Fire Research Note No. 978

LOSS OF LIFE EXPECTANCY DUE TO FIRE

by

S J Melinek

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SUMMARY

A method is presented for the calculation of the probability that death will be due to a given cause and the reduction of life expectancy. Figures are derived, based on mortality statistics for England and Wales, for use in this calculation. Values are worked out for the probability of death due to fire in Great Britain, the number of years of life lost and the reduction of life expectancy.

DEPARTMENT OF THE ENVIRONMENT AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

LIST OF SYMBOLS

b_i	annual number of births necessary to give observed population n_i in age category i assuming current rates of mortality
d	expected number who will die from specified hazard in a group of given size
d_i	annual number of deaths in age category i due to specified hazard
e	life expectancy
e'	life expectancy in absence of specified hazard
i	suffix specifying age category
l_x, l_t	probability of being alive at age x, t
l_i	integral of l_x over age category i
L	years of life lost annually due to specified hazard
n_i	population in age category i
N	size at birth of group (cohort) of people of equal age
$P(t)$	probability for person of age t that his or her death will be by specified hazard
r	annual risk of death by specified hazard
r_i	mean value of r over age category i
$R(t)$	reduction of life expectancy of person of age t by specified hazard
t, x	age
y	expected number of years of life lost from specified hazard by a group of given size during the rest of their lives

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INTRODUCTION

Perceived (ie subjective) risk is important as it determines attitudes towards risks and risk taking. To investigate perceived risk it is necessary to look at ways in which people might consider risk. It is also desirable to be able to express the magnitude of risks in terms which are meaningful and readily understood for publicity purposes, and in order to compare risks and fix levels of safety expenditure.

Measures of risk commonly used are annual number of deaths, and the number of deaths per million of population. This note considers three other ways of expressing risk, namely the proportion of deaths due to a hazard, the years of life lost and the reduction in the life expectancy of the individual. These measures are likely to be more readily understood by most people than death rates. Reduction of life expectancy also takes into account the age of accident victims by attaching more weight to the death of a young person than of an old person. Figures for the risk from fire are presented.

METHOD

Consider a group (cohort) of people of equal age. The size of the cohort at age x is Nl_x where N is the number at birth and l_x is the probability of a person being alive at age x. The cohort can therefore expect to suffer Nrl_x accidental deaths annually at age x where r is the annual probability of accidental death for a person of that age. The resultant annual number of years of life lost is $Nrl_x e'$ where e' is the life expectancy at age x in the absence of the hazard being considered.

When the cohort reaches age t there are Nl_t persons still alive where l_t is the probability of being alive at age t. The expected number of accidental deaths for these Nl_t persons suring the remainder of their lives is

$$d = \int_t^\infty Nrl_x \, dx$$

The expected number of years of life lost for these Nl_t persons is

$$y = \int_t^\infty Nrl_x e' \, dx$$

The probability for a person of age t of accidental death during the remainder of his or her life is therefore

$$\begin{aligned} P(t) &= d/(Nl_t) \\ &= l_t^{-1} \int_t^\infty rl_x \, dx \\ &= l_t^{-1} \sum_t^\infty r_i l_i \quad \text{apprcximately} \end{aligned} \tag{1}$$

where l_i = integral of l_x over age category i

r_i = mean value of r over age category i

The reduction of life expectancy for each individual is

$$\begin{aligned} R(t) &= y/(Nl_t) \\ &= l_t^{-1} \int_t^\infty rl_x e' \, dx \\ &= l_t^{-1} \sum_t^\infty r_i l_i e_i' \quad \text{approximately} \end{aligned} \tag{2}$$

where e_i' is the mean value of e' over age category i.

Substituting $r_i = d_i/n_i$ in equations (1) and (2) where d_i is the annual number of deaths and n_i the population in age category i

$$\begin{aligned} P(t) &= l_t^{-1} \sum_t^\infty d_i(l_i/n_i) \\ &= l_t^{-1} \sum_t^\infty d_i/b_i \end{aligned} \tag{3}$$

$$R(t) = l_t^{-1} \sum_{t}^{\infty} e_i' d_i / b_i \qquad (4)$$

where $b_i = n_i / l_i$.

b_i is the annual number of births necessary to give the observed population n_i in age category i, assuming current rates of mortality. Equations (3) and (4) are preferable to equations (1) and (2) for the calculation of $P(t)$ and $R(t)$ because b_i varies less than l_i.

