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Brief Report

The Economic Burden of Disease by Industry: Differences in Quality-Adjusted Life Years and Associated Costs

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Background *This study compares differences in quality-adjusted life expectancy across the eight original National Occupational Research Agenda (NORA) industry sectors.*

Methods *Data from the 1997 to 2012 National Health Interview Survey (NHIS) were used to estimate quality-adjusted life years (QALYs) for all workers and by NORA sector. Differences in QALYs were calculated and translated into economic values using estimates of the societal willingness-to-pay per QALY.*

Results *Mean QALYs across workers was 29.17 years. Among NORA sectors, wholesale, and retail trade workers had the highest average QALYs remaining (35.88), while mining workers had the lowest QALYs (31.4). The economic value of this difference ranges from $604,843 to $1,155,287 per worker depending on the societal willingness-to-pay per QALY.*

Conclusion *The value of life lost within some industries is very high relative to others. Additional investments in occupational safety, benefits, and health promotion initiatives may reduce these losses, but experimental research is needed to assess the effectiveness of such programs.* Am. J. Ind. Med. 57:757–763, 2014. *© 2014 Wiley Periodicals, Inc.*

KEY WORDS: quality-adjusted life years; QALYs; burden of disease; NORA; years of healthy life

INTRODUCTION

The health and well-being of a workforce is influenced by a complex combination of potential exposures both inside and outside the workplace. Inside the workplace, these are comprised primarily of chemical, biological, physical, and psychological hazards (including smoking and other behavioral risks among colleagues) as well as employer benefits and wellness programs. Outside of the workplace determinants of well-being include those associated with the worker's present day social circumstances (e.g., secondhand smoke, domestic violence, psychological stress, built environment) as well as one's circumstances over the life course [Murray, 2003; Krieger, 2010]. Because there is a good deal of variation in occupational exposures as well as a good deal of sociodemographic variation in the workforce,

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morbidity, and mortality risk should vary significantly across and within industry. For example, the age-adjusted proportion of workers who reported being in either fair or poor health may range from 6% among those in the services sector to 9% in the agriculture, forestry, and fishing sector [Arheart et al., 2011]. Age-adjusted mortality rates also vary dramatically by sector ranging from 490/100,000 among those employed in the healthcare and social assistance sector to 797/100,000 in the agriculture, forestry, and fishing sector [Arheart et al., 2011].

Most burden of disease studies within the occupational health literature have estimated the cost of illness (COI) attributable to certain disease- and/or occupation-linked health problems [Leigh et al., 1997; Leigh, 2000; Steenland et al., 2003; Kessler et al., 2004; Leigh et al., 2004; Prüss-Üstün et al., 2005]. Other studies have compared death rates or life expectancy by occupation to measure differences in mortality [Dubrow et al., 1987]. While life expectancy serves as a good universal measure of health impact, it does not account for changing morbidity and cannot inform how health and longevity change together over time in different population groups such as workers employed in different industries. A more comprehensive measure of the burden of disease is quality-adjusted life years (QALYs)—a standardized metric comprising both changing mortality and morbidity associated with healthcare interventions, lifestyle choices, job choice, or other characteristics [Caban-Martinez et al., 2011]. Because it is a comprehensive measure, the QALY can be used to compare industry sectors that predominantly suffer from morbid conditions (e.g., headaches or depression possibly prevalent in administrative occupations) to those that are more likely to produce fatalities (e.g., motor vehicle accidents in the transportation industry) [Dubrow et al., 1987; Steenland et al., 2003]. Understanding the overall burden of disease by industry sector using QALYs is an understudied approach to evaluating health disparities through an occupational safety/health lens. Moreover, comprehensive measures describing disparities in health and longevity across industries can be used to prioritize workplace wellness programs and other initiatives impacting worker benefits and retirement.

QALYs are used extensively in comparative effectiveness and economic evaluation studies but have not received much attention in occupational research. To fill this gap, and to garner a sense of quality of life disparities among worker groups, we estimated QALYs for U.S. workers overall and among the original eight National Occupational Research Agenda (NORA) industry sectors of the National Institute for Occupational Safety and Health (NIOSH). In addition to presenting the average overall QALYs by sector, we present average QALYs by gender and by two age subgroups (18–64 and 65+) within each sector. We also explore the economic implications of differences in QALYs using monetary conversion factors (i.e., societal cost per QALY). Results provide employers and policymakers with a sense of the comparative burden of disease among industry sectors and the economic value of reducing intersectoral disparities.

