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New Insights into the Far Eastern Pattern of Mortality

Michele Gragnolati
Princeton University

Irma T. Elo
University of Pennsylvania, popelo@pop.upenn.edu

Noreen Goldman
Princeton University

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Abstract

The Far Eastern pattern of mortality, first identified in 1980, is characterized by some of the largest sex differentials at adult ages to be found anywhere in the world. These atypically high levels of excess male mortality were present in several Far Eastern populations during the 1960s and 1970s and have progressively disappeared since that time. This study uses cause of death data to determine the diseases responsible for the existence and attenuation of these sex differences in Hong Kong, Singapore and Taiwan. The analysis focuses primarily on two hypotheses – regarding the roles of respiratory tuberculosis and liver diseases associated with hepatitis B infection – which were proposed to explain the Far Eastern pattern but were never tested. The results of our analysis indicate that respiratory tuberculosis is the single most important cause underlying the existence and attenuation of the Far Eastern pattern, that the role of liver diseases is far from clear cut, and that other causes (such as cardiovascular diseases) are important as well. Some of the risk factors which may underlie these exceptional mortality patterns are identified.

Keywords

Far East, mortality, Hong Kong, Singapore, Taiwan, respiratory tuberculosis, hepatitis B, HBV vaccine

Disciplines

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New Insights into the Far Eastern Pattern of Mortality

Michele Gragnolati[*]

Irma Elo[†]

Noreen Goldman[‡]

[*] Doctoral Candidate, Program in Population Studies, Office of Population Research, Princeton University, 21 Prospect Avenue, Princeton, NJ 08544-2091 Tel: 609-258-4945. Fax: 609-258-1039.

[†] Associate Director, Population Studies Center, University of Pennsylvania, 3718 Locust Walk, Philadelphia, PA 19104-6298. Tel: 215-898-9162. Fax: 215-898-2124.

[‡] Professor of Demography and Public Affairs, Office of Population Research, Princeton University, 21 Prospect Avenue, Princeton, NJ 08544-2091. Tel: 609-258-5724. Fax: 609-258-1039.

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ABSTRACT

The Far Eastern pattern of mortality, first identified in 1980, is characterized by some of the largest sex differentials at adult ages to be found anywhere in the world. These atypically high levels of excess male mortality were present in several Far Eastern populations during the 1960s and 1970s and have progressively disappeared since that time. This study uses cause of death data to determine the diseases responsible for the existence and attenuation of these sex differences in Hong Kong, Singapore and Taiwan. The analysis focuses primarily on two hypotheses – regarding the roles of respiratory tuberculosis and liver diseases associated with hepatitis B infection – which were proposed to explain the Far Eastern pattern but were never tested. The results of our analysis indicate that respiratory tuberculosis is the single most important cause underlying the existence and attenuation of the Far Eastern pattern, that the role of liver diseases is far from clear cut, and that other causes (such as cardiovascular diseases) are important as well. Some of the risk factors which may underlie these exceptional mortality patterns are identified.

In 1980, Goldman identified a pattern of mortality characterized by some of the largest sex differentials at adult ages in the world.[1] This pattern was present in Hong Kong, Korea, Singapore and Taiwan at varying periods between 1950 and 1980, but progressively disappeared in the most recent decades. Subsequent research efforts confirmed the existence and disappearance of this pattern and led to its inclusion in collections of model life tables, but relatively little is known about its origins. One objective of the present analysis is to analyze cause of death data for several Far Eastern populations – Hong Kong, Singapore and Taiwan – to determine the diseases responsible for the existence and attenuation of the observed levels of excess male mortality at adult ages. A second goal is to identify some of the risk factors that may underlie these exceptional mortality patterns.

BACKGROUND

The Far Eastern pattern of mortality was identified by Goldman[2] on the basis of large deviations between male death rates observed in Hong Kong, Korea, Singapore, and Taiwan and those incorporated in the Coale and Demeny regional model life tables.[3] The atypically high levels of excess male mortality at adult ages (30+) which existed in these countries during the 1960s and 1970s appear to have been the largest sex differences in mortality at adult ages found

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[1] N. Goldman, 'Far Eastern Patterns of Mortality',*Population Studies*, **34** (1980), pp. 5-17.

[2] Goldman, *loc. cit*., in fn. 1.

[3] A.J. Coale and P. Demeny, *Regional Model Life Tables and Stable Populations* (New York: Academic Press, 1983).

anywhere in the world. These patterns were consistent with Preston's earlier observation that ratios of male to female death rates in Taiwan and Hong Kong were higher than expected.[4] In recognition of the unusually large sex differences underlying these Far Eastern populations, a modified version of Goldman's Far Eastern mortality pattern was included in the United Nation's set of model life tables for developing countries.[5]

The progressive disappearance of the Far Eastern mortality pattern, first noted by Goldman in 1980, has been confirmed with more recent data by Campbell: over the past two decades, male life expectancies in Hong Kong, Singapore, and Taiwan have become increasingly close to, and in some cases higher than, those predicted from the Coale and Demeny model life tables on the basis of death rates for females and younger males.[6] In addition, a comparative study of trends in sex differences in mortality in 30 low mortality countries (that include Hong Kong and Singapore) indicates that Hong Kong and Singapore are among the very few countries (indeed, the only ones in the age group 65-74) that experienced a *decrease* in the sex ratio of all-cause mortality between 1956 and 1988.[7] As a consequence of these trends, the Far Eastern mortality pattern has essentially disappeared in these populations.

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[4] S.H. Preston, *Mortality Patterns in National Populations* (New York: Academic Press, 1976). Taiwan and Hong Kong were the only Far Eastern mortality schedules included in Preston's analysis of 41 countries.

[5] United Nations, *Model Life Tables for Developing Countries*, Department of International Economic and Social Affairs, Population Studies, No. 77 (New York, 1982). The Far Eastern mortality pattern in this collection is characterized by excessively high death rates at older ages, compared with younger ages, regardless of sex.

[6] C.D. Campbell, *Chinese Mortality Transitions: the Case of Beijing, 1700-1990*. Unpublished Ph.D. Dissertation, (University of Pennsylvania, 1995).

[7] X.H. Zhang, S. Sasaki, and H. Kesteloot, 'The Sex Ratio of Mortality and its Secular Trends', *International Journal of Epidemiology*, **24** (1995), pp. 720-729.

