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Gender Differences in the Healthy Worker Effect among Synthetic Vitreous Fiber Workers

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The aim of this study was to determine whether the healthy worker effect and its component parts operate similarly for women and men. A cohort of workers from 14 synthetic vitreous fiber factories in seven countries, employed for at least 1 year between 1933 and 1977 and followed up to the early 1990s, included 375 deaths and 53,608 person-years among females and 2,568 deaths and 210,073 person-years among males. Standardized mortality ratios for all-cause and circulatory diseases were adjusted for country, age, calendar time, and gender. In addition, internal comparisons were adjusted for time since hire and employment status. The analyses addressed the following: 1) the healthy hire effect, 2) the time since hire effect, and 3) the healthy worker survivor effect. In this cohort, an overall healthy worker effect was not present in either gender. The healthy hire effect, based on standardized mortality ratios for years 1–4 since hire, was observed in males (standardized mortality ratio (SMR) = 0.8; 95% confidence interval (CI): 0.7, 1.0) but was less in females (SMR = 0.9; 95% CI: 0.5, 1.6). The relative risks increased slightly with time since hire in males but not in females. Higher mortality ratios were seen among those leaving employment than among those who remained actively employed; however, this effect was substantially greater for women (relative risk (RR) = 3.4; 95% CI: 1.8, 6.3) than men (RR = 1.8; 95% CI: 1.5, 2.1). The gender difference for active versus inactive status was stronger up to age 60 (men: RR = 1.7; 95% CI: 1.4, 2.0; women: RR = 3.6; 95% CI: 1.8, 7.1) than above that age. In conclusion, it appears that there is a stronger selection of healthy men than women into the workforce, while health-related selection out of the workforce is stronger for women than men. *Am J Epidemiol* 1999;150: 1099–106.

cohort studies; healthy worker effect; occupational health

The healthy worker effect is often discussed in the context of male worker cohorts. Whether the healthy worker effect and its component parts operate in the same way and to the same degree in females as in males is largely unknown. In Western countries, women began entering the workforce in traditionally male-dominated jobs during World War II. Since that time, women have continued to enter the workforce in greater numbers in the manufacturing and professional sectors of business. In 1990, the US civilian workforce consisted of 46 percent women (1). Based on 1992 numbers from the United States, 32 percent of workers in the manufacturing sector were women (2). In the European Union, women are entering the workplace in greater numbers today than in the past. In 1995, women comprised 23 percent of the European manufacturing sector of business (3).

Many occupational cohorts have been constructed with male workers only. According to a survey covering 1,233 studies conducted between 1971 and 1990 published in eight occupational and cancer journals, only 169 of them (14 percent) presented any analyses of white women specifically, and only 7 percent (n = 92) presented more than five cancer site/exposure-specific risk estimates (1). There were 31 cohort studies that included women with at least five risk estimates, and these studies may or may not have included males. Many of these 31 studies were conducted outside the

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Abbreviations: CI, confidence interval; ICD-9, *International Classification of Diseases*, Ninth Revision; RR, relative risk; SMR, standardized mortality ratio.

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United States. Since 1990, there have been an additional 131 cohort studies that reported results related to occupational cancer incidence or mortality in women, many of which link job title with cancer registration data, providing little or no discussion about the healthy worker effect (Dr. S. Zahm, US National Cancer Institute, personal communication, 1997).

This paper focuses on three components of the healthy worker effect (4): 1) the healthy hire effect, 2) the time since hire effect, and 3) the healthy worker survivor effect (5, 6). First, the healthy hire effect is an initial selection process whereby healthy people are more likely to seek and gain employment. Mortality risk ratios are lowest at the time of initial hire. Second, the time since hire effect indicates that the relative risk of mortality increases with time since entering industry, a phenomenon which may occur in the absence of an association between exposure and mortality, as the mortality advantage of hiring healthy workers declines (7, 8). The healthy worker survivor effect refers to the continuing selection process, such that those who remain employed (i.e., survivors in the workforce) will tend to be healthier than those who leave employment (6). Thus, mortality ratios are lowest in the group remaining employed even as occupational mortality studies continue to follow both those still at work and those who have left employment.