The average values of P and R for the whole population can be obtained by averaging the values given by equations (3) and (4).

The life expectancy e' in the absence of the hazard is given by

$$e' = e + R \qquad (5)$$

where e is the observed life expectancy.

In the case of fire R is much smaller than e and it is sufficiently accurate to take $e' = e$.

The annual loss of life years for each age category is

$$L_i = e_i' d_i \qquad (6)$$

The equations used assumed that the death rate is constant through the age groups taken. This approximation appears to be reasonably accurate for the intervals taken in this note. It is also assumed that those who die have a life expectancy equal to the average for their age, ie that they are of average health. It may be that the life expectancy of accident fatalities is below average because unhealthy people are less likely to survive, or above average because healthy people are more active. The death rate from accidents tends to increase with age so that the life expectancy of accident fatalities is more likely to be below than above average.

DATA

For convenience the life figures for England and Wales have been taken[1,2]. Average life expectancies for Scotland and Northern Ireland are slightly lower[3].

The figures for fire fatalities are those for 1969 for Great Britain. The annual number of fire deaths in recent years (1968-71) has been approximately constant[4]. Two sets of values are taken, those from the Registrars General[5,6] (ICD No.E 890-899) and figures obtained from fire brigade reports[7]. These

figures differ for several reasons. Not all fires are known to the fire brigades. Also, the figures from the Registrars General are for deaths occurring in 1969 whereas those from the fire brigade reports are for deaths resulting from fires in 1969 and notified to the Fire Research Station within about three months from the end of 1969. The fatalities reported by the fire brigades include some deaths due to explosions. Fatalities suffered by the fire brigade have been excluded from this set of data.

Some of the data for Scotland[6] are in ten year age groups. These data have been apportioned.

Table 1 shows, for males and females in each age group, the population[3] n_i, mean life expectancy[1,2] e_i, the probability of survival[2] l_t, and l_i and b_i. From these quantities the probability P of accidental death, the annual loss of life years L and the loss of life expectancy R per individual can be calculated using equations (3) to (6).

Tables 2 and 3 show the number of deaths d_i from fire in each age category[5,6,7], the death rates r_i, and L_i, P and R. The variation of r with age is plotted in Fig.1. P is plotted in Fig.2 and R in Fig.3.

DISCUSSION

Figure 1 shows that the death rate from fire varies by an order of magnitude and is greatest for the very young and the old. The reduction in life expectancy, on the other hand, shown in Fig.3, decreases with age. It should be noted that the death rate r shown in Fig.1 represents the risk at each age whereas P and R, shown in Figs 2 and 3, depend on the risk during the remainder of the individual's life span. The total annual loss of life due to fire for the whole population is about 25 000 years.

Table 2 shows that the proportion of people who can be expected to die from fire is about 1.2×10^{-3} at birth and 1.0×10^{-3} for the whole population. The current proportion of deaths due to fire is about 1.3×10^{-3} for all deaths, 7×10^{-3} for deaths under forty five and 0.9×10^{-3} for deaths at 45 and over. More females than males die from fire.

From Fig.1 it can be seen that for old people the number of deaths reported by the Registrars General is greater than that reported by the fire brigades. These results indicate that fatal fires to which the fire brigade were not called more often involve older people. It is likely that these fires differ from those to which the fire brigade are called. In particular, the fire brigade is less

likely to be called to fires involving only ignition to clothing. There were 216 deaths in 1969 due to ignition of clothing[5,6], of which about three-quarters were people over sixty. A high proportion of fire deaths of people over sixty were due to this cause. About one-quarter of these deaths occurred in fires not known to the fire brigades[7]. The danger from these fires can be reduced by safer appliances and materials.

A small sample of people (seventeen) at the Fire Research Station were asked the following questions:

1. What do you think is the proportion of deaths in any year which are due to fire/road accidents/other accidents (eg falls, home, industrial).

