

Standardized Mortality Ratios and the "Healthy Worker Effect": Scratching Beneath the Surface

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The age-standardized mortality ratio (SMR) is a frequently used summary index of mortality in occupational epidemiologic studies. By expressing the observed mortality experience of the occupational study population relative to the mortality that would otherwise be expected (in the absence of any mortality hazard within that occupational environment), an evaluative measure of the force of mortality is obtained.

Certain basic limitations of the SMR have been discussed elsewhere. Firstly, since the SMR computation involves an indirect age-adjustment procedure,¹ hence SMR's calculated for two or more study populations, although using the same standard population death rates for calculating expected deaths, cannot themselves be directly compared to one another.²

Secondly, the actual numeric magnitude of the SMR depends directly on the choice of standard population. Many factors other than the occupational environment influence mortality, and yet only one such factor (albeit a major one) is controlled for in the computation of the SMR, namely, age. This situation is exemplified by the somewhat inappropriate, but convenient, comparison of an industrial working population with the general population. This latter population, which includes sick and disabled persons, is usually at greater mortality risk than a population of active workers healthy enough to have been (and to remain) employable. If working in a safe environment, such a population of active workers has been variously estimated to have a mortality risk 60%-90% that of the general population. This difference in mortality risk, due to selection forces, has been described as the "healthy worker effect".³ An epidemiologic comparison of a working population with the general community must take account of this effect.

A third limitation of the SMR is that it is a measure of the average relative mortality of what is usually a heterogeneous study population. As a summary index of population mortality it necessarily glosses over differences in the mortality experience of various sub-groups within the population. Now, a primary purpose of occupational epidemiologic studies is to compare the mortality experience of subgroups of workers exposed to different physico-chemical agents, or working in dif-

ferent jobs. However, there may also be major differences in mortality experience between subgroups differentiated by criteria other than work exposure. That is, the healthy worker effect may not apply equally throughout the study population. Therefore, if one attempts to improve the meaningfulness of an SMR by adjusting for the healthy worker effect, allowance must be made for variation in this effect between different age groups, different races, different work-status (active, inactive, retired, etc.) groups, different periods of observation, and different causes of death. Thus, the application of a constant adjustment factor (say .90, as recently suggested by Goldsmith⁴) will, in some circumstances, produce misleading results.

This article presents illustrative examples from a variety of occupational epidemiologic studies, to demonstrate the variation in healthy worker effect among different subgroups of workers. In each of the following examples, the standard population, with whose mortality the mortality of the occupational population is compared, is the national United States population.

Discussion

When a population of active and retired workers, embracing a large age-range, is followed for a number of years, the SMR is usually higher in the older age-bands. Figure 1 illustrates this trend, showing the SMR's in four successive age-bands within a population of 6678 male rubber workers, aged 40 or more Jan. 1, 1964 and followed for ten years. (The composition and follow-up of this study population have been described elsewhere.⁵)

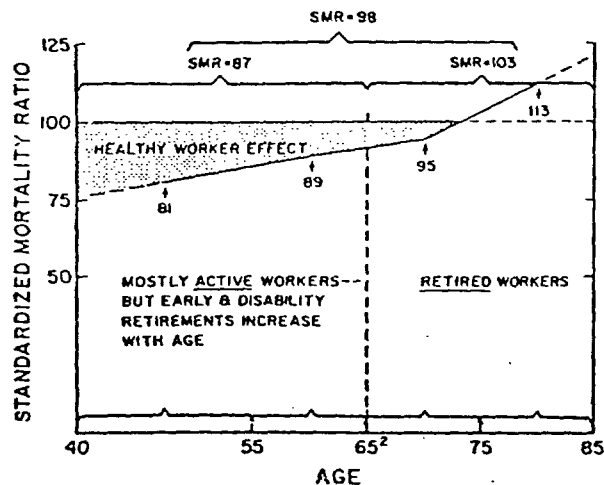
The SMR for the full age-range studied, 40-84, is 98. For the active employment age-range, 40-64, the SMR is 87; whereas for the older, post-retirement age-range, 65-84, it is 103. Within the 40-64 age-range, the SMR increases from 81 (ages 40-54) to 89 (ages 55-64). Likewise, in the post-retirement years, the SMR continues to increase, from 95 (ages 65-74) to 113 (ages 75-84).

