

FAST TRACK ARTICLE

Tenth Revision U.S. Mortality Rates for Use With the NIOSH Life Table Analysis System

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Objective: *The objective of this study was to update rate files for the NIOSH Life Table Analysis System for Personal Computers (PC LTAS) reflecting the newly adopted tenth revision changes to the International Classification of Diseases. Methods:* PC LTAS allows researchers to conduct comparative mortality and morbidity analyses for the purpose of identifying disease-exposure associations using person-time-at-risk for age, race, sex, and calendar time-specific reference rates from 1940. Previously available through 1998, files for the United States and individual states were updated through 2004 using uncensored population data. Tenth revision causes were added if compatible with earlier NIOSH death categories, based on revisions 5 through 9. A few new cause categories were added. **Results:** *The resulting NIOSH categories are described for two new U.S. rate files: 1960 through 2004 and 1940 through 2004. Conclusion:* *The new U.S. rate files are available online or on request. (J Occup Environ Med. 2006;48:662–667)*

The NIOSH Life Table Analysis System for Personal Computers (PC LTAS) uses the World Health Organization (WHO) International Classification of Diseases (ICD) code for the cause of death. The ICD codes are used by the National Center for Health Statistics (NCHS) to code annually all U.S. population deaths for compilation and publication of national and state mortality rates. Approximately each decade, the ICD codes have been revised to incorporate changes in the classification of diseases. When developed in 1970, the NIOSH Life Table program (LTAS) contained codes for three ICD revisions—the fifth (ICD-5),¹ sixth (ICD-6),² and seventh (ICD-7)³—and could analyze cohort data for the period 1940–1979.⁴ LTAS has since incorporated changes in two more revisions—the eighth (ICD-8)⁵ and ninth (ICD-9)⁶—and a version was developed for the personal computer (PC LTAS).⁷ With the addition of the tenth revision (ICD-10),⁸ PC LTAS now contains codes for cause of death for six revisions of the ICD, implemented in 1939, 1949, 1958, 1968, 1979, 1999, respectively. Each revision has its own rules for coding and selecting the underlying cause of death. PC LTAS ensures comparability of observed study deaths with the national mortality rates by coding cause of death by the rules of the revision in effect at the time of death.

Recently, mortality rate files for the NIOSH PC LTAS have been updated to reflect changes effective January 1, 1999, brought about by the tenth revision of the International Classification of Diseases (ICD-10).⁸

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The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

Authors' note: Accompanying Tables 1–4 may be accessed at www.joem.org (click "Article Plus") or www.cdc.gov/NIOSH/LTIndex.html. Files may be accessed at www.cdc.gov/NIOSH/LTIndex.html.

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U.S. reference death rates were updated with the addition of deaths for 1999 through 2003, available from the National Center for Health Statistics, and with U.S. census population estimates through 2004.⁹ The purpose of this article is to summarize for users of PC LTAS the method for updating the mortality rates and to describe the resulting changes to the cause of death categories and death rates. Updated NIOSH rate files and the current PC LTAS are available on the internet on the NIOSH homepage¹⁰ or on request.

Background

NIOSH Life Table Analysis System for Personal Computers

The original NIOSH Life Table Analysis System was developed to analyze occupational cohort studies.⁴ As the need for comprehensive analysis of occupational epidemiologic data grew, additional capabilities were added.^{7,11} The PC LTAS currently is used by researchers to analyze occupational cohort morbidity and mortality data and to calculate person-years at risk used in rates that are adjusted indirectly or directly. PC LTAS uses mortality rates to calculate indirectly adjusted standardized mortality ratios by comparing the observed number of deaths in the study population with the expected number of deaths based on rates in the general U.S. population. The person-years at risk and comparison rates are stratified by potentially confounding variables (age, race, sex, calendar time, and exposure and latency periods). Mortality rates are standardized using covariates available within the general population (generally, age, race, sex, and calendar time). Reference rate files for the U.S. population, states or counties, may be used to make external comparisons, or the rate file structure may be used to conduct within-cohort comparisons across duration or cumulative exposure categories using directly standardized rate ra-

tios. Users can create special rate categories or can substitute their own standard rates and categories. Detailed descriptions and system requirements are available online.¹⁰

Tenth Revision International Classification of Diseases Codes and NIOSH Life Table Analysis System for Personal Computers