In occupational studies, a standardized mortality ratio substantially below 1.0 (e.g., equal to or less than 0.8) is usually indicative of the presence of the healthy worker effect. In cohorts where women were included, many lack sufficient numbers of female workers, deaths, and/or person-years to analyze women as a subgroup within the cohort. Of studies evaluating both men and women, results suggest that women have lower all-cause mortality, based on a standardized mortality ratio analysis, but most previous analyses have not addressed the component parts of the healthy worker effect (9–13).

We evaluated gender differences in component parts of the healthy worker effect using a European cohort of male and female workers employed in the synthetic vitreous fibers industry (14). These fibers, commonly called man-made vitreous fibers, are used for acoustic and thermal insulation. This cohort, originally compiled to study the health effects of synthetic vitreous fibers, was chosen because it comprises a relatively large number of women employed in an industrial production process in several countries.

MATERIALS AND METHODS

The cohort is composed of 13,788 low-skilled production workers, both male and female, from 14 factories in seven countries, employed for at least 1 year in the production of synthetic vitreous fibers between 1933 and 1977 (14). This cohort of production workers excluded clerical and administrative staff. Factories vary with respect to the beginning and end of follow-up. The year in which production began ranged from 1933 to 1961. Individuals were identified from factory records and followed for mortality from the year of starting work until 1990–1992, except for one factory in which follow-up ended in 1983. Exact person-years were calculated using a SAS program adapted from the published literature (15). Workers employed less than 1 year were excluded from analysis, because they have higher mortality than do other workers. This resulted in a loss of 145,170 person-years and 1,209 deaths. There was no difference in all-cause mortality between males and females employed less than 1 year. Table 1 displays the numbers of workers, deaths, and person-years by gender and country.

Vital status was obtained from national mortality statistics in the country in which the worker was employed. Causes of death were coded nationally to the *International Classification of Diseases* (ICD)

TABLE 1. Number of workers, deaths, and person-years at risk by country and gender, seven European countries, 1933–1992

Country	Men			Women		
	Workers	Deaths	Person-years	Workers	Deaths	Person-years
Denmark	1,290	304	21,922	70	13	1,367
Finland	221	58	4,301	146	41	3,173
Norway	1,082	308	21,910	87	4	1,374
Sweden	2,682	584	49,041	696	113	15,715
United Kingdom	3,785	778	65,486	1,202	172	26,571
Germany	1,200	366	28,231	31	6	694
Italy	1,113	170	19,182	183	26	4,714
Totals	11,373	2,568	210,073	2,415	375	53,608

revision in effect at the time of death and were converted to the Ninth Revision (ICD-9).

In earlier analysis, no pattern emerged between indirect indicators of exposure to synthetic vitreous fibers and all-cause mortality among workers employed 1 year or more (14). We therefore did not consider these indicators in the present analysis. Specific job tasks for men and women were not available; however, broad job categories indicated that most (32 percent) male person-years were in primary production and preproduction of synthetic vitreous fibers, while most (58 percent) female person-years were in secondary production processes, such as finishing and packing. In earlier analysis of these data, excesses in external causes of death and lung cancer mortality were found, but not for all-cause mortality (14). Detailed gender-specific findings of mortality follow-up through 1990 have been reported (16). The outcomes of interest for this analysis of the healthy worker effect were all-cause mortality and mortality from diseases of the circulatory system (ICD-9 codes 390–459), the latter because these diseases are usually characterized by a strong healthy worker effect.

Because of lack of employment information after 1977, some assumptions were made about employment status. For workers who left synthetic vitreous fibers production before 1977, all person-years before the date of last employment are considered to be employed in the synthetic vitreous fibers industry ("active workers"), and all person-years after the date of last employment are considered not employed in this industry ("inactive workers"). For currently employed workers in 1977 in the German factory, all person-years after 1977 are inactive, since the plant closed in that year. For workers employed in 1977 in the other factories, person-years until age 60 are unknown and, after that age, person-years are inactive. Deaths (n = 239) and person-years (n = 63,180) allocated to unknown employment status were removed from analysis. For this analysis, there were 375 deaths and 53,608 person-years among women and 2,568 deaths and 210,073 person-years among men. Age 60 was chosen as the boundary for active versus inactive, because during the interval when most of the cohort was employed, age 60 was the common age of retirement in many of these countries.

