until at the youngest ages where the past decline has

been most pronounced little further change is anticipated in the immediate future'. He went on to suggest improvements of 'as much as 35 % of the present mortality in respect of ages 45–55, over 40 % at ages 55–65 and 65–75 and slightly less at ages 75–85'.

The relationship between age and the chance of dying has been a subject of interest over the years, and many efforts have been made to obtain a mathematical representation of the law of mortality since Halley constructed the first life table and De Moivre postulated a limit of life of 86 years and a dying off in arithmetic progression. The most important from an actuarial point is the Makeham–Gompertz law. Gompertz arrived at the conclusion that the force of mortality, i.e. the risk of dying, increases in geometrical progression throughout life. Makeham carried the formula a stage further and assumed that the force of mortality consisted of two parts, the one constant and the other increasing in geometrical progression throughout life. This law gives an extremely close description of many mortality tables from age 20 to the limits of life. It is not possible to give any biological meaning to the law, $\mu_x = A + Bc^x$, because the constants A and B fluctuate considerably between one life table and another although a good graduation to each is obtained. Trachtenberg (1920) found for the rural districts of England and Wales in 1911–12 a value of A which was 50 % larger and a value of B that was only one-third of that of the urban districts. A simple hypothesis that A depends on environment would not be upheld by such a result. Greenwood (1928), reviewing the 'laws' of mortality from a biological point of view, concluded that it would be unlikely that the environmental factors would be covered by a term in the expression of the force of mortality which is independent of x. A more realistic scheme was found by Kermack, McKendrick & McKinlay (1934), who showed that there were certain regularities in the course of the death-rates by ages. A twofold classification of the relative mortality by age and date of birth gave a series of parallel diagonal lines along which the proportional death-rates were constant. This diagonal law led the authors to postulate that the death-rate at any age depended upon two factors, the environment into which the persons were born and the age under consideration, the former being the more important influence. The authors concluded that environment during the early years of life were the most important factor, and any improved conditions in later ages have little direct effect in determining the death-rates at older ages. Their law gave a good description of the death-rates over the period 1845–1925. It is of interest to see whether the modern trend in mortality diverges from this law. The following is a comparison of the observed and expected values for Scotland, the expected death-rates being the predicted values of Kermack *et al.*:

	1931		1941		1951	
Age	Observed	Expected	Observed	Expected	Observed	Expected
15–	2·8	2·9	3·4	2·5	—	—
25–	3·9	4·3	4·0	3·5	2·0	3·0
35–	6·1	6·4	5·6	5·0	3·3	4·2
45–	10·4	9·8	10·6	8·4	8·1	6·7
55–	22·0	20·8	22·0	17·1	20·4	14·4
65–74	53·6	55·7	51·3	43·8	49·3	38·0

The death-rates in 1931 are in fair agreement with the predicted values but the law fails to describe the recent age trend of the death-rate. The expected death-rates in 1951 at ages 45 and over are too low, and at ages under 45 they are too high. This departure of the predicted from the observed values is in the same direction as Derrick's prediction.

Cause of death

It would be of interest to determine the causes of death which have contributed to the change in mortality, but the break in the continuity of the classification of such causes in 1950 makes it impossible to examine them in detail. For this reason a restricted list of causes has been used for the younger age groups and for the oldest ages the period has been curtailed to the last 4 years, during which the new classification was in use.

Infancy

The fall in the death-rate at ages 0–4 was mainly contributed by infant mortality, for about two-thirds of the difference between the death-rates of 1946 and 1952 was due to the saving effected in the first year of life. The rates for the last 7 years are given in Table 3.

Table 3. *Death rates per* 100,000, *ages* 1–4

Year	Infant mortality per 1000	Infectious diseases (including tuber-culosis)	Nervous system and sense organs	Respira-tory system	Digestive system	Violence	Other causes
1946	43	63·1	13·3	48·5	16·7	35·5	31·1
1947	41	72·9	13·8	48·5	17·8	29·7	34·8
1948	34	50·1	11·8	36·6	14·5	30·4	31·7
1949	32	42·1	9·6	33·1	12·0	27·6	32·0
1950	30	34·3	7·9	29·0	10·4	23·9	29·5
1951	30	33·5	8·0	27·6	9·7	26·2	30·6
1952	28	21·2	7·3	23·1	9·4	25·1	31·7

As might be expected the largest falls in the death-rates at ages 1–4 occurred in conditions due to infective processes. The rates for the two numerically important causes of death, infectious diseases, including tuberculosis, and diseases of the respiratory system, fell by two-thirds and one-half respectively. The other three specified causes also showed large relative falls.

Childhood

During school life infectious diseases and violence are the only numerically important causes of death; the rates for these causes are given in Table 4. The mortality from infectious diseases had declined by about three-quarters in both age groups and accounted for slightly more than one-half of the total decline at ages 5–9, and slightly less than one-half at ages 10–14. The death-rates from violence have fallen considerably during the past 7 years.

Ages 15–34

Tuberculosis and violence were the largest causes of death during this period of life, the rates are shown in Table 5. The fall in the tuberculosis death-rate at these

ages accounted for one-half to three-quarters of the difference between the 1946 and 1952 death-rates. The death-rate from violence at ages 20–24 has risen during the period and is now 50 % above the rate for 1946. In the other two age groups the death-rate from violence has been fairly constant.