In spite of several efforts to characterize the Far Eastern mortality pattern, relatively little is known about the causes of death that underlie the large sex differentials. Two specific hypotheses have been proposed. Goldman speculated that respiratory tuberculosis was an important contributing factor, because (1) mortality from respiratory tuberculosis was extremely high in these populations during the mid-1900s; (2) mortality rates subsequently declined; and (3) male mortality from tuberculosis greatly exceeded female mortality. However, Goldman recognized that deaths from tuberculosis were not sufficiently numerous to account for the observed levels of excess male mortality, unless tuberculosis was presumed to interact with other causes, such as cardiovascular or other respiratory diseases.[8]

Elo and Preston suggested the possible role of chronic hepatitis B virus (HBV) infection.[9] The countries identified as having the Far Eastern mortality pattern are within the region of the highest prevalence of HBV infection.[10] Also, chronic HBV infection, which occurs much more frequently among men than among women, plays a major role in the etiology of primary liver cancer and cirrhosis of the liver.[11] However, as in the case of Goldman's hypothesis regarding tuberculosis, Elo and Preston acknowledged that the Far Eastern pattern could not be eliminated simply by setting death rates from cirrhosis and primary liver cancer to more typical levels. They

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[8] Goldman, *loc. cit*., in fn. 1.

[9] I.T. Elo and S.H. Preston, 'Effects of Early-Life Conditions on Adult Mortality: A Review', *Population Index*, **58** (1992), pp. 186-212.

[10] W. Szmuness, 'Hepatocellular Carcinoma and the Hepatitis B Virus: Evidence for a Causal Association', *Progress in Medical Virology*, **24** (1978), pp. 40-69.

[11] W.S. Robinson, 'Hepatitis B Virus and the Delta Agent', in G.L. Mandell, R.G. Douglas, and J.E. Bennett (eds.) *Principles and Practice of Infectious Diseases*, Second Edition (New York: Churchill Livingstone, 1985), pp. 1002-1029; I.O.L. Ng, M.M.T. Ng, E.C.S. Lai, and S.T. Fan, 'Better Survival in Female Patients with Hepatocellular Carcinoma', *Cancer* **75** (1995), pp. 18-22.

also noted that the importance of HBV infection with regard to the Far Eastern mortality pattern would increase if HBV-induced liver impairment were to contribute to mortality from other causes.[12]

Although these earlier studies presented some viable hypotheses, these hypotheses have not been tested formally. Moreover, no study has systematically assessed the numerical importance of different causes of death with regard to the presence and subsequent attenuation of the Far Eastern mortality pattern. In this paper, we investigate the contribution of various causes of death to the excess male mortality observed in Hong Kong, Singapore, and Taiwan[13] in earlier decades and identify those causes which are primarily responsible for its decline. Following the hypotheses proposed by Goldman and Elo and Preston, we pay particular attention to the potential roles of respiratory TB and liver diseases associated with HBV infection. Because these researchers have suggested that any single cause of death, or even a group of related causes (such as liver diseases), is unlikely to account for the presence or disappearance of the Far Eastern pattern, we extend our analysis to explore 34 mutually exclusive causes of death. Subsequent to the empirical analysis, we attempt to identify a set of risk factors that are consistent with the cause of death data and that can plausibly account for the presence and subsequent reduction of the atypically high levels of male mortality in these populations.

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[12] Elo et al., *loc. cit*., in fn. 9.

[13] Although Korea was included in Goldman's original study, it is excluded from the present analysis because death registration during the period of interest was incomplete and data on causes of death are unreliable. Goldman, *loc. cit*., in fn. 1.

DATA

The population and mortality data for Hong Kong and Singapore were obtained from the World Health Organization, whereas the Taiwanese death data came from death certificate tapes provided by the Statistics Department, Ministry of Health, Republic of China and the Taiwanese population data were obtained from the Taiwan-Fukien Demographic Factbook. The population figures – annual age distributions by sex – are based on either censuses or household registration systems. The annual distributions of deaths by age, sex, and cause, tabulated according to the Seventh, Eighth, and Ninth revisions of the International Classification of Diseases, are based on vital registration data. Both population and mortality data are generally considered to be of high quality in these populations.[14]

For this analysis, causes of death are grouped into 34 mutually exclusive categories based on the corresponding codes in the Seventh, Eighth, and Ninth revisions of the ICD (see Appendix A). The period included in our analysis begins with the first year for which causes of death in our data are classified by the 150 categories of the Seventh revision of the ICD. The resulting time periods are 1960 to 1989 in Hong Kong, 1963 to 1989 in Singapore, and 1971 to 1990 in Taiwan. An examination of possible discontinuities in the cause-specific annual numbers of deaths across successive revisions of ICD codes revealed no apparent discontinuities based on the 34 cause-of-death categories included in this analysis (results not shown).

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[14] See, for example, United Nations, *op. cit.*, in fn. 5, p. 308 and p. 336; M. Mirzaee. *Trends and Determinants of Mortality in Taiwan, 1895-1975*. Unpublished Ph.D. Dissertation, Graduate Group in Demography, (University of Pennsylvania, 1979), cited in Campbell, *op. cit*., in fn. 6; United Nations, *Demographic Yearbook 1966*, Department of Economic and Social Affairs, (New York, 1967), pp. 519, 520, 529.

In order to recognize variation in causes of death across age groups and yet retain sufficient sample sizes for analysis, we focus the analysis on two adult age groups – 30-49 and 50-69 – in Hong Kong and Singapore. Because sex differentials in mortality in Taiwan did not decline for the younger age group over the relevant time period, we include only the age group 50-69 in Taiwan. For all countries, we have excluded the age group 70 and over because a large proportion of deaths at these ages was assigned to the category of ill-defined and senile causes at the start of our data series and the proportion changed dramatically over time.[15] This exclusion reduces the potential biases resulting from improvements in the classification of causes of death over time, although it does not eliminate them entirely. Below, we discuss the potential impact of changes in classification on our results.

We assign deaths from liver cancer to the category of cancers of other and unspecified sites in order to extend our data series back to the early 1960s in Hong Kong and in Singapore and to 1971 in Taiwan. Other cancers in this category include pancreas, testis, bladder, and other and unspecified sites. We are able to distinguish deaths attributable to liver cancer from these other cancers only after 1965 in Hong Kong and Singapore and after 1980 in Taiwan. In the discussion below, we make reference to analyses that separately examine the contribution of liver cancer to the decline in the Far Eastern mortality pattern for this subset of the data.[16]

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[15] In Hong Kong, for example, over 20% of the deaths at ages 70-79 were classified as ill-defined and senile in the beginning of the 1960s, but less than 2% of the deaths fell into this category in the late 1980s.

