ELIMINATING INJURY: AN INTERNATIONAL LIFE TABLE ANALYSIS

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Life tables generate the leading single summary index of population health status; namely, life expectancy at birth. Their origins may be traced back to the Romans, who created a table with five-year life expectancy projections for adults.[1] However, the first life table is generally attributed to John Graunt. His rudimentary table numbered among a series of seminal contributions to epidemiology and demography that were published in 1662.[2] Some 30 years later Edmond Halley, the celebrated astronomer, markedly advanced the concept.[3] The first complete single decrement life table appeared in 1815.

Multiple decrement life tables go beyond the single decrement procedure by distinguishing and incorporating causes of death. Life table analysis becomes especially applicable to public health and preventive medicine when these two techniques are used conjointly with a cause-elimination/modification technique. Collectively, they provide the mechanism in this study to address a series of survival questions concerning injury mortality. These questions are examined within a comparative international context

Each ensuing survival question assumes the hypothetical and total elimination of injury mortality. First, what is the impact of this modified mortality regime upon population life expectancy at birth? Secondly, how would it affect the *saved* segment of the population - those who would directly benefit from the injury elimination? Thirdly, how does eliminating injury mortality affect the probability that a 15 year old will die between ages 15 and 65? All three questions are sex-specific, and have implications for shaping health policy and planning and evaluating targeted interventions.

DATA AND METHODS

Disaggregated by sex, age and underlying cause, the mortality data cover 10 industrialized countries: Australia, Canada, France, Germany, Italy, Japan, The Netherlands, Spain, the United Kingdom and United States. Cause of death was precoded according to the Basic Tabulation List of ICD-9 with injury classified by external cause (E470-E561). The source for the mortality and related population data was the World Health Organization (WHO). Data for the United States, Italy and Spain are for 1991* and for the other countries, 1992. In addition to data availability, criteria for country selection were combined respective minimums of population 15 million, gross national product per capita of US $13,000, and population life expectancy of 75 years.[4] The population selection criterion induces data stability, and remaining criteria improve the likelihood that the mortality data are of high quality.

Aside from the technique used to calculate life expectancy for the saved,[5,6] techniques used in this computer simulation are conventional life table procedures.[7,8] The former technique can be expressed in the following formula:

$$\Delta e_{\text{saved}} = (e_0^* - e_0) \times (l_0 / i\,l_0)$$

where Δe_{saved} = gain in life expectancy for group hypothetically saved from injury mortality;

e_0^* = population life expectancy at birth in absence of injury mortality;
e_0 = population life expectancy at birth;
l_0 = life table radix (birth cohort); and
il_0 = projected injury deaths among birth cohort assuming persistence of the prevailing mortality regime.

LIFETIME, a personal computer software program developed at Macquarie University in Australia under the sponsorship of WHO, was used to perform the primary analyses.[9] A spreadsheet was used for complementary calculations. As a prelude to the life table results, unadjusted and age-adjusted injury death rates are presented. These rates were adjusted by means of direct standardization, using as the referent a European male population provided in the LIFETIME package. Like this direct standardization procedure, life table techniques facilitate fair comparison through controlling the potentially confounding effects of variation in population age composition. Except for the hypothetical injury modification, all life table calculations in this study assume a constant mortality regime.

Choice of an age floor of 15 years and a ceiling of 65 for the conditional probability survival question is arbitrary. But this floor closely coincides with the demographic take-off point for sharply elevated injury mortality rates.[10-12] The ceiling duplicates that frequently used in indexing premature mortality by rates of years of potential life lost.[13-15]

RESULTS

French males manifest the highest crude injury death rates and Spanish and British females the lowest rates (Table 1). Within nations, the male injury rate invariably exceeds the corresponding female rate. The sex differential is frequently two-fold. This reaches three-fold in the Spanish case and approaches it for the United States. Cross-national comparisons reveal rates for Dutch and

British males approximately 30 percent lower than the rate for the peak risk female population, the French.

Adjusting injury death rates for age expands the sex differentials. Moreover, French female rates fall below male rates regardless of country. Injury accounts for about 10 percent of all male deaths in France and the United States. At the other end of the continuum, it produces less than 5 percent of Dutch and British male deaths. The range for females extends from 2 percent in the British case to 7 percent for the French. Respective injury contributions to total mortality for French, Japanese, Canadian, and Italian females exceed that for British males. However, within nations the proportional injury share of male mortality consistently surpasses that of female mortality.

Assuming complete elimination of injury mortality, US males would have 2.15 years added to their life expectancy at birth (Table 2). French males would gain 2.08 years. Among males, the Dutch would receive the smallest gain with 0.88 years. Among females, the French would be the leading beneficiaries with an extended life expectancy of 1.09 years (Table 3). This is twice the projected gain for the smallest beneficiaries, Dutch females. French females would even gain more additional life through elimination of injury fatalities than would Dutch and British males. Generally within nations, male gains would be more than double corresponding female gains. By far the smallest national sex differential occurs among the Dutch. But the projected gain for Dutch females exceeds the projection for British females, and approximates that of their Spanish and Italian counterparts.

