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Steps Required to Calculate Proportionate Mortality Ratios

# Proportionate Mortality Ratio

The proportionate mortality ratio (PMR) can be used for statistical analyses of mortality data to estimate associations between exposures and causes of death of interest. Many previous publications have defined the PMR and provided statistical methods that can be used to calculate the PMR and its accompanying 95% confidence interval (CI) (e.g., Beard et al. 2017; Breslow and Day 1987; Checkoway et al. 2004; Lalich et al. 1990; Miettinen and Wang 1981; National Institute for Occupational Safety and Health [NIOSH] 2019). In essence, the PMR is calculated as the proportion of deaths from the cause(s) of interest among the exposed divided by the proportion of deaths from the cause(s) of interest (Breslow and Day 1987; Checkoway et al. 2004; Lalich et al. 1990; Miettinen and Wang 1981; NIOSH 2019). For example, suppose there is interest in estimating the association between having a usual occupation of crane and tower operator (i.e., U.S. Census Bureau 2010 occupation code 9510; U.S. Census Bureau 2020) and mortality from unspecified dementia (i.e., *International Classification of Diseases*, 10th Revision [ICD-10], code F03; National Center for Health Statistics [NCHS] 2020). In this example, the exposure is the crane and tower operators occupation and the cause of death of interest is unspecified dementia. Thus, the PMR is calculated as the proportion of deaths from unspecified dementia among crane and tower operators divided by the proportion of deaths from unspecified dementia.

The PMR can also be conceptualized as the observed number of deaths from the cause(s) of interest among the exposed divided by the expected number of deaths from the cause(s) of interest among the exposed (Breslow and Day 1987; Checkoway et al. 2004; Lalich et al. 1990; Miettinen and Wang 1981; NIOSH 2019). In this conceptualization, the expected number of deaths from the cause(s) of interest among the exposed is calculated as the proportion of deaths from the cause(s) of interest multiplied by the number of deaths from all causes among the exposed. For example, the PMR is calculated as the observed number of deaths from unspecified dementia among crane and tower operators divided by the expected number of deaths from unspecified dementia among crane and tower operators. The expected number of deaths from unspecified dementia among crane and tower operators is calculated as the proportion of deaths from unspecified dementia multiplied by the number of deaths from all causes among crane and tower operators.

PMRs range in value from zero to infinity. A value less than one indicates an inverse association, equal to one indicates no association, and greater than one indicates a positive association between the exposure and the cause(s) of death of interest. PMRs are sometimes multiplied by 100 so that a value less than 100 indicates an inverse association, equal to 100 indicates no association, and greater than 100 indicates a positive association between the exposure and the cause(s) of death of interest (e.g., Robinson et al. 2015).

PMRs can be unadjusted (i.e., crude) or they can be indirectly standardized to a standard population (e.g., deaths from all causes in a general population) to adjust for potential confounding biases. For example, the PMR for the association between having a usual occupation of crane and tower operator and mortality from unspecified dementia can be indirectly standardized by age, sex, race, ethnicity, education, etc. Categorical versions of the potential confounders are used for the indirect standardization (e.g., categories for age could be 18-24, 25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85-94, and 95-119 years).

Unadjusted or indirectly standardized PMRs can also be calculated for sub-groups defined by demographic or other variables (e.g., females only, Hispanics only, ages 18-65 year only, etc.). The dataset must first be restricted to the sub-group of interest and then the calculation of the unadjusted or indirectly standardized PMR proceeds as usual.

Unadjusted or indirectly standardized PMRs can be calculated for an individual cause of death, such as unspecified dementia, or a group of causes of death, such as demyelinating diseases of the central nervous system (i.e., ICD-10 codes G35, G36, G360, G361, G368, G369, G37, G370, G371, G372, G373, G374, G375, G378, and G379; NCHS 2020). Unadjusted or indirectly standardized PMRs can be calculated using only the underlying cause of death or underlying and multiple causes of death.

Unadjusted or indirectly standardized PMRs can be calculated for an individual exposure, such as the crane and tower operators occupation, or a group of exposures, such as material moving occupations (i.e., U.S. Census Bureau 2010 occupation codes 9510, 9520, 9560, 9600, 9610, 9620, 9630, 9640, 9650, 9720, 9730, 9740, and 9750; U.S. Census Bureau 2020). Another example of an individual exposure is the automotive repair and maintenance industry (i.e., U.S. Census Bureau 2012 industry code 8770; U.S. Census Bureau 2020), whereas another example of a group of exposures is the other services, except public administration, industries (i.e., U.S. Census Bureau 2012 industry codes 8770, 8780, 8790, 8870, 8880, 8890, 8970, 8980, 8990, 9070, 9080, 9090, 9160, 9170, 9180, 9190, and 9290; U.S. Census Bureau 2020).