Table 4. *Death-rates per* 100,000

	Ages 5–9			Ages 10–14		
Year	Infectious diseases and tuberculosis	Violence	Other causes	Infectious diseases and tuberculosis	Violence	Other causes
1946	22·7	24·0	39·3	19·6	16·1	40·6
1947	24·2	27·4	38·8	19·4	14·7	35·7
1948	16·3	23·7	35·3	12·9	12·2	34·5
1949	15·0	21·5	32·3	10·0	12·9	33·3
1950	12·7	19·1	32·5	8·0	10·1	30·2
1951	8·9	18·1	28·6	6·7	11·7	28·5
1952	6·5	16·1	26·9	4·9	10·8	26·5

Table 5. *Death-rates per* 100,000

	Ages 15–19			Ages 20–24			Ages 25–34		
Year	Tuber-culosis	Violence	Other causes	Tuber-culosis	Violence	Other causes	Tuber-culosis	Violence	Other causes
1946	50·5	23·4	58·8	99·4	23·1	84·5	73·9	25·0	111·3
1947	53·7	23·1	62·2	87·7	27·3	76·6	73·5	26·4	102·6
1948	47·8	19·6	52·6	69·6	24·0	61·1	69·7	23·2	88·9
1949	33·6	23·0	53·0	60·3	28·7	61·7	60·9	22·3	86·3
1950	19·8	22·6	47·4	37·1	31·6	55·5	44·9	25·0	86·9
1951	13·1	22·2	40·6	25·7	34·5	53·1	35·1	27·9	83·0
1952	7·5	24·2	38·5	16·1	35·9	52·0	23·7	26·4	76·7

Ages 45 *and over*

1951 was a year of heavy mortality for ages 45 and over due partly to an outbreak of influenza which had very little effect on the mortality of persons below 45. The death-rates declined in 1952 and the rates were the lowest for the past 4 years in each of the age groups. At ages 85 + the recovery from the high rate in 1951 was not so complete as in the other age groups thus the death-rate in 1952 was above that of any of the years 1942 to 1950. The death-rates for the large causes of death are shown in Table 6.

The recorded cancer death-rate at ages 85 + has shown a steady rise during the 4 years which was not apparent in the other four age groups. The mortality from vascular lesions affecting the central nervous system has tended to rise in each age group while the death-rates from arterio-sclerotic and degenerative heart disease tended to decline between ages 55 to 84. The mortality from pneumonia and bronchitis rises in years of influenza prevalence; apart from the experience of 1951, an influenza year, the death-rates from pneumonia have risen slightly in the oldest age groups, but the mortality from bronchitis has steadily declined in each of the age groups.

Table 6. *Death-rates per* 1000

Year	Neoplasms	Vascular lesions affecting central nervous system	Arterio-sclerotic and degenerative heart disease	Pneumonia	Bronchitis	Influenza	Violence	Other causes
				Ages 45–54				
1949	2·00	0·50	1·00	0·20	0·30	0·07	0·38	2·35
1950	2·03	0·51	1·00	0·18	0·28	0·06	0·39	2·25
1951	2·00	0·53	1·02	0·20	0·37	0·16	0·40	2·21
1952	2·01	0·57	1·03	0·17	0·28	0·02	0·37	1·88
				Ages 55–64				
1949	4·44	1·86	3·78	0·57	1·14	0·20	0·54	4·69
1950	4·50	1·91	3·74	0·46	1·10	0·13	0·54	4·67
1951	4·50	1·99	3·75	0·60	1·44	0·50	0·54	4·67
1952	4·58	1·99	3·60	0·46	1·06	0·06	0·53	4·14
				Ages 65–74				
1949	8·41	6·36	12·57	1·46	2·85	0·49	0·82	10·14
1950	8·36	6·68	12·22	1·21	2·74	0·31	0·83	10·33
1951	8·33	6·81	12·82	1·66	3·59	1·47	0·86	10·72
1952	8·26	6·75	11·73	1·32	2·65	0·14	0·81	9·47
				Ages 75–84				
1949	12·71	16·53	37·86	3·69	6·75	1·21	2·07	24·91
1950	13·10	17·63	37·74	3·41	6·42	0·78	2·15	25·76
1951	13·13	18·82	39·84	4·79	8·43	3·82	2·28	26·79
1952	13·08	18·32	35·43	3·93	5·85	0·36	1·96	23·68
				Ages 85+				
1949	13·43	28·13	93·62	8·85	14·44	2·68	5·37	60·97
1950	14·03	31·27	93·33	8·18	13·87	1·89	5·50	59·52
1951	15·30	37·28	111·84	12·85	19·63	8·76	6·66	68·55
1952	15·46	36·49	99·35	10·62	13·48	0·85	5·88	59·89

SUMMARY

In the period following the last war a large acceleration has occurred in the rate of decline of the death-rates of the younger age groups. The oldest age groups have not shared in this improvement. This course of the death-rates is in striking contrast to the predictions of two decades ago when it was thought that any substantial improvement in the age specific rates was most likely to occur at the older ages. A large part of the fall at younger ages has been due to the decrease in mortality from infectious diseases and tuberculosis. The death-rates at ages 5–24 are now probably almost at a minimum and if a further appreciable improvement is to be made in them the death-rate from violence must be reduced. Violent deaths account for roughly one-third of all deaths in this age range.

REFERENCES

DERRICK, V. P. A. (1927). *J. Inst. Actu.* **58**, 117.
EDITORIAL (1925). *J. Inst. Actu.* **56**, 180.
GREENWOOD, M. (1925). *Metron, Roma*, **2**, 1.
GREENWOOD, M. (1928). *J. Hyg., Camb.*, **28**, 267.
KERMACK, W. O., MCKENDRICK, A. G., MCKINLAY, P. L. (1934). *Lancet*, *i*, 698.
TRACHTENBERG, H. L. (1920). *J. R. statist. Soc.* **83**, 656.

(*MS. received for publication* 25. III. 54)