Sources of Variation in U.S. Mortality: A Latent Variable Analysis

Andrew Stokes and Chris Tencza, University of Pennsylvania

Introduction

Modifiable risk factors exert a strong influence on health and mortality within the United States, accounting for about half of annual deaths. Identifying the role of modifiable risk factors in US mortality patterns is challenging as mortality data do not provide information on the risk factor(s) that gave rise to a particular disease. We explore a new indirect method for estimating mortality effects of leading risk factors, which relies on vital statistics data. Our basic assumption is that most spatial variation in cause-specific mortality rates is a manifestation of a small number of latent variables. Although these factors are not directly observable, we hypothesize that they are indirectly identifiable through the imprint they leave on patterns of mortality.

Data

Mortality data by underlying cause of death, sex, age and US state were obtained for years 2000-2009 from the National Center for Health Statistics and denominators for the corresponding years were derived from the bridged-race population files obtained from the Census Bureau. Causes of death were classified using a scheme developed at the University of Washington. Cause-specific death rates for white adults ages 20-64 were calculated on the combined 2000-2009 data by sex and age-standardized to the US 2000 census population. Within each sex, if a particular cause contributed fewer than 10,000 deaths over the interval 2000-2009 for males or 5,459 deaths for females, it was eliminated from the analysis. These exclusion criteria yielded 33 causes of death for men and 31 for women for the analysis.

Methods

We use factor analysis, a method for determining the structure embedded in a set of variables and describing that structure in terms of a set of factors which are construed as being representative of latent variables. Our methodological approach is based on the premise that individual causes of death are each partial and indirect representations of underlying risk factors. Factor analysis provides a manner of partitioning the variance among the entire set of causes of death into a component of shared variance (shared across multiple variables) and a component of unique variance (variance specific to a particular variable and random error). We implement the analysis separately by sex, on state-by-cause matrices. Orthogonal rotation (varimax) is specified and the first 3 factors are retained based on examination of screeplots

Table 1. Eigenvalues, Discrete and Cumulative Proportion of Variance Explained

	Male			Female		
Factor	Eigenvalue	Proportion	Proportion, cumulative	Eigenvalue	Proportion	Proportion, cumulative
1	11.940	0.362	0.362	11.075	0.357	0.357
2	4.910	0.149	0.511	4.395	0.142	0.499
3	3.572	0.108	0.619	2.649	0.085	0.584
4	1.792	0.054	0.673	1.997	0.064	0.649
5	1.760	0.053	0.726	1.400	0.045	0.694
6	1.139	0.035	0.761	1.304	0.042	0.736
7	1.073	0.033	0.794	0.861	0.028	0.764
8	0.936	0.028	0.822	0.728	0.023	0.787
9	0.607	0.018	0.840	0.688	0.022	0.810
10	0.487	0.015	0.855	0.514	0.017	0.826
11	0.386	0.012	0.867	0.359	0.012	0.838
12	0.347	0.011	0.877	0.253	0.008	0.846
13	0.263	0.008	0.885	0.238	0.008	0.854
14	0.204	0.006	0.891	0.194	0.006	0.860
15	0.192	0.006	0.897	0.144	0.005	0.864