The explanation for this gradient has several facets, partly overlapping. In terms of pathologic processes, the diseases causing excess mortality in this population are mostly long-term or chronic (e.g. cancers, chronic lung disease) occurring only after a sufficient period of exposure and/or time since first exposure and therefore most evident at older ages.

In terms of the healthy worker effect, younger workers are

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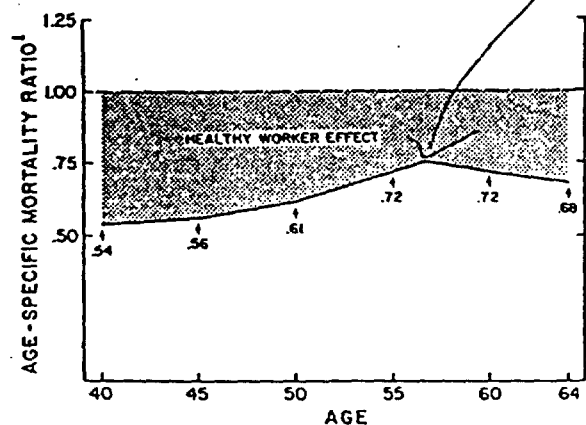
Presented at the 60th Annual Meeting of the American Occupational Medical Association, American Industrial Health Conference, San Francisco, April 14-17, 1975.



1. Expected deaths calculated from 1968 U.S. male age-specific death rates within 5-year age-bands.
2. Normal retirement occurs at age 65.

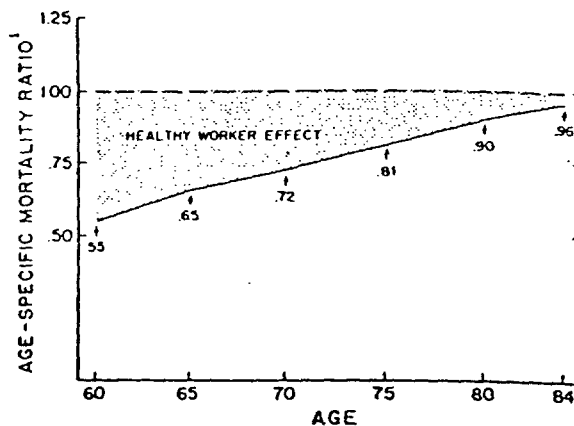
Fig 1. — Decline in healthy worker effect with age, male rubber workers.

least distant from the time of initial selection (i.e. hiring on) and are therefore most likely to demonstrate the survival advantage resulting from their initial better-than-community-average health status. In addition, within the age-range 40-64, workers developing discomforting illnesses are most likely to voluntarily extend the selection process by leaving the industry, if still young enough to have the emotional, mental and financial independence necessary to learn a new job or trade. The SMR for the younger years, 40-54, therefore remains low. However, older workers in this 40-64 age-range, if unhealthy, are more likely to either stay on in less demanding jobs (e.g. janitorial) or take an early or disability retirement and thus remain on the company's pension register. The SMR for ages 55-64, in Figure 1, is thus based on a mixture of active and early or disabled retirees. Within the post-retirement age-range, 65-84, the "healthy worker" selection process no longer operates actively. The residual survival advantage it confers



1. Ratio of life-table q_x values in Bell System male employees, 1959-63, to U.S. males, 1960.

Fig 2. — Mortality experience of a population of actively employed male workers.



1. Ratio of q_x values for actuarially-defined population of non-disabled industrial retirees, 1968-72, to U.S. males, 1968.

Fig 3. — Further evidence of declining carry-over of the healthy worker effect in post retirement age range.

declines with age, as the retirees come to increasingly resemble the general population in their health status characteristics. The healthy worker effect disappears by around age 75.