MATERIALS AND METHODS

This analysis utilized a pooled sub-sample of 238,569 employed respondents aged 18–88 from the National Health Interview Survey (NHIS), survey years 1997–2012 [US Department of Health and Human Services, 2013]. These respondents represent an estimated annual average of 127,957,143 U.S. residents aged 18 and older. The NHIS is a nationally representative, multipurpose household survey of the U.S. civilian non-institutionalized population conducted annually [US Department of Health and Human Services, 2013]. In addition to a wide range of self-reported demographic and health data, the NHIS contains substantial information concerning employment. Detailed employment information coded by occupation and industry was collected on all subjects $\geq$18 years who reported working (paid and unpaid) during the 2 weeks before the survey date. The original eight NORA industry sectors defined using the North American Industry Classification System (NAICS), which has replaced the U.S. Standard Industrial Classification (SIC) system, include: (1) agriculture, forestry, fishing (NAICS code 11); (2) construction (23); (3) healthcare and social assistance (62); (4) manufacturing (31–33); (5) mining (21); (6) services (51–56, 61, 71–72, 81, 92); (7) transportation, warehousing, utilities (48–49, 22); and (8) wholesale, retail trade (42, 44–45). Recently, NORA redefined the industry list to include two additional sectors: oil and gas extraction and public safety. Data collection and analysis for this study were conducted prior to the addition of these two sectors; therefore, this study did not estimate QALYs for oil and gas extraction and public safety.

Following methods by Erickson and Wilson [1995], quality-adjusted life expectancy was calculated using the self-reported health and activity limitation measures from the NHIS and life expectancy data from the National Vital Statistics System [Erickson and Wilson, 1995]. In this approach, the five levels of self-perceived health generated from the question "Would you say your health in general is excellent, very good, good, fair, or poor?" are combined with six activity limitation measures (not limited; limited-other; limited-major; unable-major; limited in instrumental activity of daily living (IADL); and limited in self-care activity of daily living (ADL) into a single score, called the "Health and Activity Limitation Index (HALex))." Each potential combination of self-perceived health and activity limitations is associated with a unique HALex score. A survey participant was given a score of 1.00 if she/he had no role limitation and was in excellent general health or was given a score of 0.10 if she/he reported having limitations in several activities and reported being in poor health. A score of 1.00 is conceptually equivalent to one full year lived in perfect health. HALex scores are used to weight the average life expectancy for an individual (based on age and gender) to determine the adjusted number of remaining years of perfect health (i.e., number of QALYs) an individual is expected to have. Life expectancy data are available from the Centers for Disease Control and Prevention's National Center for Health Statistics (NCHS). In general, having a lower quality-adjusted life expectancy implies that a group carries a greater burden of disease either because it has higher morbidity, higher mortality, or both.

Although somewhat controversial, a QALY can be expressed in terms of a monetary value. Several studies have estimated the societal willingness-to-pay (WTP) per QALY, which ranges from $33,702 to more than $580,000 [Hirth et al., 2000; Kenkel, 2006]. WTP is an economic concept describing the maximum amount an individual is willing to pay for a good or service, or to avoid harm [Gafni, 1998]. WTP per QALY describes the full societal value placed on 1 year of optimal health. The United States Food and Drug Administration (FDA) has used a more conservative monetary conversion factor of $100,000 per QALY to examine the impact of various regulatory issues [US Department of Health and Human Services, 1999]. Because, there is no consensus on the best "average" estimate of the societal value of a QALY, the current analysis used a middle average across four unique approaches to valuing life described in the study by Hirth et al. [2000] for the upper bound ($257,717 per QALY in 2013 dollars) and the FDA value ($134,926 per QALY in 2013 dollars) for the lower-bound to compare high-cost- and low-cost-per-QALY scenarios [US Department of Health and Human Services, 1999; Hirth et al., 2000].

RESULTS

Table I presents QALYs, incremental QALYs, and the corresponding high- and low-economic costs associated with comparisons across the eight NORA sectors. The table also reports the NHIS sample size for these analyses for all workers, by gender, and by age subgroup within sector. Incremental QALYs are calculated for each NORA industry by subtracting the sector's average QALYs from the QALYs in wholesale and retail trade (the sector with the greatest number of QALYs). This captures the relative disadvantage in terms of health and longevity experienced by one sector relative to the "optimal" sector (optimal in terms of QALYs remaining).