A limitation of using PMRs for analysis is that cause-specific PMRs are mutually dependent (Checkoway et al. 2004; Miettinen and Wang 1981). In other words, an increased PMR for one cause of death means there will be a decreased PMR for another cause of death and vice versa (i.e., PMRs may be artificially increased or decreased; Checkoway et al. 2004; Miettinen and Wang 1981). Please see Miettinen and Wang (1981) for an explanation regarding how to address this limitation.

# Steps to Calculate an Unadjusted Proportionate Mortality Ratio

An unadjusted PMR is calculated using the following steps:

1. Determine the exposure (e.g., an individual or a group of industry or occupation codes[s]).
2. Determine the outcome/cause(s) of death of interest (e.g., an individual or a group of ICD-10 code[s]) using underlying cause of death only or underlying and multiple causes of death.
3. Calculate (i.e., count) the number of deaths from all causes.
4. Calculate (i.e., count) the number of deaths from the cause(s) of interest.
5. Calculate (i.e., count) the number of deaths from all causes among the exposed.
6. Calculate (i.e., count) the (observed) number of deaths from the cause(s) of interest among the exposed.
7. Calculate the proportion of deaths from the cause(s) of interest as the number of deaths from the cause(s) of interest divided by the number of deaths from all causes.
8. Calculate the expected number of deaths from the cause(s) of interest among the exposed as the proportion of deaths from the cause(s) of interest multiplied by the number of deaths from all causes among the exposed.
9. Calculate the unadjusted PMR by dividing the observed number of deaths from the cause(s) of interest among the exposed by the expected number of deaths from the cause(s) of interest among the exposed.
10. If desired, multiply the unadjusted PMR by 100.

# Steps to Calculate an Indirectly Standardized Proportionate Mortality Ratio

An indirectly standardized PMR is calculated using the following steps:

1. Determine the exposure (e.g., an individual or a group of industry or occupation codes[s]).
2. Determine the outcome/cause(s) of death of interest (e.g., an individual or a group of ICD-10 code[s]) using underlying cause of death only or underlying and multiple causes of death.
3. Determine the covariates (e.g., age, sex, race, ethnicity, education, etc.) that will be used to indirectly standardize the PMR.
4. Sort the entire dataset by the covariates (i.e., potential confounders) that will be used to indirectly standardize the PMR. The sorted dataset is essentially stratified by the combination of the covariates that will be used for indirect standardization.
5. Calculate (i.e., count) the number of deaths from all causes within strata of the covariates used for indirect standardization.
6. Calculate (i.e., count) the number of deaths from the cause(s) of interest within strata of the covariates used for indirect standardization.
7. Calculate (i.e., count) the number of deaths from all causes among the exposed within strata of the covariates used for indirect standardization.
8. Calculate (i.e., count) the (observed) number of deaths from the cause(s) of interest among the exposed within strata of the covariates used for indirect standardization.
9. Calculate the proportion of deaths from the cause(s) of interest within strata of the covariates used for indirect standardization. The proportion of deaths from the cause(s) of interest is calculated as the number of deaths from the cause(s) of interest divided by the number of deaths from all causes.
10. Calculate the expected number of deaths from the cause(s) of interest among the exposed within strata of the covariates used for indirect standardization. The expected number of deaths from the cause(s) of interest among the exposed is calculated as the proportion of deaths from the cause(s) of interest multiplied by the number of deaths from all causes among the exposed.
11. Calculate the overall observed number of deaths from the cause(s) of interest among the exposed by summing the stratum-specific observed number of deaths from the cause(s) of interest among the exposed.
12. Calculate the overall expected number of deaths from the cause(s) of interest among the exposed by summing the stratum-specific expected number of deaths from the cause(s) of interest among the exposed.
13. Calculate the indirectly standardized PMR by dividing the overall observed number of deaths from the cause(s) of interest among the exposed by the overall expected number of deaths from the cause(s) of interest among the exposed.
14. If desired, multiply the indirectly standardized PMR by 100.