2. The average life span is about seventy years. How much do you think this average would be increased if each of these causes of death were eliminated?

These questions, particularly the latter, were found difficult to answer. A wide range of responses were given. The median replies were:

Fire	10^{-4}, 1 week
Road accident	10^{-3}, 3 months
Other accident	10^{-3}, 6 months.

The estimated effects on life expectancy are of the right order but the assumed proportion of deaths due to each cause is too low by a factor of about ten. Except in the case of fire there was no apparent correlation between the estimated chance of death from a cause and the effect on life expectancy.

CONCLUSIONS

1. The average annual death rate from fire in Great Britain is about 15 per million. The rate is higher for the very young and the old.

2. The annual loss of life expectancy due to fire for the whole population is about 25 000 years.

3. The proportion of people who can expect to die in a fire is approximately 10^{-3}.

4. The reduction of life expectancy due to fire is about ten days at birth and five days for the average member of the population.

5. Some deaths occur in fires not known to the fire brigades. These fires include in particular about one-quarter of deaths due to ignition of clothing.

6. The response from a small sample indicated that people find it more difficult to estimate the probability of death from specified causes than the reduction in life expectancy. The probabilities were underestimated in most cases.

REFERENCES

1. English Life Tables No.12. Registrar General's Decennial Supplement (England and Wales) 1961. Life Tables. HMSO, 1968.

2. The Registrar General's Quarterly Return for England and Wales, No.494. 2nd Quarter. HMSO, 1972.

3. Annual Abstract of Statistics No.108. HMSO, 1971.

4. United Kingdom Fire and Loss Statistics 1971. HMSO, 1973.

5. The Registrar General's Statistical Review of England and Wales for 1969. Part 1, Medical. Table 17. HMSO, 1971.

6. Annual Report of the Registrar General for Scotland, 1969. Part 1, Mortality Statistics, Table C2.1. Edinburgh. HMSO, 1971.

7. NORTH, M. A. Private communication, 1973.

Table 1

Population and life expectancy
Great Britain, 1969

Males

Age, x years	n_i '000	e_i years	l_x*	l_i years	$b_i = n_i/l_i$ '000/year
Under 1	458	69.5	1.000	0.98	466
1-4	1866	67.3	0.980	3.91	482
5-9	2278	63.0	0.977	4.88	467
10-14	1972	58.1	0.975	4.87	405
15-19	1899	53.2	0.973	4.85	391
20-24	2089	48.5	0.968	4.83	433
25-29	1725	43.7	0.964	4.81	359
30-34	1655	38.9	0.960	4.78	346
35-39	1640	34.1	0.954	4.75	345
40-44	1668	29.5	0.947	4.70	355
45-49	1829	25.0	0.933	4.61	397
50-54	1492	20.9	0.908	4.45	336
55-59	1605	17.1	0.867	4.19	384
60-64	1438	13.7	0.802	3.77	381
65-69	1126	10.7	0.701	3.17	355
70-74	706	8.3	0.563	2.41	293
75-79	440	6.4	0.398	1.57	281
80-84	228	4.9	0.236	0.84	272
85 and over	112	3.4	0.107	0.42	267
Total	26246			68.8	

*Value at beginning of age group

For definition of symbols refer to list of symbols

Table 1 cont'd

Females

Age, x years	n_i '000	e_i years	l_x*	l_i years	$b_i = n_i/l_i$ '000/year
Under 1	435	75.6	1.000	0.99	441
1-4	1792	73.4	0.985	3.93	456
5-9	2164	69.0	0.982	4.91	441
10-14	1872	62.1	0.981	4.90	382
15-19	1844	59.2	0.980	4.89	377
20-24	2067	54.3	0.978	4.88	423
25-29	1694	49.4	0.976	4.87	348
30-34	1593	43.6	0.973	4.86	328
35-39	1576	39.7	0.970	4.84	326
40-44	1649	35.1	0.964	4.80	343
45-49	1855	30.5	0.954	4.73	392
50-54	1573	26.1	0.937	4.63	340
55-59	1754	21.9	0.913	4.48	392
60-64	1649	17.9	0.877	4.26	387
65-69	1438	14.3	0.823	3.92	367
70-74	1157	11.0	0.740	3.42	339
75-79	839	8.2	0.619	2.80	300
80-84	519	6.1	0.454	1.80	289
85 and over	306	4.2	0.270	1.24	247
Total	27776			75.1	