[16] Liver cancer is classified as 155 in both the Seventh and Eighth ICD revisions and B095 in the Ninth revision.

METHODS

In an exploratory stage of this analysis, we examined the time trends in sex differentials in mortality (for all causes combined and for specific causes) according to two measures: (1) the absolute difference between male and female death rates; and (2) the ratio of male to female rates. Although we refer to the sex ratios at various points in the discussion, we have chosen to focus the analysis on the absolute difference between male and female rates (heretofore referred to as the sex difference) for two reasons. First, it permits us to decompose the sex differential at a single point in time, as well as progressive changes in the differential over time, into the contributions of various causes of death. This decomposition is based on the fact that the total death rate is the sum of cause-specific rates and, similarly, that the difference between the male and female total death rates is the sum of the differences between male and female cause-specific rates. Second, the cause-specific ratios become very unstable as the number of deaths from selected causes declines over time.

Figures 1a and 1b indicate the uniqueness of mortality trends in the Far Eastern populations, as measured by either the sex ratio or the sex difference. The figures compare sex differentials in mortality for the age group 65-69 at two levels of adult life expectancy, based on the three Far Eastern populations, Japan, several Western countries, and the four families of the Coale and Demeny model life tables. Each point in Figure 1a corresponds to the sex ratio in mortality (at ages 65-69) at the time when female e_{30} was equal to 45.0 years plotted against the corresponding value of the sex ratio at the time when female e_{30} was equal to 48.8 years; these two values of e_{30} correspond to those observed in Taiwan in 1972 and 1991 respectively. Figure 1b shows the analogous points for the sex difference in the mortality rates. The graphs demonstrate clearly that the trends in sex differentials at older ages in the three Far Eastern

countries stand distinctly apart from those documented elsewhere, whether we focus on the ratios of male to female rates or on the differences between these rates. In the majority of countries, mortality declines have been accompanied by a substantial increase in the sex differential in mortality at older ages. Only in Hong Kong, Singapore, and Taiwan, and to a lesser extent in Japan, have mortality declines been associated with a decline in the sex differential.[17]

Our analysis is based primarily on two cause-specific measures (p_i and b_i, described below) that pertain to the sex difference in mortality. These measures have been calculated separately for each of the three Far Eastern countries and for each of the two age intervals (30-49 and 50-69). Prior to their calculation, death rates for the 20-year age intervals were age-standardized within five-year age groups.[18]

In order to identify the causes of death that contribute most to the sex difference in mortality in earlier decades, we estimate cause-specific contributions (p_i) to the sex difference in mortality in the first three-year period covered by our data series in each country:

$$p_i = ({}_{20}SDR^m_{x,i} - {}_{20}SDR^f_{x,i}) / ({}_{20}SDR^m_x - {}_{20}SDR^f_x), \qquad (1)$$

where ${}_{20}SDR^m_{x,i}$ and ${}_{20}SDR^m_x$ represent age-standardized male death rates for cause i and for all causes combined at ages x to x+20 respectively, and ${}_{20}SDR^f_{x,i}$ and ${}_{20}SDR^f_x$ represent the corresponding age-standardized female rates. The proportionate contributions by cause of death (p_i) sum to one and can be found in Appendix B.

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[17] The results are similar for other adult age groups.

[18] The death rates in the 20-year age intervals were age-standardized by five-year age groups using a female Model West population with e_0=65 and an intrinsic rate of growth of 0.01. This population was chosen following the analysis of S.H. Preston, N. Keyfitz, and R. Schoen, *Causes of Death: Life Tables for National Populations*, (New York: Academic Press, 1972); and Campbell, *op. cit.*, in fn. 6.

To identify the causes of death that are primarily responsible for the decline in the sex difference in mortality over time, we estimate a set of linear regression models, derived from earlier work by Preston.[19] In equation (2), the cause-specific sex difference in mortality is modeled as a linear function of the overall sex difference in mortality, for each of the 34 causes of death, as follows:

$$ {}_{20}SDR^{m}_{x,i,t} - {}_{20}SDR^{f}_{x,i,t} = a_i + b_i \, ({}_{20}SDR^{m}_{x,t} - {}_{20}SDR^{f}_{x,t}), \qquad (2) $$

where ${}_{20}SDR^{m}_{x,i,t}$ and ${}_{20}SDR^{m}_{x,t}$ are defined as in the previous equation, except that all measures in equation (2) refer to year t.[20] Separate models are estimated for each of the three countries and for each of the two age groups. We focus our discussion on the slope coefficients b_i. For each age group, the sum of the b_i coefficients across all causes equals one; thus, b_i can be interpreted as the proportionate change in the sex difference in the overall death rate that is attributable to a change in the sex difference in the death rate for cause i.[21] The b_i coefficients are presented in Appendix C.

Although our analysis of changes in the sex difference over time is based largely on the b_i coefficients, we also estimate a second set of regression models (equation (3)) which provide information about the mortality declines for each sex. In these models, we estimate the cause-specific contributions to the mortality decline over time *separately* for males and for females, in each age group, as follows:

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[19] Preston, *op. cit*., in fn. 4.

[20] Equations (2) and (3) are estimated from death rates for single calendar years.

[21] See Preston, *op. cit*., in fn. 4, p. 19, for a discussion of these regression coefficients. Preston's analysis is based on equation (3), but the interpretation of the coefficients extends readily to equation (2).

$$_{20}SDR_{x,i,t} = c_i + d_i \ _{20}SDR_{x,t} \ , \qquad (3)$$

where $_{20}SDR_{x,i,t}$ and $_{20}SDR_{x,t}$ are defined as in equation (2) and can represent either sex. In equation (3), the slope coefficients d_i for a given sex, which sum to unity within each age group, represent the proportion of the change in the standardized death rate from all causes combined that can be attributed to a change in the death rate from cause i for the specified age group. The d_i coefficients offer additional insights into the attenuation of the sex difference by providing separate estimates of the cause-specific contributions to the mortality decline for males and for females. The d_i coefficients are presented in Appendix D.

ANALYSIS OF CAUSE-SPECIFIC MORTALITY

Although we present estimates for all 34 causes of death in the appendices, we focus our discussion on the most important causes of death with respect to the presence of the Far Eastern pattern and its attenuation over time. In Tables 1-3 we present estimates of the ten largest values of p_i and the ten largest values of b_i for Hong Kong, Singapore and Taiwan respectively. Recall that p_i denotes the proportion of the sex difference in mortality that can be attributed to cause i during the *initial* time period of analysis, while b_i denotes the proportion of the *change* in the sex difference from all causes combined that can be attributed to the change in the sex difference in death rates from cause i over the 20- to 30-year period covered by our data series. For example, as shown in Table 1 for the age group 30-49, respiratory tuberculosis accounts for 33.0% (p_i=0.330) of the sex difference in mortality in Hong Kong in the period 1960-62, and 44.0% (b_i=0.440) of the decline in the sex difference in all-cause mortality between 1960 and 1989.