For ease of interpretation, Table I reports average QALYs across all U.S. workers at the top, followed by gender-specific QALYs, and then lists sectors in descending order of QALYs thereafter. QALYs for each sector are further stratified by age subgroup representing workers ages 18–64 and workers 65 and older. Age subgroups are highlighted to show that certain sectors have relatively more older or younger workers, which would impact the overall quality-adjusted life expectancy per sector. Older persons have less remaining years of life and typically experience more morbidity, and therefore have fewer QALYs remaining relative to younger persons [Caban-Martinez et al., 2011]. The core analysis and discussion, however, is focused on workers ages 18–64, representing the majority of workers in all sectors.

Average QALYs remaining from the time of interview to death across all sectors was 29.17 years. Females had greater average QALYs than males (30.41 vs. 27.83). Among industries, the highest average QALYs were found in the wholesale and retail trade sector (35.88 years of optimal health remaining). The lowest average QALYs were among the agriculture, forestry, fishing (31.98 years); transportation, warehousing, utilities (31.62 years); and mining (31.4 years) sectors.

Incremental QALYs report the relative disadvantage in quality-adjusted life expectancy experienced by a particular sector relative to the most advantaged sector (wholesale and retail trade, with an average of 35.88 QALYs remaining). Among NORA sectors, the transportation, warehousing, utilities, and the mining sectors are most disadvantaged relative to wholesale and retail trade with 4.26–4.48 fewer QALYs remaining. In pecuniary terms, this represents a lifetime loss of $575,407 (using low WTP per QALY) to $1,155,287 (high WTP per QALY) for the average worker in these sectors. The agriculture, forestry, fishing and manufacturing sectors have 3.9 and 3.93 fewer QALYs, (respectively) with associated losses valued between $526,456 and $1,012,069 depending on which WTP per QALY estimate is used. Construction workers have 3.14 fewer QALYs representing a loss between $423,014 and $807,983. Finally, the healthcare and social assistance and services sectors experience 1.61 and 2.02 fewer QALYs, respectively, valued between $217,181 and $521,668. The national scope of these losses is substantial. Using the more conservative estimates of the societal WTP per QALY and extrapolating average QALYs to all workers in a sector, the total annual losses relative to wholesale and retail trade range from $340 billion in the mining sector to $14.8 trillion in the services sector.

DISCUSSION

The goal of this study was to empirically assess differences in health and longevity across the original eight NORA industries using QALYs to provide a new perspective on health disparities in the U.S. workforce. We find that

TABLE I. Average and Incremental QALYs and Associated Costs (in 2013 dollars), by NORA Sector