The follow-up intervals for each individual were used to classify person-time and deaths into strata defined as follows: age at risk, 25 two-year intervals: <35, 35–36, 37–38, ..., 79–80, ≥81; calendar period at risk: <1969, 1970–1974, 1975–1979, 1980–1984, ≥1985; time since first employment (years): 1–9, 10–19, 20–29, ≥30; and employment status: "active" (employed in the synthetic vitreous fibers industry) and "inactive" (not employed in the synthetic vitreous fibers industry). Age at risk was stratified into 2-year categories to better control confounding.

Standardized mortality ratios for all-cause and circulatory diseases were calculated for comparison with the national population. The expected values were calculated based on country-, age-, calendar time-, and gender-specific mortality rates and multiplied by accumulated person-years for each cell. The observed/expected ratio represents the standardized mortality ratio. Ninety-five percent confidence intervals were calculated based on the Poisson distribution. Internal comparisons were carried out by fitting Poisson regression models to the natural log of observed death rates; relative risks and 95 percent confidence intervals were then calculated by exponentiating the coefficients. The significance level for p values is 0.05 (two tailed).

Preliminary results indicated that duration of employment and age at last employment were not related to mortality in either males or females and therefore were excluded from further analysis. Information on job task within the production process was not available, but analysis of the main department of employment was not associated with overall and circulatory disease mortality (14, 16). All variables were treated as categorical and coded with indicator variables. Each model was adjusted for age at risk, calendar time, gender, country, time since first employment, and employment status. A linear test for trend was conducted for time since first employment. The STATA software program was used for multivariate statistical analysis (17).

RESULTS

Table 1 presents the number of person-years and deaths by country and gender. The United Kingdom provided the most number of deaths and person-years for both males and females in this cohort. Table 2 presents person-years by gender for time since first employment, age at hire, calendar year of hire, and employment status. The mean age at hire for females was 2 years younger than the mean age at hire for males (29.12 vs. 31.31 years); their mean time since first employment was 2.6 years longer than that of males (25.76 vs. 23.13 years), and their mean time since last employment was 3.6 years longer than the mean of males (19.51 vs. 15.88 years). Each of these gender comparisons was significantly different (p < 0.05). Thus, women were hired at younger ages and contributed longer to follow-up than did males, on average. Women hired between 1931 and 1949 contributed approximately 40 percent of their total person-years, while men hired during this same interval con-

TABLE 2. Person-years at risk by gender and selected employment variables, seven European countries, 1933–1992

	Men		Women	
	No.	%	No.	%
Time since hire (years)				
1–9	79,847	38.0	17,610	32.8
10–19	70,602	33.6	16,174	30.2
20–29	40,307	19.2	10,735	20.0
≥30	19,317	9.2	9,089	17.0
Age at hire (years)				
<25	75,695	36.0	24,335	45.4
25–34	63,508	30.2	14,721	27.5
35–44	40,085	19.1	9,842	18.4
45–54	22,920	10.9	3,768	7.0
≥55	7,865	3.7	942	1.8
Calendar year at hire				
1944 and before	16,183	7.7	9,784	18.3
1945–1949	25,445	12.1	11,885	22.2
1950–1954	33,188	15.8	7,344	13.7
1955–1959	40,037	19.1	7,147	13.3
1960 and after	95,220	45.3	17,448	32.5
Employment status				
Active	65,789	31.3	12,008	22.4
Not active	144,284	68.7	41,600	77.6

tributed only 20 percent of their total person-years. Conversely, workers hired in 1960 or later contributed 33 percent of person-years among women and 45 percent among men.

Table 3 shows results of the standardized mortality ratio analysis by gender. For men and women, the all-cause standardized mortality ratios were 1.07 (95 percent confidence interval (CI): 1.03, 1.11) and 0.98 (95 percent CI: 0.87, 1.08), respectively. The standardized mortality ratios for circulatory diseases were somewhat lower than those for all causes in both men (1.03; 95 percent CI: 0.97, 1.09) and women (0.89; 95 percent CI: 0.75, 1.04). Neither outcome was significantly different between men and women (p = 0.9). There does not appear to be a strong overall healthy worker effect in this cohort, based on the standardized mortality ratio of all-cause or all-circulatory diseases; however, the standardized mortality ratios are lower for women than for men.