Table 2. Factor Loadings, Males

Smoking and Obesity		Substance Abuse		Injuries	
Cause of Death	Loading	Cause of Death	Loading	Cause of Death	Loading
Lung Cancer	0.92	Liver Cancer	0.80	Self-inflicted Injuries	0.82
Ischemic Heart Disease	0.87	Hepatitis	0.80	Transport Injuries	0.71
Colorectal Cancer	0.85	Interpersonal Violence	0.79	Other Accidents	0.66
Lymphatic Cancers	0.83	Liver Cirrhosis	0.78	Accidental Drowning	0.65
Pancreatic Cancer	0.80	Accidental Poisonings	0.70	Falls	0.64
COPD	0.79	Other Digestive Diseases	0.66	Prostate Cancers	0.48
Cerebrovascular Disease	0.76	HIV/AIDS	0.62	Skin Cancer	0.42
Diabetes Mellitus	0.73	Alcoholic Liver Cirrhosis	0.60	COPD	0.41
Esophagus Cancer	0.72	Hypertensive Heart Disease	0.56	Respiratory Diseases	0.38
Respiratory Diseases	0.68	Cardiomyopathy	0.52	Aneurysm	0.31
Oral Cancer	0.67	Oral Cancer	0.43	Alcoholic Liver Cirrhosis	0.29
Aneurysm	0.63	Stomach Cancer	0.42	Other Digestive Diseases	0.28
Bladder Cancer	0.58	Cerebrovascular Disease	0.34	Cerebrovascular disease	0.27
Transport Injuries	0.50	Alcohol Poisoning	0.32	Alcohol Poisoning	0.25
Other Accidents	0.49	Respiratory Diseases	0.27	Diabetes Mellitus	0.22
Other Digestive Diseases	0.49	Colorectal Cancer	0.26	Interpersonal Violence	0.20
Liver Cirrhosis	0.47	Falls	0.26	Hepatitis	0.16
Stomach cancer	0.45	Aneurysm	0.26	Ischemic Heart Disease	0.15
Brain Cancer	0.43	Skin Cancer	0.25	Accidental Poisonings	0.15
Skin Cancer	0.31	Ischemic Heart Disease	0.21	Liver Cirrhosis	0.15
Cardiomyopathy	0.27	Transport Injures	0.19	Oral Cancer	0.11
Accidental Poisonings	0.25	Accidental Drowning	0.19	Colorectal Cancer	0.08
Prostate Cancers	0.23	Diabetes Mellitus	0.18	Lung Cancer	0.05
Liver Cancer	0.21	Prostate Cancers	0.15	Liver Cancer	0.05
Interpersonal Violence	0.17	Self-inflicted Injuries	0.15	Brain Cancer	0.04
Self-inflicted Injuries	0.17	Lymphatic Cancers	0.13	Lymphatic Cancers	-0.05
Hypertensive Heart Disease	0.12	COPD	0.13	Esophagus Cancer	-0.16
Hepatitis	0.12	Bladder Cancer	0.07	Hypertensive Heart Disease	-0.18
Accidental Drowning	-0.02	Lung Cancer	0.05	Pancreatic Cancer	-0.19
Alcoholic Liver Cirrhosis	-0.22	Pancreatic Cancer	0.03	Cardiomyopathy	-0.21
Falls	-0.24	Other Accidents	-0.08	HIV/AIDS	-0.35
HIV/AIDS	-0.27	Esophagus Cancer	-0.24	Bladder Cancer	-0.39
Alcohol Poisoning	-0.52	Brain Cancer	-0.39	Stomach cancer	-0.49