*Value at beginning of age group

Note: e_i, l_x and l_i are from data for England and Wales

Table 2

Deaths due to fire

Deaths classified by Registrar General as due to fire and flames[5,6]
Great Britain, 1969

Males

Age years	d_i	r_i x 10^6	$L_i = e_i\ d_i$ years	P* x 10^3	R* days
Under 1	19	41	1320	1.0	10
1-4	63	33	4240	1.0	9
5-9	16	7	1008	0.9	6
10-14	2	1	116	0.9	5
15-19	7	4	372	0.9	5
20-24	10	5	485	0.8	5
25-29	14	8	612	0.8	4
30-34	5	3	195	0.8	4
35-39	9	5	307	0.8	3
40-44	14	8	413	0.8	3
45-49	21	11	525	0.7	3
50-54	16	11	334	0.7	2
55-59	15	9	256	0.7	2
60-64	26	18	356	0.7	2
65-69	20	18	214	0.7	2
70-74	30	42	249	0.7	1
75-79	22	50	141	0.8	1
80-84	33	145	162	0.9	1
85 and over	27	241	92	1.0	1
All	369	14	11398	0.8	4

*Value at beginning of age group

For definition of symbols refer to list of symbols

Table 2 cont'd

Females

Age years	d_i	r_i x 10^6	$L_i = e_i\ d_i$ years	P* x 10^3	R* days
Under 1	12	28	907	1.5	11
1–4	50	28	3670	1.5	11
5–9	18	8	1242	1.4	8
10–14	7	4	435	1.4	7
15–19	2	1	118	1.4	6
20–24	2	1	109	1.4	6
25–29	5	3	247	1.4	6
30–34	11	7	480	1.3	6
35–39	6	4	238	1.3	5
40–44	4	2	140	1.3	5
45–49	11	6	336	1.3	5
50–54	22	14	574	1.3	5
55–59	20	11	438	1.3	4
60–64	32	19	573	1.3	4
65–69	36	25	515	1.2	4
70–74	71	61	781	1.2	3
75–79	86	103	705	1.2	3
80–84	60	116	366	0.9	2
85 and over	54	176	227	0.8	1
All	509	18	12100	1.3	6

*Value at beginning of age group

Table 3

Deaths due to fire

Deaths in fires known to the fire brigade[7]
Great Britain, 1969

Males

Age years	d_i	r_i x 10^6	$L_i = e_i\ d_i$ years	P* x 10^3	R* days
Under 1	17[x]	37	1182.	1.1	12
1–4	70[x]	37	4711	1.1	11
5–9	11	5	693	0.9	8
10–14	4[x]	2	2324	0.9	7
15–19	12	6.	638	0.9	7
20–24	25	12	1212	0.9	7
25–29	20[x]	12	874	0.8	5
30–34	20	12	778	0.8	5
35–39	16[x]	10	546	0.7	4
40–44	26[x]	16	767	0.7	3
45–49	18	10	450	0.6	2
50–54	10	7	209	0.6	2
55–59	25[x]	16	428	0.6	2
60–64	20	14	274	0.5	2
65–69	26[x]	23	278	0.5	1
70–74	23[x]	33	191	0.5	1
75–79	18	41	115	0.5	1
80–84	24[x]	105	118	0.6	1
85 and over	15	135	51	0.5	1
All	400	15	15839	0.8	5

*Value at beginning of age group

[x]Increased by one to allow for person of unknown age

For definition of symbols refer to list of symbols

Table 3 cont'd

Females

Age years	d_i	r_i x 10^6	$L_i = e_i\ d_i$ years	P* x 10^3	R* days
Under 1	8	18	605	1.2	11
1-4	52	29	3817	1.3	10
5-9	14	6	966	1.1	7
10-14	5	3	310	1.1	6
15-19	4	2	237	1.1	6
20-24	4	2	217	1.1	6
25-29	11	6	543	1.1	6
30-34	7	4	305	1.0	5
35-39	9	6	357	1.0	5
40-44	6	4	211	1.0	4
45-49	10	5	305	1.0	4
50-54	15	10	392	1.0	4
55-59	21	12	460	1.0	4
60-64	30	18	537	1.0	3
65-69	38[x]	26	543	0.9	3
70-74	51	44	561	0.9	2
75-79	49	58	402	0.8	2
80-84	47	91	287	0.7	1
85 and over	43	141	181	0.6	1
All	424	15	11235	1.0	5