Figure 2 presents the mortality experience of a population of actively employed male workers in the Bell System. Single-year age-specific mortality ratios are plotted for these active male employees, aged 40-64 (from data published previously³). The healthy worker effect is greatest at the youngest ages and declines steadily with age until eight years before normal retirement, when, presumably, the out-selection of the less healthy (via early retirement) causes the healthy worker effect to increase among the remaining active workers. (This phenomenon of the increase in healthy worker effect in the later years of working, and the accompanying mortality experience of early and retired workers, is currently under investigation within the rubber industry.⁶)

In similar vein, Figure 3 provides further evidence of the declining carry-over of the healthy worker effect in the post-retirement age-range. Life table (q_x) data for an actuarially

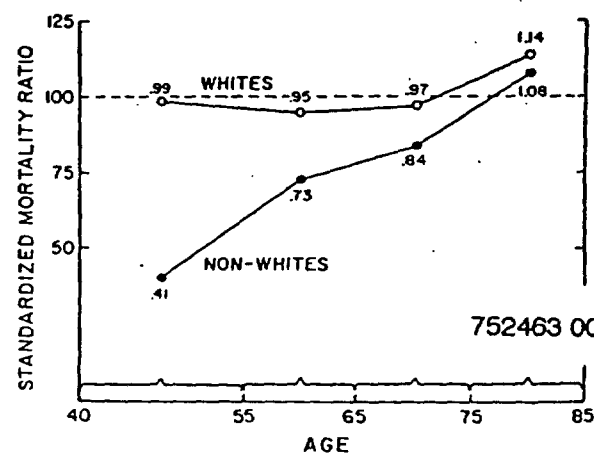
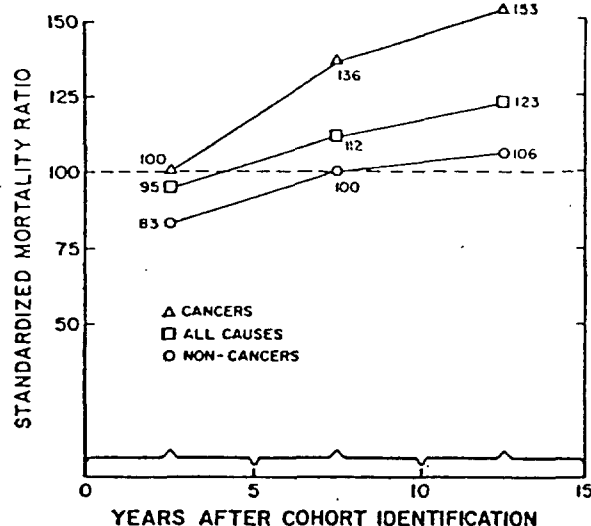


Fig 4. — Healthy worker effect is greater for nonwhites than whites, at all ages.

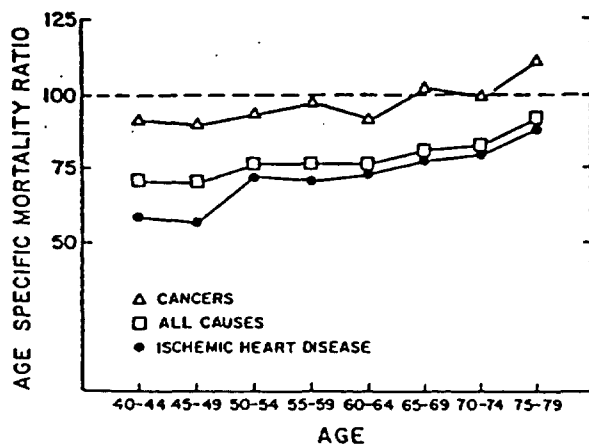


Graph based on tabular data from Enterline, P.E. (1965).

Fig 5. — Decline in the healthy worker effect with passage of time after initial identification of a cohort of active workers (asbestos products).

defined population of nondisabled male, industrial retirees, 1968-72,⁷ indicate an initial mortality of only 55% of the general population. This effect declines steadily with age such that, at age 84, the mortality is 96% of the general population.

Figure 4 shows that, within the same rubber worker population of Figure 1, the healthy worker effect is greater for nonwhites than whites, at all ages. In particular, nonwhite male workers in the active employment age-range, 40-64, are at a substantial survival advantage compared to the national nonwhite male population (many of whom are unemployed, indigent, retired due to poor health, or working in hazardous occupations.) That is, the quality of the comparison differs for the two race groups. On the one hand, working-class whites are being compared to the national average "middle-class" white population; on the other hand, working-class nonwhites



Source: Graph based on tabular data from Milham, S. (1974).

Fig 6. — Considerable difference can occur in the healthy worker effect for different causes of death (carpenters and joiners).