Respiratory Tuberculosis

Our results provide strong empirical support for the importance of respiratory tuberculosis in all three countries, both with regard to levels of excess male mortality at the start of the data series and with regard to the decline in this excess over time. As shown in Tables 1-3, respiratory tuberculosis accounts for the largest fraction of the sex difference in the earliest time period in both age intervals examined in Hong Kong (33.0% at ages 30-49 and 19.8% at ages 55-59) and at ages 50-69 in Singapore (22.4%) and Taiwan (16.4%). In all cases but one (the younger age group in Singapore), respiratory tuberculosis also makes a larger contribution (more than 35%) to the decline in the sex difference than does any other cause of death. As a consequence of the well-established declines in tuberculosis mortality in the decades following World War II, tuberculosis was no longer a numerically important cause with respect to the sex difference in mortality in any of the three Far Eastern populations by the late 1980s.

Liver Diseases

In contrast to the role of respiratory tuberculosis, the contribution of liver diseases to the Far Eastern pattern and to its attenuation over time is less clear cut. Both liver cirrhosis and cancers of other and unspecified sites (which include liver cancer) make substantial contributions to the sex difference at the start of the data series, but they appear less important for the decline in the sex difference. At ages 50-69 in Taiwan, for example, the *combined* contribution of these causes to the sex difference in 1971-73 was 16.6%, larger than that of respiratory tuberculosis. Whereas liver cirrhosis appears among the ten largest b_i coefficients and accounts for 8.8% of the decline in the sex difference (Table 3), mortality from cancers of other and unspecified sites leads to a *widening* of the sex difference over time (note the negative b_i coefficient in Appendix C). An analysis of the contribution of primary liver cancer to the sex difference in mortality in 1981-

83 and to the decline in the sex difference between 1981 and 1990 yields results similar to those shown for cancers of other and unspecified sites (results not shown).

In Hong Kong, the combined contribution of liver cirrhosis and cancers of other and unspecified sites to the *initial* sex difference is also sizable at ages 30-49, 17.7%, and about half as large at ages 50-69, 8.5%. But, as in Taiwan, only liver cirrhosis appears among the ten largest contributors to the *decline* in the sex difference and only at ages 30-49 (Table 1). Mortality trends from cancers of other and unspecified sites make a trivial contribution (-0.6%) to the *widening* of the sex difference in the older age group and contribute only modestly (2.1%) to the decline in the sex difference at ages 30-49 (Appendix C). As in Taiwan, findings from separate analyses of liver cancer are generally consistent with the results shown for cancers of other and unspecified sites (results not shown).

The data suggest that mortality trends from cancers of other and unspecified sites have been more important for the decline in the sex difference in Singapore than in Hong Kong or Taiwan. Liver cirrhosis appears to be noteworthy only for the younger age group, where it is among the ten largest contributors to the initial sex difference and to its decline (Table 2). The two categories together account for 17.4% of the decline in the sex difference in mortality between 1963 and 1989 in the younger age group and 9.6% of the decline in the older group. These declines arise primarily from decreases in death rates from cancers of other and unspecified sites (Appendix D). Unfortunately, estimates pertaining to this residual group of cancers are likely to be especially unreliable in Singapore, because of well-recognized problems

in the coding of liver cancer, particularly among women. These problems render any further attempts to distinguish liver cancer from other cancers in the residual category futile.[22]

Other Causes of Death

Ages 30-49

A number of other causes play a role in the presence and attenuation of the Far Eastern pattern. For example, in the younger age group, accidents and injuries, diseases of digestive system and ill-defined and senile causes appear among the top ten causes with respect to both p_i and b_i values in Hong Kong and Singapore (Tables 1 and 2). Other respiratory diseases (e.g., bronchitis, pneumonia, influenza, other chronic obstructive pulmonary diseases, and diseases of the upper respiratory track) and to a lesser extent cancer of the buccal cavity and pharynx contribute to both the initial sex difference and to its decline in Hong Kong, while in Singapore ischemic heart disease makes the largest contribution to the initial sex difference and to its decline. Stomach cancer appears among the leading causes contributing to the decline in the sex difference in Hong Kong and Singapore (although it is not a major contributor to the initial sex difference). Death rates from stomach cancer declined rapidly among both sexes during this time

[22] For example for women at ages 30-39, the percentage of deaths in Singapore assigned to primary liver cancer among deaths from cancers of other and unspecified sites ranges from 0% in 1966-68 and 1975-80 to a high of 18.9% in 1987-90. In all age groups, these percentages tend to increase over time. The percentages for men also suggest an increase over time in the proportion of deaths assigned as primary liver cancer. It is not possible to determine whether these trends indicate an increase in death rates or reflect changes in coding or improvements in diagnosis over time. Stuver and Trichopoulos note that between 1968-72 and 1983-87 there appears to have been a slight decrease in the incidence of primary liver cancer for Chinese males in Singapore and a stable pattern for Chinese females, while death rates from primary liver cancer for both sexes increased during the same period. The authors suggest that these trends are at least in part the result of changes in the coding of incidence and mortality data for primary liver cancer. See S.O. Stuver and D. Trichopoulos, 'Liver Cancer', *Cancer Surveys*, **19/20** (1994), pp. 99-124.

period and the difference between male and female death rates has been virtually eliminated (results not shown).

Ages 50-69

Diseases of the digestive system, stomach cancer, and other respiratory diseases also make important contributions to the decline in the sex differences in all three countries in the older age group. In addition, unlike at the younger ages, cardiovascular diseases are generally important with respect to both the initial sex difference and its decline. As shown in Appendix D, death rates from most cardiovascular diseases for ages 50-69 declined over the past two to three decades for both males and females in each country, but the particular cardiovascular diseases that are important with regard to the Far Eastern mortality pattern vary across the three countries.