*Value at beginning of age group

[x]Increased by one to allow for person of unknown age

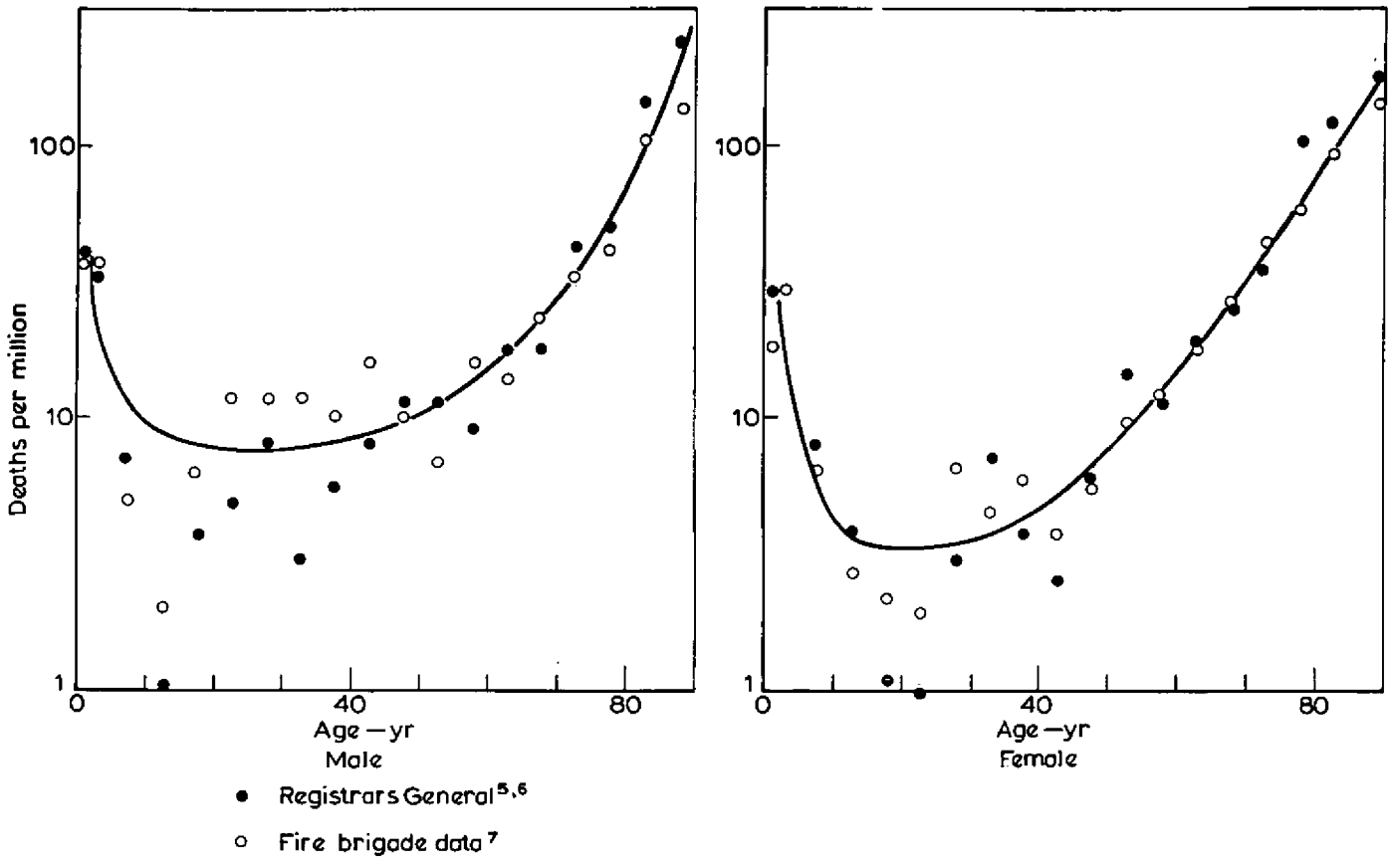