NORA sector	NHIS sample size	Quality-adjusted life expectancy (average QALYs)	Incremental QALYs[a]	Costs ($)–WTP high[b]	Costs ($)–WTP low[c]
All U.S. workers	476,699	29.17 (0.06)	—	7,517,976 (15,028)	3,935,986 (7,868)
		[29.06–29.29]	—	[7,488,467; 7,547,486]	[3,920,536; 3,951,435]
Females	268,253	30.41 (0.07)	—	7,837,876 (17,038)	4,103,467 (8,920)
		[30.28–30.54]	—	[7,804,419; 7,871,334]	[4,085,951; 4,120,984]
Males	208,446	27.83 (0.07)	—	7,172,200 (16,884)	3,754,957 (8,840)
		[27.7–27.96]	—	[7,139,045; 7,205,356]	[3,737,599; 3,772,315]
Wholesale, retail trade	43,467	35.88 (0.09)	*Reference sector	—	—
		[35.7–36.06]			
Ages 18–64	41,476	36.85 (0.09)			
		[36.68–37.03]			
Ages 65+	1,991	11.16 (0.08)			
		[11–11.32]			
Healthcare and social assistance	39,117	34.27 (0.08)	−1.61 (0.08)	414,829 (21,143)	217,181 (11,069)
		[34.11–34.43]	[1.45–1.77]	[373,311; 456,347]	[195,444; 238,917]
Ages 18–64	37,328	35.13 (0.08)			
		[34.97–35.28]			
Ages 65+	1,789	12.20 (0.1)			
		[12.01–12.4]			
Services	116,136	33.86 (0.06)	−2.02 (0.06)	521,668 (15,379)	273,116 (8,052)
		[33.74–33.97]	[1.91–2.14]	[491,468; 551,868]	[257,305; 288,927]
Ages 18–64	110,989	34.74 (0.06)			
		[34.63–34.86]			
Ages 65+	5,147	11.52 (0.06)			
		[11.4–11.63]			
Construction	18,391	32.75 (0.11)	−3.14 (0.11)	807,983 (27,536)	423,014 (14,416)
		[32.54–32.96]	[2.93–3.34]	[753,912; 862,055]	[394,705; 451,323]
Ages 18–64	17,895	33.27 (0.10)			
		[33.06–33.47]			
Ages 65+	496	11.07 (0.14)			
		[10.8–11.34]			
Manufacturing	34,361	31.95 (0.08)	−3.93 (0.08)	1,012,069 (20,102)	529,862 (10,524)
		[31.8–32.11]	[3.77–4.08]	[972,594; 1,051,543]	[509,195; 550,528]
Ages 18–64	33,561	32.39 (0.08)			
		[32.25–32.54]			
Ages 65+	800	11.4 (0.14)			
		[11.13–11.66]			
Transportation, warehousing, utilities	16,740	31.62 (0.11)	−4.26 (0.11)	1,099,063 (29,410)	575,407 (15,397)
		[31.39–31.84]	[4.04–4.49]	[1,041,312; 1,156,815]	[545,172; 605,643]
Ages 18–64	16,266	32.12 (0.11)			
		[31.9–32.35]			
Ages 65+	474	10.98 (0.16)			
		[10.67–11.29]			
Agriculture, forestry, fishing	5,424	31.98 (0.25)	−3.9 (0.25)	1,005,564 (64,367)	526,456 (33,699)
		[31.49–32.47]	[3.41–4.39]	[879,168; 1,131,959]	[460,283; 592,630]
Ages 18–64	5,007	33.63 (0.24)			

(*Continued*)

TABLE I. (*Continued*)

NORA sector	NHIS sample size	Quality-adjusted life expectancy (average QALYs)	Incremental QALYs[a]	Costs ($)—WTP high[b]	Costs ($)—WTP low[c]
		[33.16–34.1]			
Ages 65+	417	10.10 (0.17)			
		[9.77–10.43]			
Mining	1,151	31.4 (0.45)	−4.48 (0.45)	1,155,287 (116,603)	604,843 (61,047)
		[30.51–32.29]	[3.59–5.37]	[926,316; 1,384,259]	[484,967; 724,719]
Ages 18–64	1,107	32.17 (0.44)			
		[31.31–33.03]			
Ages 65+	44	10.26 (0.43)			
		[9.43–11.1]			

Notes: QALYs, quality-adjusted life years; NORA, National Occupational Research Agenda; WTP, willingness to pay. Standard errors in parentheses. 95% confidence intervals in brackets.

[a]Incremental QALYs are calculated relative to the wholesale, retail trade sector (i.e., the sector with the greatest average QALYs).

[b]The high value per QALY is $257,717 and reflects the middle average across four different methods to valuing life presented in Hirth et al. [2000]. Estimates are rounded to the nearest dollar.

[c]The low value per QALY is $134,926 based on an estimate used by the U.S. Food and Drug Administration for various regulatory studies [USDHHS, 1999]. Estimates are rounded to the nearest dollar.

workers in the wholesale and retail trade, healthcare and social assistance, and services sectors experience the highest quality-adjusted life expectancy; whereas, workers in the transportation, warehousing, utilities, and mining sectors are at the greatest disadvantage. In monetary terms (using the FDA's more conservative cost-per-QALY estimate), this disadvantage represents a loss of approximately $500,000 over the life course for the average worker in these sectors. On a national level (using population estimates tied to the NHIS sample size), the loss to the transportation, warehousing, utilities sector is $4.5 trillion; losses to the mining sector are $340 billion.

Some limitations are notable. The NHIS data are cross-sectional, thus temporal associations and causal mechanisms between industry, individual level characteristics, and QALYs cannot be determined. The fact that the NHIS collects data from a representative sample of the U.S. civilian population annually, however, makes it a powerful surveillance tool to look at pooled data and trends in a range of factors impacting workers over time.