The effect of hiring workers healthier than the general population can be operationalized by evaluating the standardized mortality ratios during the early period of follow-up (1–4 years since first employment) (5). The all-cause standardized mortality ratios for the healthy hire effect in males and females were 0.82 (95 percent CI: 0.68, 0.98) and 0.94 (95 percent CI: 0.50, 1.60), respectively (p value of difference = 0.72). For all countries combined, there is a healthy hire effect in men, while in women this effect, to the extent it is present, is weaker and unstable. Because the number of deaths from circulatory diseases among women was small, the healthy hire effect for this group of diseases was not evaluated for 1–4 years since first employment.

The time since hire effect occurs as a cohort ages and its health status declines (5, 7). This effect can be evaluated by examining in internal comparison the changes in the relative risks across categories of time since first employment (tables 4 and 5). After adjustment for age, calendar time, country, and employment status, men exhibit a slight increase in all-cause relative risks with longer time since first employment. In contrast, for women, the all-cause relative risks declined substantially with increasing time since hire, but this trend was unstable. For neither men nor women did the test for linear trend approach statistical significance. Similar results were seen for circulatory disease mortality (table 5).

The healthy worker survivor effect operates to the extent that workers remaining employed have a lower risk of mortality than do workers who leave employment in an industry. In this cohort both men and women have greater risk of mortality after leaving employment in the industry than do production workers who remain actively employed in the synthetic vitreous fibers industry, the reference group (table 4). This effect is substantially larger for women than for men; the difference is significant. The gender difference is especially strong among production workers less than age 60, that is, not yet of retirement age. In general, the healthy worker survivor effect operates in the same direction and shows a similar gender pat-

TABLE 3. Standardized mortality ratios (SMRs) and 95% confidence intervals (CIs) by gender, seven European countries, 1933–1992

Cause of death	Men			Women			p value of difference*
	Observed deaths	SMR	95% CI	Observed deaths	SMR	95% CI	
All causes	2,568	1.07	1.03, 1.11	375	0.98	0.87, 1.08	0.92
Cardiovascular diseases	1,134	1.03	0.97, 1.09	148	0.89	0.75, 1.04	0.90

* Difference in SMRs between men and women.

TABLE 4. Relative risk (RR) of mortality from all causes by time since hire, employment status, age, and gender, seven European countries, 1933–1992

	Men			Women			*p* value of difference*
	Observed deaths	RR†	95% CI‡	Observed deaths	RR†	95% CI	
Time since hire (years)							
1–9	342	1.00	Reference	36	1.00	Reference	
10–19	708	0.98	0.85, 1.13	71	0.75	0.48, 1.17	0.21
20–29	805	1.04	0.89, 1.21	96	0.70	0.46, 1.11	0.11
≥30	713	1.10	0.93, 1.31	172	0.66	0.41, 1.08	0.05
p value for χ^2 test for trend§		0.35			0.42		
Employment status							
Active	253	1.00	Reference	12	1.00	Reference	
Not active	2,315	1.80	1.54, 2.09	363	3.40	1.82, 6.35	0.04
Age (years)							
≤60	640	1.69	1.42, 2.02	107	3.59	1.82, 7.09	0.04
>60	1,675	2.07	1.58, 2.71	256	2.52	0.61, 10.45	0.78

* Difference in mortality between men and women.
† Adjusted for age, calendar period, country, time since hire, and employment status.
‡ CI, confidence interval.
§ Significance level for linear trend for categories of time since hire.

tern for circulatory diseases as all-cause mortality (table 5).

DISCUSSION

The main conclusion from this analysis is that, in this cohort of synthetic vitreous fibers workers in seven countries, three components of the healthy worker effect operate somewhat differently for women as compared with men. The healthy hire effect is weak in men and less evident in women. For women, the mortality ratios declined with longer follow-up, while for men the mortality ratios increased with longer follow-up. There was no significant trend of increasing mortality ratios with time since hire in either gender, but in women relative risks declined with increasing

TABLE 5. Relative risk (RR) of mortality from circulatory diseases (ICD-9* codes 390–459) by time since hire, employment status, age, and gender, seven European countries, 1933–1992