Table 3. Factor Loadings, Females

Substance Abuse		Smoking and Obesity		Injuries	
Cause of Death	Loading	Cause of Death	Loading	Cause of Death	Loading
Interpersonal Violence	0.90	Colorectal Cancer	0.84	Brain Cancer	0.73
Cirrhosis of the Liver	0.82	Lymphatic Cancer	0.86	Self-inflicted Injuries	0.46
Accidental Poisoning	0.81	Lung Cancer	0.82	Transport Injuries	0.42
Self-inflicted Injuries	0.80	Breast Cancer	0.80	COPD	0.38
Hepatitis	0.80	Ischemic Heart Disease	0.79	Accidental Exposure, unspec.	0.36
Other Digestive Diseases	0.73	Cervical Cancer	0.70	Skin Cancer	0.25
Cerebrovascular Disease	0.64	COPD	0.64	Diabetes Mellitus	0.25
Transport Injures	0.63	Cerebrovascular Disease	0.57	Alcoholic Liver Cirrhosis	0.20
Respiratory Diseases	0.62	Diabetes Mellitus	0.54	Cerebrovascular Disease	0.20
Liver Cancer	0.61	Accidental Exposure, unspec.	0.49	Respiratory Diseases	0.17
Cardiomyopathy	0.56	Other Digestive Diseases	0.47	Lung Cancer	0.11
COPD	0.54	Pancreatic Cancer	0.40	Pancreatic Cancer	0.11
Diabetes Mellitus	0.53	Respiratory Diseases	0.38	Falls	0.11
Hypertensive	0.51	Oral Cancer	0.34	Other Digestive Diseases	0.07
Ischemic Heart Disease	0.49	Transport Injuries	0.33	Accidental Poisoning	0.06
Alcoholic Liver Cirrhosis	0.43	Skin Cancer	0.31	Colorectal Cancer	0.04
Accidental Exposure, unspec.	0.40	Cardiomyopathy	0.29	Alcohol	0.03
Alcohol	0.32	Liver Cancer	0.28	Ischemic Heart Disease	0.01
Colorectal Cancer	0.31	Tissue Cancer	0.28	Lymphatic Cancer	0.01
Cervical Cancer	0.24	Brain Cancer	0.24	Cardiomyopathy	-0.07
Skin Cancer	0.17	Cirrhosis of the Liver	0.24	Liver Cancer	-0.10
Lung Cancer	0.16	Interpersonal Violence	0.24	Interpersonal Violence	-0.11
Breast Cancer	0.14	Accidental Poisoning	0.12	Cervical Cancer	-0.13
Lymphatic Cancer	0.12	HIV/AIDS	0.08	Tissue Cancer	-0.15
Brain Cancer	0.08	Hypertensive	0.04	Oral Cancer	-0.15
Stomach cancer	0.07	Stomach cancer	-0.03	Breast Cancer	-0.16
Pancreatic Cancer	-0.08	Hepatitis	-0.13	Cirrhosis of the Liver	-0.18
HIV/AIDS	-0.09	Self-inflicted Injuries	-0.19	Hepatitis	-0.21
Falls	-0.13	Falls	-0.38	Hypertensive	-0.51
Oral Cancer	-0.17	Alcoholic Liver Cirrhosis	-0.57	Stomach cancer	-0.72
Tissue Cancer	-0.27	Alcohol	-0.75	HIV/AIDS	-0.78

Figure 1: Male Factor Score Maps

Factor 1, Males

Factor 2, Males

Factor 3, Males

Figure 2: Female Factor Score Maps

Factor 1, Females

Factor 2, Females

Factor 3, Females

Figure 3: Latent Variable Associations with All-Cause Mortality: Age-Patterns, Males

Figure 4: Latent Variable Associations with All-Cause Mortality: Age-Patterns, Females

Conclusion

Modifiable risk factors have left a clear and identifiable imprint on US mortality patterns.

In the factor analysis, three factors capture about 60% of US mortality variation among whites in the age-range 20-64 for both males and females.

Our analysis suggests that these factors represent smoking and obesity, substance abuse and injuries, results which are consistent across sex.

The effects of these risk factors are strongly patterned geographically, with the largest effects of smoking and obesity observed in the Southeast, while the effects of substance abuse and injuries are most significant in the Southwest and Rocky mountain states respectively.

Examination of age-patterns shows a general trend of increasing effects of smoking and obesity with age, decreasing effects of injuries and an inverse-U pattern for injuries, with some variation in the age-pattern of the effects for injuries across sex.

This method represents a powerful new tool for identifying the contribution of modifiable risk factors to mortality patterns in countries with vital statistics data.

References

Gavrilova NS, Semyonova VG (2002) Mortality Crisis in Russia: New Health Threats. Population (English Edition): 1–33.

Lozano R, Naghavi M, Foreman K, et al (2012) Global and Regional Mortality from 235 Causes of Death for 20 Age Groups in 1990 and 2010: a Systematic Analysis for the Global Burden of Disease 2010. The Lancet 380: 2095-2128

Mokdad AH (2005) Actual Causes of Death in the United States, 2000. JAMA 291: 1238–1245.

Penn Demography