Figure 1 Death rate from fire, 1969

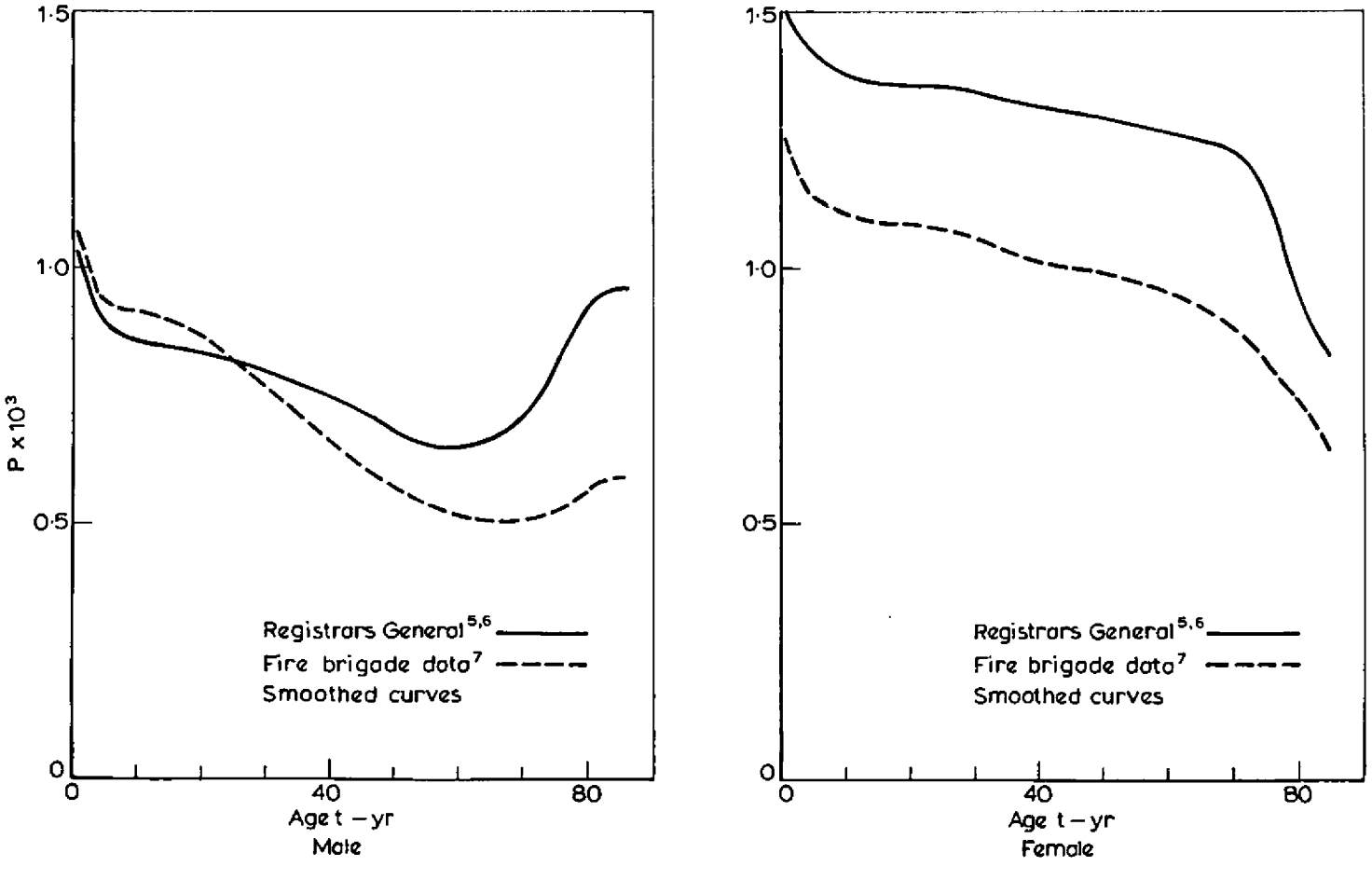

Figure 2 Probability (P) for person of age t that his or her death will be from fire