	Men			Women			*p* value of difference†
	Observed deaths	RR‡	95% CI*	Observed deaths	RR‡	95% CI	
Time since hire (years)							
1–9	114	1.00	Reference	10	1.00	Reference	
10–19	302	1.03	0.82, 1.30	26	0.78	0.35, 1.73	0.16
20–29	367	1.09	0.86, 1.39	35	0.65	0.29, 1.47	0.23
≥30	351	1.21	0.94, 1.58	77	0.61	0.26, 1.41	0.13
p value for χ^2 test for trend§		0.30			0.64		
Employment status							
Active	87	1.00	Reference	4	1.00	Reference	
Not active	1,047	1.80	1.40, 2.31	144	2.52	0.85, 7.52	0.55
Age (years)							
≤60	214	1.65	1.22, 2.25	28	2.73	0.78, 9.57	0.45
>60	833	2.06	1.38, 3.08	116	1.95	0.26, 14.76	0.98

* ICD-9, *International Classification of Diseases*, Ninth Revision; CI, confidence interval.
† Difference in mortality between men and women.
‡ Adjusted for age, calendar period, country, time since hire, and employment status.
§ Significance level for linear trend for categories of time since hire.

follow-up. The healthy worker survivor effect was evident in both sexes but was stronger in women. In other words, leaving employment in the synthetic vitreous fibers industry confers greater all-cause mortality than does remaining employed in the industry, but more so in women than men. This gender difference was greatest for workers who left employment before age 60. In general, results for the component parts of the healthy worker effect appeared similar for deaths from circulatory diseases as compared with all-cause mortality, except for death from circulatory diseases before age 60. In sum, it appears that there is a slightly stronger selection of healthy men than women into the workforce, while health-related selection out of the workforce is stronger for women than men.

We have evaluated components of the healthy worker effect by gender using a cohort of European workers producing synthetic vitreous fibers who were employed at least 1 year, which excluded administrative and clerical staff. Our conceptual approach included both standardized mortality ratio analysis and internal comparison. Standardized mortality ratio analysis compares workers entering employment with the general population from which the workers were hired; it can demonstrate whether or not those seeking and gaining employment are healthier than the general population. Evaluation of the healthy hire effect cannot be based on an internal comparison. Thus, despite limitations to comparing standardized mortality ratios, such comparisons are the only approach to examine the healthy hire effect.

In the occupational epidemiology literature, gender differences in components of the healthy worker effect have received little attention (1). Since 1990, over 30 cohort studies were identified containing results for males and females within the same occupational cohort; many of these cohorts are within the manufacturing sector. Of these, few published studies present sufficiently detailed analyses to evaluate the healthy worker effect. Our discussion focuses on studies of manufacturing cohorts with sufficient analyses to discuss the component parts of the healthy worker effect.

Our finding that females have lower all-cause standardized mortality ratios than males was similar to results reported for other manufacturing cohorts. In a cohort of US chrysotile asbestos textile workers, Brown et al. (10) found a significant deficit in the standardized mortality ratio among women but not among men, although this deficit could have been based on underascertainment of deaths in women. In a cohort of US asbestos textile workers, Dement et al. (18) found that white men had a higher standardized mortality ratio (SMR) (1.48; 95 percent CI: 1.38, 1.58) than did white women (SMR = 1.21; 95 percent CI: 1.11, 1.32). Similar findings have been reported for Italian male (11) and female (12) metal miners, for US workers from a cable manufacturing plant employed during World War II (13), in women and men exposed to mercury in the fur hat industry (19), and in a cohort of US rubber workers (20–22). Exceptions to this pattern were observed in another cohort of US rubber workers (23), a cohort of nuclear workers (9), and a cohort of furniture manufacturers (24).

In this analysis, the healthy hire effect was evaluated using mortality between the second and fifth years of employment. The lack of a strong healthy hire effect in either gender (SMRs were 0.82 for males and 0.94 for females) is somewhat unusual for occupational cohorts. For instance, Fox and Collier (5) found that the overall mortality of male vinyl chloride workers during the period immediately after starting employment was low (SMR = 0.37). This cohort did not include females. In two cohorts of skilled nuclear workers, the healthy hire effect was more pronounced for females than males (9, 25). However, it should be noted that differences between our results and those of others may be related to socioeconomic status, since workers in the synthetic vitreous fibers industry are less skilled than are workers from the nuclear industry.