In Hong Kong and Taiwan, cerebrovascular disease (i.e., stroke) emerges as particularly noteworthy, accounting for about one-quarter of the decline in the sex difference in Taiwan and about one-sixth in Hong Kong. When examining cerebrovascular diseases in these populations, it is important to recognize that whereas hemorrhagic stroke comprises a relatively small proportion of cerebrovascular events in Caucasians (between 6 and 12%), as much as one-fifth to one-half of strokes in Chinese populations are estimated to be hemorrhagic.[23] An examination of our data for Hong Kong, which contains information on subtypes of stroke, reveals that: (1) the mortality declines for stroke in Hong Kong result primarily from declines in hemorrhagic stroke,

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[23] C.Y. Huang, F.L. Chan, Y.L. Yu, E. Woo and D. Chin, 'Cerebrovascular Disease in Hong Kong Chinese', *Stroke*, **21** (2) (1990); pp. 230-235; C.-C. Chang and C.-J. Chen, 'Secular Trend in Mortality from Cerebral Infarction and Cerebral Hemorrhage in Taiwan, 1974-1988', *Stroke*, **24** (1993), pp. 212-218; A.M. Ostfeld, 'A Review of Stroke Epidemiology', *Epidemiologic Reviews*, **2** (1980), pp.136-151.

rather than from cerebral infarction; and (2) sex differences in mortality from this subtype are more pronounced than those from cerebral infarction, particularly in the early 1960s (results not shown). Although our data do not permit examination of mortality by stroke type in Taiwan, a separate analysis of stroke mortality in Taiwan during the period from 1974 to 1988 reveals similar trends to those we find for Hong Kong.[24]

In addition to cerebrovascular diseases, hypertension, ischemic heart disease, and other circulatory diseases (which include such ailments as pulmonary embolism, cardiac dysrhythmias, atherosclerosis and arterial embolisms) are associated with notable contributions to the decline in the sex difference in Hong Kong. In Taiwan only hypertension and cerebrovascular diseases appear among the ten largest b_i values, while in Singapore, other circulatory diseases and hypertension are the most important cardiovascular causes underlying the reduction of the sex difference.

Finally, we note the prominence of ill-defined and senile causes in accounting both for the initial sex difference and for its decline. As noted earlier, the percentage of deaths classified as ill-defined and senile has declined considerably over time, and by the late 1980s this category accounted for extremely low proportions of deaths in all age intervals. In order to investigate the possible bias resulting from changes in the assignment of deaths to this category, we re-estimated the regression model for the b_i's in equation (2) for each country and age interval by holding constant the sex difference in the death rate for the "ill-defined and senile" category (i.e., by

[24] Chang et al., *loc. cit*., in fn. 23.

introducing the sex difference for this category as an independent variable).[25] The results from these analyses alter only slightly the findings discussed above. The main effect of controlling for the death rate from senile and ill-defined causes is to elevate in prominence the role of other respiratory diseases in all three countries, particularly in the older age group. In addition, the role of cerebrovascular diseases in the older age group is diminished in Hong Kong.

POTENTIAL RISK FACTORS

Although the results presented in the previous section identify the causes of death that account for the presence and attenuation of excess male mortality in Hong Kong, Singapore, and Taiwan, they do not directly address the question of what factors produced such large differentials in the first place or why they gradually disappeared. We explore these issues below by examining epidemiological evidence on environmental and genetic risk factors in these Far Eastern populations that are likely to be associated with large sex differences in morbidity or mortality.

Given that the major causes of death in these Far Eastern countries are clearly associated with environmental and life style factors (as is the case for most chronic diseases), several researchers have speculated that such factors may be responsible for the high death rates and in some cases, the high levels of excess male mortality in these countries.[26] These environmental

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[25] For a similar approach, see Preston, *op. cit*., in fn. 4, p.26.

[26] C.-P. Wen, S.-F. Tsai, and S.-P. Tsai, 'Mortality Experience in a Rapidly Developing Economy in Taiwan: Infant Mortality, Gender Gap, and Occupational Risks', *Asia-Pacific Journal of Public Health*, **6** (1992/1993), pp. 218-225; Chang et al., *loc. cit*., in fn. 23.

and life style factors include substance use – smoking, alcohol consumption and drug use – as well as diet, crowding, pollution, and occupational hazards.

It is not implausible that sex differences in substance use are at least partly responsible for the previously high levels of excess male mortality at adult ages. Smoking and alcohol consumption are known risk factors for several diseases that we identified above as the leading causes associated with the Far Eastern mortality pattern. For example, smoking is a known risk factor for cerebrovascular disease, ischemic heart disease, hypertension, and chronic respiratory diseases such as bronchitis and emphysema; excessive alcohol consumption is a risk factor for cerebrovascular disease and cirrhosis of the liver.[27] Some researchers have also found that smoking and drinking are risk factors for cancer of the stomach, although results across studies are inconsistent.[28]

In support of the potential importance of substance use is the finding that sex differences in the prevalence of smoking in Far Eastern countries have been consistently large.[29] Recent

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[27] World Health Organization, *Smoking Control Strategies in Developing Countries*, (Geneva: World Health Organization, 1983); World Health Organization, *Tobacco and Women.* (Geneva: World Health Organization, 1992); R. Peto, A.D. Lopez, J. Boreham, M. Thun and C. Heath, Jr., 'Mortality from Tobacco in Developed Countries: Indirect Estimation from National Vital Statistics', *Lancet*, **399** (1992); pp. 1268-1278; C.A. Camargo, Jr., 'Moderate Alcohol Consumption and Stroke', *Stroke*, **20** (1989), pp. 1611-1626; J.B. Wyngaarden and L.H. Smith, Jr.(eds.), *Textbook of Medicine - Cecil*, 18th Edition, (Philadelphia: W.B. Saunders Company, 1988).

[28] J. Hu, S. Zhang, E. Jia, Q. Wang, S. Liu, Y. Liu, Y. Wu, and Y. Cheng, 'Diet and Cancer of the Stomach: A Case-Control Study in China', *International Journal of Cancer*, **41** (1988), pp. 331-335; H.-H. Lee, H.-Y. Wu, Y.-C. Chuang, A.-S. Chang, H.-H. Chao, K.-Y. Chen, H.-K. Chen, G.-M. Lai, H.-H. Huang, and C.-J. Chen, 'Epidemiologic Characteristics and Multiple Risk Factors of Stomach Cancer in Taiwan', *Anticancer Research*, **10** (1990), pp. 875-882; W.-C. You, W.J. Blot, Y.-S. Chang, A.G. Ershow, Z.-T. Yang, Q. An, B. Henderson, G.-W. Xu, J.F. Fraumeni, Jr., and T.-G. Wang, 'Diet and Risk of Stomach Cancer in Shandong, China', *Cancer Research*, **48** (12) (1988), pp. 3518-3523.