The NIOSH mortality rate files are organized using ICD codes with causes of death grouped consistently across the time period. Since the adoption by the National Center for Health Statistics (NCHS) of the fifth Revision in 1940,¹ there have been five subsequent revisions of the ICD (in 1949, 1958, 1968, 1979, and 1999). Each revision has its own coding and selection rules for the underlying cause of death.^{2,3,5,6} Like the U.S. cause of death statistics, cohort death rates are based on the underlying cause of death, although multiple cause of death analysis can also be conducted. The underlying cause of death is defined as the disease or injury that initiated the sequence of events leading directly to death. It is selected from the conditions entered in the cause of death section on the death certificate by the certifying physician, coroner, or medical examiner based on the sequence of events and coding rules⁹ specified by the International Classification of Diseases. Since the implementation of the tenth revision of the ICD in the United States in 1999, all U.S. deaths have been coded by nosologists according to tenth revision rules.⁸

Due to changes in medical nomenclature and knowledge, the tenth revision uses twice as many nosologic codes for causes of death as does ICD-9. Additionally, the tenth revision is a structural break with past revisions because it has alphanumeric rather than numeric categories. The intent of the World Health Organization in making these changes was to stay abreast with advances in medical science and ensure the international comparability of health statistics. According to the WHO, the underlying cause, using ICD codes,

is that occurring at the earliest point in the causal chain of morbid events when a public health action might have prevented the disease. Reductions in the age-standardized death rates are often used as a measure of progress against disease.¹²

Materials and Methods

Incorporation of Tenth Revision Codes by the NIOSH Working Group

The NIOSH working group incorporated tenth revision codes into the PC LTAS for the time period 1940–2004 after review for compatibility with NIOSH death categories that are based on revisions 5 through 9. Using the ASCII version of the ICD-9 to ICD-10 translator,¹³ the NIOSH working group compared all equivalent disease codes for the translation of ICD-9 codes with ICD-10 and vice versa for 12,421 causes of death. Then, all possible equivalent codes were reviewed for their appropriateness and use consistent with the preexisting NIOSH cause of death categories. If a ninth revision code split into more than one code in the tenth revision, decisions were based on the number of population deaths.

New NIOSH Cause of Death Categories

New causes of death or tenth revision codes with no equivalency in the ninth revision were identified and assigned to a NIOSH cause of death category. These included mesothelioma, cancer of the pleura, chronic obstructive pulmonary disease (COPD), terrorism, and 20 new NIOSH unintentional injury cause of death categories.

Revised Cause of Death Categories

Other categories were revised to accommodate trends in medical nomenclature and diagnosis, including non-Hodgkin lymphoma, multiple myeloma, leukemia, cancer of the

liver, lymphosarcoma/reticulosarcoma, pneumonia, chronic bronchitis, emphysema, asthma, Alzheimer disease, and others. For all changed or new NIOSH death categories, the fifth, sixth, seventh, eighth, and ninth revisions were reviewed and corresponding codes were moved into the appropriate categories. This ensured that deaths were grouped correctly and consistently over the time interval.

Invalid Codes

It should be noted that some codes in ICD-10 and earlier revisions have been deemed invalid by NCHS. Invalid codes are unsuitable for use as underlying or multiple cause codes (eg, F00: dementia in Alzheimer disease). Nosologists trained by NCHS do not use invalid codes to code the certificate's causes of death.¹⁴ Although a high proportion of invalid codes were deleted from the PC LTAS rate files' descriptive tables (Tables 1 and 3)*, a few codes may have inadvertently remained in the descriptive tables as part of sequences. However the invalid codes are not included in the NIOSH rate files; researchers should be vigilant in excluding them from the study cohort's observed death file.

U.S. Rates and NIOSH Life Table Analysis System for Personal Computers

Updated major and minor NIOSH cause of death categories were created for two mortality rate files that cover different time periods (Tables 2 and 3). The NIOSH-119 mortality rate file incorporates ICD codes stratified by sex, race, and 5-year calendar time periods from 1960 through 2004 (Table 1). The NIOSH-92 mortality rate file incorporates ICD codes stratified by sex, race, and 5-year calendar time periods from 1940 to 2004 (Table 3). Rates for individual states also

were created for the period 1960–2004. County rates may be requested.

Extrapolation of Rates

To provide denominator data for current and future studies, U.S. mortality rates for 2004 were extrapolated. The extrapolation used the averaged actual rates for the previous 4-year interval, 2000 to 2003. The 2000–2004 period populations were obtained from the intercensal estimates provided by the U.S. Census Bureau.