Different attitudes toward hiring men and women, for example, through differences in preemployment screenings, may have contributed to our results; however, we have no direct information on this issue.

Fox and Collier (5) observed that the mortality advantage conferred by employment attenuates with time since hire because of a decline in health status, particularly among those who leave employment. In two Canadian cohorts (25) and a cohort of US nuclear workers (9), standardized mortality ratios increased to a greater extent in men than in women with increasing time since hire. Our results do not strongly support the notion that all-cause or circulatory diseases mortality increases with increasing time since hire, possibly because we adjusted for age and other factors. In preliminary analyses, we observed a significant trend with time since hire (results not shown), when we controlled for age at risk in 5-year intervals, as well as for calendar time and employment status. This trend was removed after controlling for age at risk using 25 two-year age intervals. Adjustment for socioeconomic status was not possible, although in this cohort the relative risks do not increase with time since hire. Arrighi and Hertz-Picciotto (26) reported similar findings for an arsenic-exposed cohort. Once they included age, calendar year, and employment status in the regression models, time since hire no longer was associated with the outcome.

The concept that healthy persons remain in the workforce and have a lower mortality risk than those

who do not remain employed has been termed the healthy worker survivor effect (5, 6, 27). The phenomenon has been found in industrial cohorts, as well as in community-based studies (28, 29). The inactive segment of the cohort consists of those who are employed elsewhere, retired, on disability, or unemployed (6). We observed a favorable health status among active compared with inactive workers in both males and females, with a stronger differential in females. Other analyses of the survivor effect have been limited to males. Active workers in the rubber (22) and nuclear (25) industries, among others, have lower mortality ratios than those retired or no longer employed in the same industries. A healthy worker survivor effect appeared to have attenuated the effect of arsenic on lung cancer (30).

In the present analysis, the gender difference in active versus inactive workers is our most compelling finding. While both men and women who have left the synthetic vitreous fibers industry show higher mortality rates than do those still at work in the industry, rate ratios comparing active with inactive workers are higher for women than men. The reasons for these findings are not entirely clear. The healthy worker survivor effect may be a consequence of risk factors other than synthetic vitreous fibers acquired while employed in the synthetic vitreous fibers industry or the psychosocial consequences of unemployment itself (28). There are a variety of sociologic variables, such as bereavement (31), depression, social isolation (32, 33), and inadequate medical care, that may play a role in higher mortality risk after employment, but these factors do not necessarily affect women more than men (34).

There are several limitations to our study. We lacked a full employment history on cohort members. Women and men may have been more exposed in other industries before or after employment in the synthetic vitreous fibers industry, contributing to increased mortality risk in workers no longer employed in the synthetic vitreous fibers industry.

Our findings could not be explained as being due to factors such as age of hire or year of hire, in spite of the fact that most women were hired during the World War II era and immediately afterward, whereas men were mostly hired after 1960. Women were hired at younger ages and worked a shorter amount of time than did men. However, all our analyses controlled for age, calendar year, and time since hire.

We had no information on the reproductive history of women in the cohort, so it is unknown whether women in this cohort had fewer children than women who did not work. Even if these working women were less fertile (35), fertility is not known to be protective for all-cause or circulatory diseases mortality and, hence, would not be relevant for these analyses.

We did not have detailed information on job task and duties of cohort members, only the department of employment. Women were more frequently employed in secondary production. Job tasks in primary production in this industry were more likely to require physical efforts than tasks in secondary production. However, employment in different departments was not associated with differences in mortality (16).

Since 1950, the labor force participation rate for US women has increased 173 percent (36). Between 1950 and 1994, the labor force participation rate for women increased from 33.9 per 100 women in 1950 to 58.5 per 100 women in 1994, as compared with that for men, whose rate decreased from 86.4 per 100 in 1950 to 75.0 per 100 men in 1994. In the United States, there has been a strong trend of workers away from manufacturing (23.1 percent of working women in 1950 and 11.4 percent in 1994) (36); the corresponding trend in Europe has been weaker (3).

Reducing bias from the healthy worker effect should be considered for all occupational cohort studies of men and women, irrespective of possible gender differences in the magnitude of bias. The increased participation of women in the workforce and the strong healthy worker survivor effect among women together underscore the need to apply methods designed to reduce possible bias (6, 30).

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