A second limitation is that the NHIS only captures the respondent's current job at the time of survey—data are not available to show the impact of employment transitions and/or working in multiple industries over time. Third, life expectancy is assumed to be fairly consistent across industry sectors. We know, however, that there is differential mortality among sectors and within sectors [Fleming et al., 2010]. For instance, those employed in the wholesale and retail trade and the construction sectors had a higher risk of death relative to those employed in the healthcare and social assistance sector (hazard ratio wholesale and retail trade = 1.09; 95% confidence interval = [1.04–1.14]; construction = 1.05; [1.00–1.12]). For these two sectors, disease burden may be slightly underestimated and QALYs slightly overestimated since we did not adjust the industry-specific mortality risk when calculating QALYs.

Furthermore, females have longer life expectancy than males [US Department of Commerce, 2012]; therefore, sectors that are predominantly female like healthcare and social assistance will have relatively more QALYs remaining compared to the mining and agriculture, forestry, and fishing sectors, which are predominantly male. Within sector, age will impact quality-adjusted life expectancy. Persons 65 and older not only have fewer years of life remaining but also tend to suffer more disabling conditions and report declining health status [Caban-Martinez et al., 2011]. As a result, they have relatively fewer QALYs remaining than workers ages 18–64. Agriculture, forestry, and fishing have a greater proportion of older workers and fewer overall QALYs than wholesale and retail trade, which has a greater proportion of younger workers. The absolute difference in average QALYs is relatively small, however, since more than 93% of workers in each sector were ages 18–64.

Disease burden in the wholesale and retail trade and the construction sectors is potentially underestimated due to the healthy worker effect [Fleming et al., 2010]. The healthy worker effect is a phenomenon in which the observed mortality and/or morbidity rates among workers are lower than they should be because individuals with a chronic disability or severe illness leave the workforce and are not included in the estimates of occupation- or industry specific mortality risk [Shah, 2009].

A fourth limitation is that the NHIS's HALex is not a preference-based health-related quality of life (HRQL) measure, and does not capture the health utility associated with multiple domains across the physical and mental health spectra. "Preference-based" refers to the process of surveying a representative sample from the general population about how they rank different diseases, conditions, symptoms, and other characteristics. These rankings are translated into HRQL scores that are considered representative of societal preferences for health status. Although not preference-based, the HALex has been successfully translated into a measure of "years of healthy life" (YHL) allowing us to estimate QALYs (noting the potential lack of sensitivity to certain diseases or conditions) [Erickson and Wilson, 1995; Muennig and Gold, 2001]. Moreover, evidence suggests that the degree of comparability between the HALex and preference-based HRQL measures (such as the EuroQol EQ-5D) may be better than expected, as they are shown to rank health states similarly and are statistically relatable through two-part linear transformations that do not impose a strict lower bound of zero [EuroQol Group, 1990; Fryback et al., 2010].

Finally, in the wake of health care reform and the Patient Protection and Affordability Care Act's integration of comparative effectiveness research, using cost-per-QALY as a "threshold" to make treatment recommendations is discouraged [Newmann and Weinstein, 2010]. There are various factors influencing this stance including concerns that existing cost-per-QALY estimates do not accurately represent certain population subgroups (minorities, the elderly, and the disabled); and that using these estimates to inform resource allocation decisions will force policy makers to ration care [Newmann and Weinstein, 2010]. This issue is more relevant, however, for studies that are conducting cost-effectiveness analyses of two or more competing health care programs or interventions; less so for a descriptive study such as this one. Furthermore, the Institute of Medicine has named priority areas for continued research, which includes comparative effectiveness research and health disparities [Iglehart, 2009]. The estimation of cost-per-QALY differences among industry sectors can therefore provide a compelling financial rationale for dedicating resources toward interventions designed to reduce these disparities.

Despite these limitations, the NHIS data are unique in providing reported functional capabilities, medical conditions, and self-perceived health among certain demographic subpopulations and among NORA industries for the entire U.S. population. Although these data do not describe predictors of greater/lesser burden of disease, the information on QALYs by gender and sector provides a starting point to think about differences in health-related quality of life in U.S. workers. These findings are of interest to employers and government officials seeking to understand health disparities across and within industries. Additional investments in occupational safety, benefits, and health promotion initiatives may reduce losses associated with industry, but experimental research is needed to assess the effectiveness of such programs.

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