Verification of Rates

Ratios of 1999 to 1998 underlying cause of death counts were compared. The exceptions, for which the ratios differed from unity by more than 10%, were categorized. Counts of ICD codes within categories were made and cells were audited. LTAS rates were compared against U.S. mortality rates.

Results

An overview of changes in the rate structures is described below.

The New NIOSH-119, for Time Period 1960–2004

The new NIOSH U.S. death rate categories for the time period 1960–2004 are described in Table 1*. Updating the rate files with the tenth revision resulted in increasing the number of minor rate categories from 99 to 119. The additional minor categories are primarily due to the addition of more detailed cause-specific ICD codes for occupational respiratory disease, cancer, and unintentional injuries available in the tenth revision. Table 1 lists all ICD codes for each cause of death for the four ICD revisions used during the years 1960 through 2004. The major changes in disease categories of NIOSH-119 that resulted from the impact of the tenth revision are described subsequently.

Cancer Categories

Mesothelioma. A new category (Minor 31 in the NIOSH-119 and Minor 28 in NIOSH-92 rate files),

contains four-digit tenth revision codes for mesothelioma of the pleura, peritoneum, pericardium, or an unspecified site. The new rate category for mesothelioma will invoke death rates only from 1999 forward because previous revisions had no codes for mesothelioma. It should be noted because of the new mesothelioma codes under C45.0–C45.9 available in 1999, rates for cancer of the pleura (Minor 17) and peritoneum (Minor 14) are discontinuous for the 1995–1999 and the 2000–2004 rates for the following reasons. Before the tenth revision of the ICD, mesothelioma deaths were coded to the site specified on the death certificate. For example, some were coded as pleural cancer (Minor 17 in the NIOSH-119 and Minor 16 in the NIOSH-92) and some as cancer of the peritoneum (Minor 14 in the NIOSH-119 and Minor 13 in NIOSH-92). When no site was specified, the code for cancer without specification of site was used, eg, 199 in the ninth revision. When “malignant” was not specified on the death certificate, the code for a benign or neoplasm of unspecified nature could have been used in the seventh revision. Not until 1999 with the implementation of the tenth revision has it been possible to construct a reliable and accurate death rate for mesothelioma using vital statistics data.

Table 2 displays the number of deaths¹⁵ coded to mesothelioma in 1999 under the new tenth revision code, C45, compared against the previous year, 1998. Options for coding mesothelioma (as cancer) are compared across prior revisions (fifth, sixth, seventh, eighth, ninth). U.S. mesothelioma deaths for 1999 are compared against the previous year, 1998.

Table 2 shows that in 1999, there were 2343 deaths for which the underlying cause was mesothelioma and were coded to C45; however, most ($n = 1647$) were not specified by site. There were 227 deaths from mesothelioma of the pleura in 1999. Only 99 deaths were coded to cancer of the

*Authors' note: Tables 1–4 of the manuscript may be requested from the corresponding author or accessed at either <http://www.cdc.gov/NIOSH/LTIndex.html> or at <http://www.joem.org>.

pleura in 1999 compared with 410 in 1998. This suggests that most pleural mesotheliomas were coded to cancer of the pleura in 1998 and earlier years. The number of peritoneal cancers dropped from 804 in 1998 to 650 in 1999. Of two recently published studies, one reported based on accumulated SEER tumor registry data that malignant mesothelioma accounted for only 20% of peritoneal cancer in men but 98% of pleural cancer.¹⁶ Assuming a similar percentage (20%) among mesothelioma mortality data, it would not be reasonable to consider all cancer of the peritoneum to be mesothelioma.

It is of interest that a slight majority (381 of 696 [55%]) of U.S. deaths from mesothelioma of specified site occurring in 1999 (on Table 2) was of sites other than pleura, peritoneum, or pericardium. From Table 2, it appears that using codes for cancer of the pleura will result in an overestimate of the actual number of pleural mesotheliomas. *More importantly, using codes for cancer of pleura, peritoneum, and pericardium will underestimate by over 200% the total number of mesotheliomas.*

A French study found mesothelioma accounted for 80% of pleural cancer in men and 50% in women.¹⁷ Based on the SEER data described here, it might be reasonable to consider cancer of the pleura to be mesothelioma. However, pleural cancer is inseparable from other lung cancer in codes of the fifth and sixth revisions. The site-specific codes for mesothelioma newly available in the tenth revision will allow calculation of a more accurate death rate starting in 1999. However, researchers are cautioned that the tenth revision codes will not resolve all issues that surround mesothelioma and other causes; it remains essential to review the written death certificate whenever possible. Although the *tenth revision* has improved the identification and rates for causes such as mesothelioma or lymphoma, caution should be used for deaths before 1999.