[29] S.L. Koong, M.D. Malison, and A.K. Nakashima, 'A Prevalence Survey of Behavioural Risk Factors in Taipei City, Taiwan', *International Journal of Epidemiology*, **19** (1990), pp. 154-159; I. Waldron, G. Bratelli, L. Carriker, W.-C. Sung, C. Vogeli, and E. Waldman, 'Gender Differences in Tobacco Use in Africa, Asia, the Pacific, and Latin America', *Social Science and Medicine*, **27** (1988), pp. 1269-1275.

estimates for Taiwan indicate extremely large sex differences in the prevalence of smoking throughout adulthood. For example, in the period 1970-1990, between 60 and 80 percent of men aged 30 and over were smokers, in contrast to prevalence rates typically below five percent among middle-age women and below 15 percent among older women; similarly, in Singapore, a fairly high proportion of men are regular smokers whereas smoking is uncommon among women.[30] Although the prevalence of smoking appears to be decreasing in some cases, such as in Singapore[31] and among older age groups in Taiwan,[32] these declines are too recent and too modest to be a major factor underlying the decreases in excess levels of adult male mortality over the last two to three decades. Smoking is also unlikely to account for the previously high levels of excess male mortality from tuberculosis, an infectious disease for which smoking has not been a notable risk factor.[33]

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[30] C.P. Wen, S.P. Tsai, and D.D. Yen, 'The Health Impact of Cigarette Smoking in Taiwan', *Asia-Pacific Journal of Public Health*, **7** (1994), pp. 206-213; Koong et al., *loc. cit*., in fn. 29; K. Hughes, P.P.B. Yeo, K.C. Lin, A.C. Thai, S.P. Sothy, K.W. Wang, J.S. Cheah, W.O. Phoon, P. Lim. 'Cardiovascular Diseases in Chinese, Malays, and Indians in Singapore. II. Difference in Risk Factor Levels', *Journal of Epidemiology and Community Health*, **44** (1990), pp. 29-35. The large sex differences in smoking in the Far Eastern countries seem to be inconsistent with relatively modest sex differences in mortality from lung cancer. The latter arise from the atypically high rates of lung cancer among Chinese women, which are believed to be unrelated to smoking patterns. See I.T.M. Kung, K.F. So, and T.H. Lam. 'Lung Cancer in Hong Kong Chinese: Mortality and Histological Types, 1973-1982', *British Journal of Cancer*, **50** (1984), pp. 381-388; C. La Vecchia, F. Levi, F. Lucchini, S. Franceschi and E. Negri, 'Worldwide Patterns and Trends in Mortality from Liver Cirrhosis, 1955 to 1990', *Annals of Epidemiology* **4** (6) (1994), pp. 480-486.

[31] World Health Organization, *op. cit.*, in fn. 27.

[32] Wen et al., *loc. cit.*, in fn. 30.

[33] D.W. and R.M Des Prez, 'Mycobacterial Diseases,' in G.L. Mandell, R.G. Douglas, and J.E. Bennett (eds.) *Principles and Practice of Infectious Diseases*, Second Edition (New York: Churchill Livingstone, 1985), pp. 2213-2220; Wen et al., *loc. cit*., in fn. 26 speculate that exposure to crowded environments and air pollution have contributed to the high rates of tuberculosis (as well as emphysema, which is included in the category for other respiratory diseases) in Taiwan. However, it is unclear how these factors would account for the large observed sex differences in these diseases.

Large sex differences in alcohol consumption also exist in these countries. Koong et al., for example, note higher alcohol consumption along with higher rates of binge drinking and heavy chronic drinking among men than among women in Taiwan.[34] Nevertheless, the amount of alcohol consumed in Taiwan is not large,[35] a conclusion supported by the low incidence of alcoholic liver disease in this country.[36] Similar patterns exist in Singapore: in a study of cardiovascular risk factors, Hughes et al. found low rates of moderate and heavy alcohol consumption among males in Singapore and negligible rates among females.[37] Although recent increases in alcohol consumption in Hong Kong, particularly of Western liquors, has lead to a growing presence of alcohol-related liver cirrhosis, alcohol consumption patterns during recent decades are unlikely to account for the trends observed in this analysis.[38] Specifically, in a comparative analysis of liver cirrhosis mortality in industrialized countries, Hong Kong and Singapore emerged as distinct from all other countries in their substantial downward trends between 1955 and 1990.[39] While changes in alcohol consumption and changes in the rates of hepatitis B virus infection are the most likely explanations for changes in prevalence of liver

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[34] Koong et al., *loc. cit*., in fn. 29.

[35] C-J. Chen, K-Y. Liang, A-S. Chang, Y-C. Chang, S-N. Lu, Y-F. Liaw, W-Y. Chang, M-C. Sheen, and T-M. Lin. 'Effects of Hepatitis B Virus, Alcohol Drinking, Cigarette Smoking and Familial Tendency on Hepatocellular Carcinoma', *Hepatology*, **13** (1991), pp. 398-405.

[36] K.C. Lam, C.L. Lai, P.C. Wu and D. Todd, 'Etiological Spectrum of Liver Cirrhosis in the Chinese', *Journal of Chronic Diseases*, 33 (1980), pp. 375-381.

[37] Hughes et al., *loc. cit*., in fn. 30.

[38] Lam et al., *loc. cit.*, in fn. 36.

[39] La Vecchia et al., *loc. cit.*, in fn.30.

cirrhosis worldwide, in the case of Taiwan, Hong Kong and Singapore, the latter explanation is far more plausible than the former (see discussion below).

Information on levels and sex differences in drug use during the mid-1900s is scarce. High levels of opium use in China during the early 1900s,[40] resulting largely from the active opium trade, may have led to frequent use in neighboring Chinese populations. Data from Singapore indicate that opium was the first drug to be abused in Singapore and was easily (and legally) obtainable until the Second World War. During the ensuing two decades, drug abuse resulted mostly from opium, morphine, and cannabis.[41] Allan notes that, unlike alcoholism, drug addiction was a problem in Hong Kong during the 1960s.[42] It is possible that such drug abuse, likely to have been much more common among men than among women,[43] exacerbated male mortality from such diseases as tuberculosis and other respiratory diseases.

While it is likely that smoking and drug use have had a notable impact on excess male mortality, it is more difficult to make a convincing case for environmental factors, such as crowding, pollution and a poor diet (e.g., a diet high in fat and low in fresh fruit and vegetables). Although there is medical evidence linking these factors with some of the infectious and chronic diseases appearing in Tables 1-3, there is no evidence that men have had substantially greater

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[40] It is estimated that about 20% of the adult Chinese population was smoking opium in 1906. M.M. Cohen, 'History of Opium and Opiates', *Texas Medicine*, **65** (1) (1969), pp. 76-85.