With the hypothetical elimination of injury mortality, the combination of suicide, homicide, unintentional motor vehicle crashes and falls are associated with between 64 percent and 81 percent of the projected male life expectancy gains by country (Table 4). The corresponding female range is 62 percent and 80 percent (Table 5). Elimination of either motor vehicle traffic crash fatalities (E471) or suicides (E54) would commonly exercise a greater impact upon projected life expectancy gains than would elimination of fatal falls (E50) or homicides (E55). Disaggregating gains in terms of these four external injury causes, within an international comparative context, highlights certain national injury problems. Motor vehicle crashes stand out as an injury category for Spain and Italy, as does homicides for the United States. More evident in the female case, elimination of homicide in the United States would produce proportionally larger gains in life expectancy than would elimination of suicide. Also prominent in these international comparisons is the fall category for Italian females. Only in Japan and Spain is intentional injury mortality, that is, suicide and homicide combined, proportionally less significant for males than females.

When the study focus shifts to the saved population, the group hypothetically spared through injury mortality elimination, the largest projected gains are found to accrue to US, Spanish and Australian males (Table 6). Italian, Dutch and French females would receive the smallest gains. US males register the largest individual gain with a projected 32 additional years of life. US females would be the top beneficiaries among their sex with an additional 28 years of life. A stark contrast is provided by Italian females, whose gain would be 14 years. Within nations, sex differentials range from 11 years among Italians to 4 years among Japanese and Americans.

Table 7 shows country-specific probabilities for males exact age 15 years dying between exact ages 15 and 65. With injury mortality eliminated, the most substantial risk reduction would occur among French and Japanese males. Canadian, US, Australian and Spanish males exhibit similar gains. The smallest gains would accrue to Dutch and British males. The projected range extends from 9 percent for Dutch males to 17 percent for French males.

Decline in the probability of a female exact age 15 years dying between ages 15 and 65, after elimination of injury mortality, typically is much smaller than for a corresponding male (Table 8). Australian, Canadian, Italian, British and US females exhibit approximately 60 percent of the risk reduction projected for their male counterparts. By contrast, French and Japanese females would attain nearly 90 percent and 80 percent of the risk reduction projected for their male opposites, respectively.

DISCUSSION AND CONCLUSION

Life expectancy is an intuitive and readily interpretable measure. This life table parameter is useful for summarizing and assessing population health status and associated change.[16,17] Reflecting their large injury mortality burdens, the French and US populations would gain the longest extension of life if injury mortality were eliminated. This pertains irrespective of sex. The Dutch and British provide the greatest contrast. Nevertheless, relative benefits associated with injury elimination vary considerably cross-nationally according to which life table analysis is performed. For example, although British males represent a low risk group for injury mortality, they rank high as potential beneficiaries in the saved calculations.

This cross-national research will be extended. Survival questions of the type addressed here concerning injury will be posed in regard to major chronic and communicable diseases. Also of interest are the specific roles of these diseases and injury in secular changes in life expectancy.

The l_x life table function is used to model survival at the population level. However, this mortality survival curve limits attention to quantity of life. Germane to quality of life, there are two other survival curves that potentially could be generated. Respectively they model morbidity and disability. [18] But there is a caveat regarding their utility in cross-national comparisons. As documented, international cause-of-death comparisons could be diminished if not invalidated by differences in case ascertainment and coding practices.[11,19] Comparisons based also on disability and morbidity are all the more susceptible to such discrepancies.

Attaining high quality and uniform morbidity and disability data, and then integrating them into a composite life table measure like health expectancy,[20-23] will necessitate a high degree of international consultation and cooperation. Indeed, some progress in forging such links has been reported. [24] Relevant questions, where possible, could be embodied in ongoing national probability surveys, exemplified by the US National Health Interview Survey.[22] Although greatly magnifying cost, self-reporting of health status ideally should be augmented by a mental and physical examination to assess health and functionality more objectively. Finally, refined life table approaches must allow for the fact that morbidity and disability, unlike death, can be transitory. This requires multistate as opposed to unistate analyses.[23,25]

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Table 1. Injury Death Rates Unadjusted and Age-Adjusted by Sex and Country, 1992 *

	Unadjusted Rate		**Adjusted Rate****		**Injury Deaths as % of All Deaths**	
	M	F	M	F	M	F
Australia	58.7	24.99	59.55	22.46	7.8	3.8
Canada	64.25	28.32	64.61	24.46	8.5	4.5
France	101.13	62.08	95.69	38.80	10.4	7.3
Germany	69.59	42.32	66.62	27.82	6.6	3.7
Italy +	68.51	37.80	63.88	24.48	6.6	4.2
Japan	64.84	31.27	63.52	25.40	8.4	5.0
Netherlands	41.58	29.99	41.44	21.49	4.7	3.6
Spain +	71.97	23.93	69.47	20.23	8.3	3.0
UK	44.74	24.05	43.47	17.53	4.1	2.2
USA +	87.00	32.62	86.31	28.86	9.5	4.0

* Rates expressed per 100,000 population.