Other Cancer. For consistency, the former categories of cancer of the biliary passages, liver, and gallbladder (Minor 11) and cancer of the liver not specified (Minor 12) were combined to form one new category.

Lymphoma and lymphosarcoma/reticulosarcoma, handled as two minors in one of the previous versions of PC LTAS rates, were combined in one category, non-Hodgkin's lymphoma, 35 in the new NIOSH-92 rate file, and Minor 38 in the NIOSH-119 rate file. (Multiple myeloma was retained in each file as a separate minor.) The combined category resulted from numerous transitions in nosologic coding and nomenclature that have occurred from 1950–1999. Most notably, the proportion of all non-Hodgkin's lymphomas coded as lymphosarcoma and reticulosarcoma has declined substantially over recent decades, from 43% in 1979 to 3% in 1999.¹⁵ Pre-1960 rates for many of the individual diseases contained in this category were unavailable to NIOSH due to limitations in source data. However, the data available indicate that most non-Hodgkin's lymphoma and multiple myeloma deaths will be properly classified in these early years.

Some immunoproliferative diseases that are now classified by the tenth revision as cancer were reclassified and put into the appropriate NIOSH cancer categories when separate codes were available. For example, the tenth revision defined panmyelosis (C94.4) and myelofibrosis (C94.5) as malignant disease rather than benign, and they were accordingly placed in the leukemia category (Minor 40 in the NIOSH-119 and Minor 37 in the NIOSH-92). However, corresponding ninth revision codes 238.7 and 289.8 for panmyelosis and myelofibrosis could not be differentiated from other related diagnoses, and these codes remained in Minor 43, other benign and unspecified neoplasms, and Minor 47, all other diseases of blood forming organs, in the NIOSH-119. The codes for macroglobulinemia

(Waldenstrom) were moved from multiple myeloma into the non-Hodgkin's lymphoma minor due to recent diagnostic changes for this disorder.¹⁸ These codes are 275.5 in the eighth revision, 273.3 in the ninth revision, and C88.0 in the tenth revision.

Other Disease Category Changes

The nonmalignant respiratory disease categories includes diseases of occupational etiology, including asbestosis (Minor 68), silicosis (Minor 69), and other pneumoconiosis (Minor 70) that are specified separately in the NIOSH-119 from other respiratory disease (Minor 71). Emphysema and chronic bronchitis were combined with COPD not otherwise specified into a new category, Minor 66 in NIOSH-119 and Minor 62 in NIOSH-92, to align with current diagnostic practice (which classifies the majority of chronic bronchitis and emphysema as COPD). This also accommodates coding changes within the tenth revision; when COPD is mentioned in conjunction with emphysema, bronchitis, or asthma in the tenth revision, a new code, J44.8, "other specified COPD," is invoked. The airflow obstruction associated with asthma is largely reversible, unlike abnormalities associated with bronchitis and emphysema, and has a primarily immunologic etiology. Thus, asthma, Minor 67 in NIOSH-119 and Minor 63 in NIOSH-92, remained separate minor categories in the new rate files.

Several musculoskeletal diseases, including intervertebral disc disorders, polymyalgia rheumatica, and peripheral neuropathies, were moved from the other cause category (now Minor 119) into the other musculoskeletal disease category (Minor 80). Although these conditions are infrequently the underlying cause of death, they are responsible for substantial morbidity among the working population. Crystal arthropathies, other than gout, were moved out of the other or residual cause category (Minor 119) and moved into the

arthritis and spondylitis category (Minor 78). As in the earlier rate files, most infectious diseases, except for tuberculosis and HIV-related disease, were placed in Minor 119—the NIOSH residual category that contains all other causes of death.