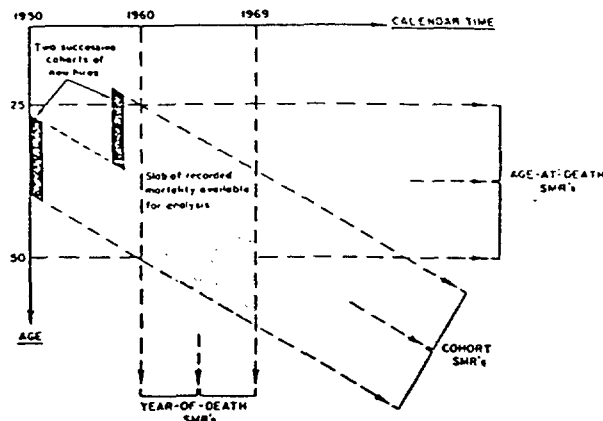


Fig 7. — Three different "directions" that can be followed in calculating SMR's.

are being compared to the national average "lower-class" non-white population. The assessment of race-specific healthy worker effects is therefore confounded by class differences. Clearly, the greater the proportion of nonwhites in a working population, the lower the race-standardized SMR's will tend to be and the greater the risk of not perceiving an actual, but small or moderate, excess of mortality.

Figure 5 illustrates the decline in the healthy worker effect with the passage of time after the identification of a cohort of already active workers. The graphs are based on tabular data from a cohort mortality study of asbestos products workers, by Enterline.⁸ When follow-up is achieved of a total cohort, including those that quit or retire early for health reasons, then the initial healthy worker effect associated with active employment declines with time, because of the absence of any continued selection process. For total mortality, the effect in this cohort disappeared after five years largely due to the increase in cancer mortality in the second and third quinquennial period of follow-up.

Figure 6 illustrates the considerable difference that can occur in the healthy worker effect for different causes of death. The graphs are based on tabular data from a cross-sectional study of mortality in carpenters and joiners, by Milham.⁹ At all ages, there is an obvious mortality deficit of about 25% for ischemic heart disease, whereas for cancers the mortality ratio remains in the vicinity of 100 throughout. Although part of this higher figure for cancer may reflect excess deaths from certain specific cancers for which Milham reports that these workers are at increased risk of death, part of the explanation lies in the cause-specific variation in the healthy worker effect. Where cancer is a "silent" disease, with long-deferred clinical manifestations, ischemic heart disease is a chronic and readily detectable condition. Heart disease is therefore much more likely to be selected against than is cancer, in the recruitment and retention of an active workforce.

Finally, Figure 7 presents, diagrammatically, three different "directions" that can be followed in calculating SMR's. A "slab" of recorded mortality experience within an occupational population (see hatched area, Fig 7) may result in an overall SMR of, say, 85. However, by partitioning the total mortality experience in different directions, significant excursions above and below that figure may be detected. SMR's

can be calculated by age at death, by successive cohorts (year of birth, or year of hire cohorts), or by year of death. The choice of one or more of these approaches depends upon one's anticipations of the data.

An example of variation in SMR's by age at death has been given in Figure 1. An example of mortality differences between year-of-hire cohorts is to be found in a recent study of bladder cancer deaths, during 1967-71, in a population of 16,035 British rubber workers.¹⁰ Workers joining the industry before 1950 had a bladder cancer SMR of 130, while for those joining in or after 1950 the SMR was 97. The major presumed bladder carcinogen, beta-naphthylamine, was removed from the British rubber industry in 1949. The third approach, using year-of-death SMR's (i.e. period mortality), would be useful in identifying temporary mortality excesses resulting from some short-term exposure to an agent whose use was subsequently discontinued (for reasons, say, unrelated to health). For example, a chemical with potent respiratory sensitization or irritation properties might precipitate excess deaths among workers with chronic respiratory ailments. Mortality analysis by year-of-death SMR's would best identify this problem.

Summary

The age-standardized mortality ratio (SMR) is a relative index of mortality, expressing the mortality experience of the study population relative to that of a comparison ("standard") population. With the general population as the "standard", the SMR for an occupational population will underestimate the mortality experience of that latter population (since it comprises individuals necessarily healthy enough to be employable — and whose mortality risk is therefore initially lower than the

general population average). However, this "healthy worker effect" does not apply equally to all groups within the study population. Therefore, if one attempts to adjust for this effect, the summary nature of the SMR must be recognized, and allowance must be made for variation in the healthy worker effect between different age groups, different races, different work-status groups, different causes of death, and different elapsed-time periods of observation.

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