[41] T.C. Chao, 'The Spectrum of Drug Abuse in Singapore', *Journal of Forensic Medicine and Pathology*, **1** (1) (1980), pp. 84-85.

[42] W.G.L. Allan, 'Tuberculosis in Hong Kong Ten Years Later', *Tubercle*, **54** (1973), pp. 234-246.

[43] For example, 96% of heroin abusers arrested in Singapore in 1977 were males. S.H. Teo, K.T. Chee and C.T. Tan, 'Heroin Abuse in Singapore—A Profile and Characteristics Study', *Singapore Medical Journal*, **19** (2) (1978), pp. 65-70.

exposure to these risk factors than have women. Occupational risks have been suggested as possible sources of excess mortality in Taiwan, but little evidence has been put forth to account for the excess mortality risks experienced by some occupational groups.[44]

In the case of cardiovascular diseases, it is possible that sex differences in blood pressure account for at least a portion of the male excess in mortality. Hughes notes, for example, that the sex differences in hypertension in Singapore exceed those typically found in Western populations, although he recognizes that excess male mortality in Singapore may also result from increased male susceptibility to the effects of high blood pressure.[45] High blood pressure is the most clearly established risk factor for stroke,[46] and it may be more important risk factor for hemorrhagic than for other types of stroke.[47] As noted earlier, not only do hemorrhagic strokes constitute a large fraction of cerebrovascular events in these countries, but the sex difference in mortality from this sub-type is greater than from cerebral infarction, as is the decline in mortality during recent decades. Another possible explanation for the male excess in stroke mortality is that alcohol consumption appears to promote hemorrhagic stroke,[48] but the low levels of drinking in these Far Eastern populations weakens this hypothesis.

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[44] Wen et al., *loc. cit*., in fn. 26.

[45] K. Hughes. 'Trends in Mortality from Hypertensive and Cerebrovascular Diseases in Singapore, 1959 to 1983', *International Journal of Epidemiology*, **16** (1987), pp. 18-24.

[46] Ostfeld, *loc. cit*., in fn. 23.

[47] J. He, M.J. Klag, Z. Wu, and P.K. Whelton, 'Stroke in the People's Republic of China. I. Geographic Variation in Incidence and Risk Factors', *Stroke*, **20** (1995), pp. 2228-2232.

[48] C.A. Camargo, Jr., *loc. cit*., in fn. 27; N. Goldman and S. Takahashi, 'Old-age Mortality in Japan: Demographic and Epidemiological Perspectives', in: G. Caselli and A.D. Lopez (eds.) *Health and Mortality Among Elderly Populations* (Oxford: Oxford University Press, 1996).

High prevalence rates of hepatitis B virus (HBV) in Far Eastern populations may also have affected levels and sex differences in mortality. HBV has been endemic in Far Eastern countries and the carrier rate for the HBV antigen has been high.[49] Epidemiological studies strongly indicate that prior infection with HBV and subsequent development of the chronic carrier state (with retention of the HBV antigen) play a causal role in the etiology of primary liver cancer and cirrhosis of the liver.[50] Indeed, infection with the hepatitis B virus in early life is thought to be the primary factor underlying the exceptionally high rates of liver cancer in Chinese populations.[51]

High death rates from liver diseases in Chinese populations are accompanied by high levels of excess male mortality. Reasons for the male predominance include the higher likelihood that men become chronic hepatitis B antigen carriers than women (even when men and women have equal exposure to HBV), the greater likelihood that male HBV carriers become cirrhotic, and higher levels of alcohol abuse among men. Lin et al. note that other variables, including misdiagnosis of cause of death, viral factors, and genetic factors, may also be responsible for the high sex ratios for liver cancer and cirrhosis mortality.[52] Death rates from

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[49] See, for example, T.M. Lin. W.T. Tsu, and C.J. Chen. 'Mortality of Hepatoma and Cirrhosis of Liver in Taiwan', *British Journal of Cancer*, **54** (1986), pp. 969-976.

[50] For example, in a large prospective study of Chinese men in Taiwan, the relative risk of dying from primary liver cancer among those testing positive for HBV was over 200:1 while that for liver cirrhosis was about 50:1. The death rate from causes other than liver cancer and cirrhosis was 34 percent higher among those testing positive for HBV as compared with those testing negative for the virus. R.P. Beasley, C.-C. Lin, L.-Y. Hwang, and C.-S. Chien, 'Hepatocellular Carcinoma and Hepatitis B Virus: A Prospective Study of 22,707 Men in Taiwan', *Lancet*, November **21** (1981), pp. 1129-1133.

[51] K.F. Wellmann, N.R. Vemula and K.E. Gerstmann, 'Hepatic Cancer in Chinese: A Chapter in 'Geographic Pathology', *American Journal of Chinese Medicine*, **VIII** (1) (1980), pp. 1-16.

[52] Lin et al., *loc. cit.*, in fn. 49.

causes other than liver cancer and cirrhosis are also higher among chronic carriers of HBV, a finding which raises the possibility that the high prevalence of HBV has contributed to the Far Eastern mortality pattern beyond its impact on liver diseases.[53]

Although the discussion presented above has focused on environmental risk factors associated with excess levels of male mortality, genetic factors may also play a role. The importance of genetic together with environmental variables in producing sex differences in mortality worldwide have been clearly established.[54] In addition, differences between Chinese and other ethnic groups in patterns of stroke and liver disease suggest that genetic factors related to ethnicity may also play an important role in the etiology of the Far Eastern mortality pattern. For example, while environmental factors such as alcohol consumption and diet are established risk factors for stroke, and some of these factors (such as low levels of serum cholesterol) are thought to be risk factors specifically for hemorrhagic stroke,[55] these variables by themselves are unlikely to account for the large ethnic differences in stroke patterns. In the case of liver cancer, Wellmann et al. discount genetic explanations, arguing that much lower rates of liver cancer among China-born immigrants than among Chinese residing in their own countries (especially, Singapore and Hong Kong) favor an environmental, rather than a racial explanation.[56] Nevertheless there are several ethnic differences regarding immune response to the hepatitis B

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[53] Beasley et al., *loc. cit*., in fn. 50; Elo et al., *loc. cit*., in fn. 9. Allan also speculates that the high toxicity from tuberculosis drugs experienced by Chinese patients may result from the considerable trauma to their livers (e.g., from viral infections). Allan, *loc. cit*., in fn. 42.