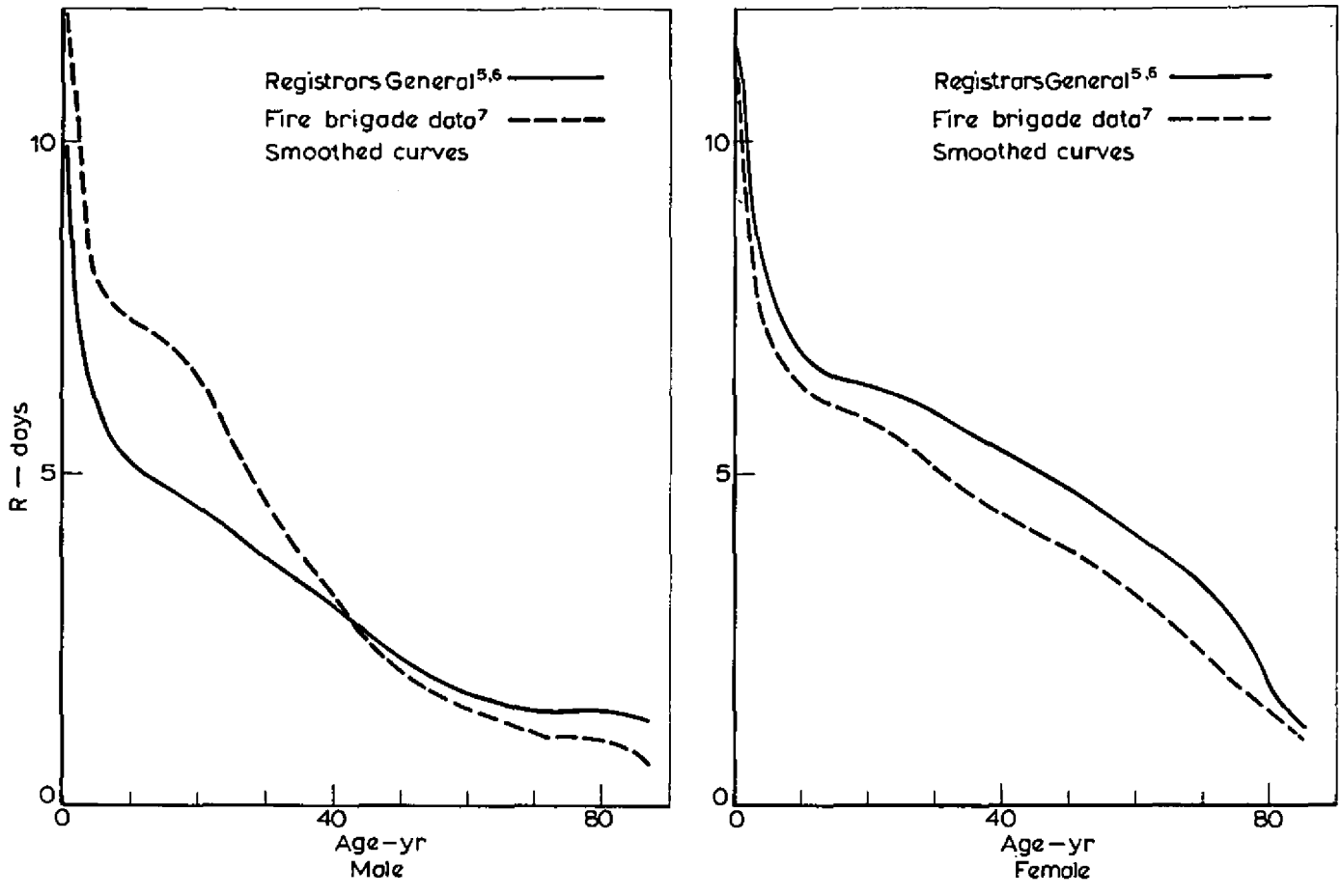

Figure 3 Reduction of life expectancy due to fire, R

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