** Adjusted through direct standardization using the LIFETIME computer package's European male population as the referent.

+ 1991 data.

Table 2. Life Expectancy at Birth with and without Injury Mortality by Country: Males, 1992

	e_0 Injury Present	e_0 Injury Absent	Added Years
Australia	74.56	76.06	1.50
Canada	74.77	76.38	1.61
France	73.65	75.73	2.08
Germany	72.58	73.98	1.40
Italy*	73.58	74.96	1.38
Japan	76.15	77.56	1.41
Netherlands	74.27	75.15	0.88
Spain*	73.29	74.99	1.70
United Kingdom	73.58	74.61	1.03
United States*	72.00	74.15	2.15

* 1991 data.

Table 3. Life Expectancy at Birth with and without Injury Mortality by Country: Females, 1992

	e_0 Injury Present	**e_0 Injury Absent**	**Added Years**
Australia	80.54	81.19	0.65
Canada	81.16	81.88	0.72
France	82.10	83.19	1.09
Germany	79.19	79.85	0.66
Italy*	80.31	80.87	0.56
Japan	82.58	83.28	0.70
Netherlands	80.34	80.87	0.53
Spain*	80.52	81.09	0.57
United Kingdom	79.14	79.59	0.45
United States*	79.01	79.86	0.85

* 1991 data.

Table 4. Percentage Contribution to Life Expectancy Gains through Injury Elimination by Country and Cause: Males, 1992

	Motor Vehicle Crash	**Falls**	**Suicide**	**Homicide**	**Other Injury**
Australia	28.7	4.7	33.3	4.0	29.3
Canada	27.3	6.2	32.3	4.3	29.9
France	29.3	6.7	28.8	1.9	33.3
Germany	35.0	8.6	30.0	2.9	23.5
Italy*	44.9	9.4	14.5	9.4	21.7
Japan	30.5	5.7	32.6	1.4	29.8
Netherlands	34.1	7.9	32.9	5.7	19.4
Spain*	45.9	3.5	12.9	1.8	35.9
United Kingdom	29.1	6.8	28.1	2.9	33.1
United States*	28.8	3.7	20.9	21.4	25.2

* 1991 data.

Table 5. Percentage Contribution to Life Expectancy Gains through Injury Elimination by Country and Cause: Females, 1992

	Motor Vehicle Crash	**Falls**	**Suicide**	**Homicide**	**Other Injury**
Australia	33.9	10.8	23.1	6.1	26.1
Canada	31.9	15.3	22.2	5.5	25.1
France	22.0	16.5	23.8	2.7	35.0
Germany	28.8	18.2	27.3	4.5	21.2
Italy*	33.9	28.6	14.3	3.6	19.6
Japan	22.9	4.3	37.1	2.9	32.8
Netherlands	24.5	20.7	32.1	5.7	17.0
Spain*	43.9	5.3	14.0	1.7	35.1
United Kingdom	26.7	13.3	17.8	4.4	37.8
United States*	36.5	5.9	14.1	17.6	25.9

* 1991 data.

Table 6. Gains in Life Expectancy* for those Saved from Injury Mortality by Sex and Country, 1992

	Δe_o Male	Δe_o Female	Sex Difference
Australia	30.28	23.24	7.04
Canada	28.76	20.75	8.01
France	23.94	16.10	7.84
Germany	25.96	18.29	7.67
Italy**	25.05	13.84	11.21
Japan	23.19	18.86	4.35
Netherlands	24.20	15.99	8.21
Spain**	30.58	24.79	5.79
United Kingdom	29.85	21.71	8.14
United States**	31.63	27.55	4.13

* Expressed in years.

** 1991 data.

Table 7. Probability of Dying between Exact Ages 15 and 65 years if Exact Age 15 by Country with and without Injury Mortality Elimination: Males, 1992

	Probability		
	Injury Present	**Injury Absent**	**% Decline**
Australia	0.1813	0.1541	15.0
Canada	0.1883	0.1591	15.5
France	0.2250	0.1870	16.9
Germany	0.2310	0.2040	11.9
Italy*	0.2022	0.1766	12.6
Japan	0.1642	0.1381	15.9
Netherlands	0.1801	0.1646	8.6
Spain*	0.2121	0.1808	14.8
United Kingdom	0.1973	0.1776	10.0
United States*	0.2458	0.2083	15.3

* 1991 data.

Table 8. Probability of Dying between Exact Ages 15 and 65 years if Exact Age 15 by country with and without Injury Mortality Elimination: Females, 1992

	Probability		
	Injury Present	**Injury Absent**	**% Decline**
Australia	0.1007	0.0915	9.2
Canada	0.1059	0.0959	9.4
France	0.0937	0.0797	15.0
Germany	0.1133	0.1038	8.4
Italy*	0.0945	0.0874	7.5
Japan	0.0792	0.0698	11.9
Netherlands	0.1049	0.0977	6.8
Spain*	0.0891	0.0808	9.4
United Kingdom	0.1208	0.1140	5.7
United States*	0.1377	0.1254	9.0

* 1991 data.