# Steps to Calculate a 95% Confidence Interval for the Proportionate Mortality Ratio

A two-sided 95% CI for an unadjusted or indirectly standardized PMR is calculated using formulas based on Byar’s approximation to the exact Poisson test (Breslow and Day 1987; NIOSH 2019). Here are some abbreviations that will be needed to understand the formulas:

O: (overall) observed number of deaths from the cause(s) of interest among the exposed

E: (overall) expected number of deaths from the cause(s) of interest among the exposed

Z: standard normal distribution critical value (i.e., approximately 1.96) needed to calculate a two-sided 95% CI for the unadjusted or indirectly standardized PMR

LCL: lower confidence limit

UCL: upper confidence limit

A two-sided 95% CI for an unadjusted or indirectly standardized PMR is calculated using the following steps:

1. For an unadjusted PMR, repeat steps 1-8 under “Steps to Calculate an Unadjusted Proportionate Mortality Ratio”. For an indirectly standardized PMR, repeat steps 1-12 under “Steps to Calculate an Indirectly Standardized Proportionate Mortality Ratio”.
2. Calculate the lower confidence limit using the following formula (Breslow and Day 1987, p. 69; NIOSH 2019, p. 66):

$$LCL=\frac{O×\left(1-\frac{1}{9×O}-\frac{Z}{3×\sqrt{O}}\right)^{3}}{E}$$

1. Calculate the upper confidence limit using the following formula (Breslow and Day 1987, p. 69; NIOSH 2019, p. 66):

$$UCL=\frac{\left(O+1\right)×\left(1-\frac{1}{9×\left(O+1\right)}+\frac{Z}{3×\sqrt{\left(O+1\right)}}\right)^{3}}{E}$$

1. If desired, multiply the lower and upper confidence limits by 100.

# Steps to Calculate an Unadjusted or Indirectly Standardized Proportionate Mortality Ratio and 95% Confidence Interval for a Sub-Group

An unadjusted or indirectly standardized PMR and 95% CI for sub-groups defined by demographic or other variables (e.g., females only, Hispanics only, ages 18-65 year only, etc.) is calculated using the following steps:

1. Restrict the dataset to the sub-group of interest.
2. For an unadjusted PMR, repeat steps 1-10 under “Steps to Calculate an Unadjusted Proportionate Mortality Ratio”. For an indirectly standardized PMR, repeat steps 1-14 under “Steps to Calculate an Indirectly Standardized Proportionate Mortality Ratio”.
3. Repeat steps 1-4 under “Steps to Calculate a 95% Confidence Interval for the Proportionate Mortality Ratio”.

# References

Beard JD, Steege AL, Ju J, Lu J, Luckhaupt SE, Schubauer-Berigan MK. Mortality from amyotrophic lateral sclerosis and Parkinson’s disease among different occupation groups — United States, 1985-2011. MMWR Morb Mortal Wkly Rep. 2017;66(27):718-722. https://doi.org/10.15585/mmwr.mm6627a2.

Breslow NE, Day NE. Statistical Methods in Cancer Research. Volume II—The Design and Analysis of Cohort Studies. IARC Scientific Publications No. 82. Lyon, France: International Agency for Research on Cancer; 1987. https://publications.iarc.fr/Book-And-Report-Series/Iarc-Scientific-Publications/Statistical-Methods-In-Cancer-Research-Volume-II-The-Design-And-Analysis-Of-Cohort-Studies-1986.

Checkoway H, Pearce N, Kriebel D. Research Methods in Occupational Epidemiology. 2nd ed. New York, NY: Oxford University Press, Inc.; 2004.

Lalich N, Burnett C, Robinson C, Sestito J, Schuster L. A Guide for the Management, Analysis, and Interpretation of Occupational Mortality Data. DHHS (NIOSH) Publication No. 90-115. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health; 1990. https://www.cdc.gov/niosh/docs/90-115/pdfs/90-115.pdf?id=10.26616/NIOSHPUB90115.

Miettinen OS, Wang J-D. An alternative to the proportionate mortality ratio. Am J Epidemiol. 1981;114(1):144-148. https://doi.org/10.1093/oxfordjournals.aje.a113161.

National Center for Health Statistics. Classification of Diseases, Functioning, and Disability Homepage. http://www.cdc.gov/nchs/icd/. Updated June 20, 2020. Accessed May 6, 2021.

National Institute for Occupational Safety and Health. LTAS Manual. https://www.cdc.gov/niosh/ltas/pdf/LTAS-manual-2014.pdf. Updated February 21, 2019. Accessed May 6, 2021.

Robinson CF, Walker JT, Sweeney MH, Shen R, Calvert GM, Schumacher PK, Ju J, Nowlin S. Overview of the National Occupational Mortality Surveillance (NOMS) system: leukemia and acute myocardial infarction risk by industry and occupation in 30 US states 1985-1999, 2003-2004, and 2007. Am J Ind Med. 2015;58(2):123-137. https://doi.org/10.1002/ajim.22408.

U.S. Census Bureau. Industry and Occupation Code Lists & Crosswalks. https://www.census.gov/topics/employment/industry-occupation/guidance/code-lists.html. Updated August 31, 2020. Accessed May 6, 2021.