Expansion of Injury Categories

Previously, the NIOSH rate files had only four categories for deaths due to unintentional injury: transportation accidents, accidental poisoning, accidental falls, and other accidents.⁷ For the NIOSH-119, these categories were expanded to 27 more specific injury categories (Minors 91–117). The new categories identify specifics of the cause of death such as falls from ladders, down stairs or from buildings, and so on. Similarly, transportation injuries are broken down by subcategories, including transportation and passenger type. The old category, “other accidents,” was expanded into several new causal subgroups: fire, drowning, struck by falling object, suffocation, explosion, electrocution, and others. The usefulness of more detailed categories has been shown in an analysis of construction worker deaths¹⁹ that identified trade-specific injuries among operating engineers, including falls from buildings.

Lastly, a new PC LTAS minor, terrorism, was added: Minor 118, in the NIOSH-119 and Minor 91 in the NIOSH-92. This new category was created for deaths due to terrorism, a new class of codes created by NCHS after the terrorism-related deaths in New York City, Washington, DC, and Pennsylvania.²⁰ These codes are not standard WHO codes. They currently reflect 2922 deaths occurring in 2001 related to the terrorist incidents of September 11, 2001.

The New NIOSH-92, for Time Period 1940–2004

The NIOSH-92 death categories are shown in Table 3. The purpose of the NIOSH-92 rate file is to analyze risk in study cohorts with follow up beginning in the 1940s or 1950s. It incorporates death rates from six re-

visions of the ICD. The NIOSH-92 was updated similarly to the NIOSH-119 wherever possible. Due to limitations (less specificity) of death codes before 1960, there were fewer changes as a result of the transition, ie, more specific ICD codes do not exist for the earlier revisions. Additionally, some of the changes made to minors for the NIOSH-119 could not be implemented in the NIOSH-92 because specific codes added for the tenth revision could not be differentiated from the broader codes of the fifth and sixth revisions due to limitations in the source codes. However, all possible changes were made to make previous revisions compatible with the changes of the tenth revision.

Verification of the Revised Rates

To evaluate the impact of the new classification system on death counts for the PC LTAS disease categories, all U.S. deaths occurring in 1999 (ICD-10), 1998, and 1997 (ICD-9) were coded to NIOSH-119 categories and summarized by gender, race, and 5-year age groups (beginning at age 15–19 and ending at age 85 and above). In general, ratios of 1999 to 1998 underlying cause of death counts were similar to those for 1998 to 1997 (before the change to ICD-10). Exceptions, for which the ratio of 1999 to 1998 deaths differed from unity by more than 10%, fell into three groups (Table 4): 1) those caused by regrouping of the PC LTAS classifications (eg, creation of new mesothelioma category reducing the number of pleural cancers); 2) coding rule changes in ICD-10 that would be expected to lead to increases in some categories (eg, Alzheimer disease) and decreases in others (eg, pneumonia), which have been evaluated in bridge-coded comparability studies between ICD-10 and -9²¹; and 3) other sources of nonrandom and random variability. Some of the other differences include motor vehicle traffic category ratios (Minors 92–96, NIOSH-119),

which fluctuate because of changes in how unspecified occupants of vehicles are classified in the tenth revision. Similarly, changes in coding of unclassified fractures may account for some of the decrease in unspecified falls, Minor 102, NIOSH-119 (Table 4).

As an additional verification, lists of ICD counts were made for the ICD codes within each NIOSH-119 category. Checks of sums by gender, race, and age group assured that all ICD codes were counted. A small subset of the cells was audited to count each contributing ICD code. Some cells were chosen by the highest and lowest ratio of the counts, and others were selected at random. PC LTAS rates were compared against U.S. mortality rates on CDC Wonder¹⁵ using NIOSH cohort mortality study data. Ideally, the PC LTAS rates generated should be compared for accuracy against rates developed by another institution; however, none are presently available.

Summary

The new national and state rate files for use with PC LTAS that incorporate tenth revision ICD codes stratified by age, gender, race, and calendar time for 1960 through 2004, and national rate files for 1940 through 2004, are available at: <http://www.cdc.gov/NIOSH/LTIndex.html> or on request. For the NIOSH-119 rates for the period 1960–2004, the number of cause of death categories was increased primarily to allow for more detailed categories of occupational respiratory disease, cancer (including mesothelioma), and unintentional injuries and to accommodate changes in tenth revision nosologic coding. NIOSH-92 rate files were created for the earlier time period, 1940–2004, to analyze risk in study cohorts with follow up that begin in the 1940s and 1950s. State rates for the United States using the new categories were created for 1960 through 2004.

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