[54] See for example, I. Waldron, 'What do we know about Causes of Sex Differences in Mortality? A Review of the Literature', *Population Bulletin of the U.N.*, **17-20** (1984-85), pp. 59-76.

[55] Goldman et al., *loc. cit.*, in fn.48.

[56] Wellmann et al., *loc. cit.*, in fn. 51.

virus that are not readily explicable on the basis of environmental factors. In a study of HBV infection by ethnic group in Singapore, the carrier rate of the HBV antigen among the Chinese was considerably greater than among the Malays or Indians, for both sexes;[57] Blumberg et al. suggest the possibility of a genetic trait that predisposes one to the HBV carrier state[58]. In the same study, the maternal-infant transmission rate of HBV during the perinatal period was far higher among the Chinese than among the other groups. In a study of ethnic differences in immune response to the hepatitis B vaccine in Taiwan, children in Han Chinese villages showed different levels of serologic response than did children in aboriginal villages; these differences were attributed to host factors rather than to characteristics of the vaccine.[59]

DISCUSSION

In the previous section, we identified several factors which may have contributed to the large sex differences in mortality observed in Taiwan, Singapore and Hong Kong as well as some which are unlikely to have had much of an impact. For example, high smoking rates almost exclusively among men are likely to have played some role in producing excess male mortality from cardiovascular and respiratory diseases, while alcohol consumption appears to be an insignificant risk factor in these populations. At the same time, however, the relative importance

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[57] S.H. Chan and C.J. Oon, 'Epidemiology of HBS Infection in Singapore', *Asian Pacific Journal of Allergy Immunology*, **2** (1) (1984), pp. 139-143.

[58] B.S. Blumberg, B.J.S. Gerstley, D.A. Hungerford, W.T. London and A.I. Sutnick, 'A Serum Antigen (Australia Antigen) in Down's Syndrome, Leukemia and Hepatitis', *Annals of Internal Medicine*, **66** (1967), pp. 924-931.

[59] L.-C. Hsu, S.-R. Lin, H.-M. Hsu, W.-H. Chao, J.-T. Hsieh, M.-C. Wang, C.-F. Lu, Y.-H. Chang and M.-S. Ho, 'Ethnic Differences in Immune Responses to Hepatitis B Vaccine', *American Journal of Epidemiology*, **143** (7) (1996), pp. 718-724.

of different environmental factors and the relative impact of environmental versus genetic explanations remain largely unknown. Our knowledge is limited by our incomplete understanding of the complex networks of risk factors underlying each disease, particularly the major chronic diseases, as well as by limited data on even readily identifiable risk factors (e.g., data on levels and trends in drug use).

On the other hand, there is evidence that public health and biomedical improvements in recent decades played an important role in the attenuation of the Far Eastern pattern, via the reduction in both male and female mortality from the leading chronic and infectious diseases. For example, improved management of hypertension (through screening and the use of hypertensive drugs) appears to be one important factor underlying the contribution of cardiovascular diseases, particularly cerebrovascular diseases, to the reduction of the overall sex difference in mortality.[60] Given the higher male rates from these diseases in the past, the observed decline in the (absolute) sex difference could have occurred even if the control of hypertension did not selectively benefit males.

Foremost among the diseases that declined during recent decades is tuberculosis, one of the leading (if not the leading) causes of death from infectious disease in these countries during the 1950s and 1960s, and one which was characterized by sex differences far greater than those

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[60] Epidemiologists have speculated that the control of hypertension is likely to be at least partly responsible for declines in cardiovascular mortality. For a discussion of this issue in the U.S., Singapore, and Hong Kong, see Ostfeld, *loc. cit.,* in fn. 23; K. Hughes, 'Trends in Mortality from Ischaemic Heart Disease in Singapore, 1959 to 1983', *International Journal of Epidemiology*, **15** (1) (1986), pp. 44-50; and T.S. Yu, S.L. Wong, O.L. Lloyd and T.W. Wong, 'Ischaemic Heart Disease: Trends in Mortality in Hong Kong, 1970-89', *Journal of Epidemiology and Community Health*, **49** (1995), pp. 16-21.

experienced by Western populations during the early twentieth century.[61] Results presented here demonstrate clearly that respiratory tuberculosis was the single most important cause of death underlying the existence and attenuation of the Far Eastern mortality pattern. The drastic reduction in death rates from tuberculosis subsequent to the mid-1900s resulted largely from widespread use of the BCG vaccine,[62] anti-tuberculous chemotherapy, improvements in the health care system, health education, and improved nutrition and sanitation.[63]

Our results have also demonstrated that the relation between liver diseases and the Far Eastern mortality pattern is far from clear cut. Although liver cirrhosis and liver cancer accounted for a substantial fraction of the excess male mortality in these populations several decades ago, their contribution to the observed declines in the sex difference is modest. This is particularly notable for liver cancer, which has been characterized by *increasing* death rates in some of the countries and age groups studied here. Unfortunately, this part of the analysis is potentially compromised by misclassification of cause of death. For example, it is quite possible that the observed trends in mortality from liver cancer reflect improvements in diagnosis and coding of this disease rather than a true increase in death rates.

Because hepatitis B virus infection is thought to be the primary contributing factor for liver-associated mortality in these Far Eastern populations, as well as for the large sex difference from

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[61] Goldman, *loc. cit.*, in fn. 1. Higher male than female mortality from tuberculosis throughout adulthood appears to occur at the later stages of tuberculosis epidemics. See E.R.N. Grigg, 'The Arcana of Tuberculosis. With a Brief Epidemiologic History of the Disease in the U.S.A.', *The American Review of Tuberculosis and Pulmonary Diseases*, **78** (2) (1958), pp. 151-172.

[62] For example, the percentage of newborns in Hong Kong receiving BCG rose from only 4 percent in 1952 to 97 percent in 1972. Allan, *loc. cit*, in fn. 42.

these causes, a reduction in the incidence of the hepatitis B virus infection would be expected to result in a decline in mortality from liver diseases and a concomitant reduction in excess male mortality. We have been unable to uncover trend data on the incidence of hepatitis B virus infection for Far Eastern populations, data which could have clarified the role of HBV in the observed trends.[64] Nevertheless, it seems very likely that changing patterns of liver-related diseases over the next few decades will be associated with further reductions in sex differences in mortality in these populations, as the recent widespread introduction of the HBV vaccine leads to a declining prevalence of serum positivity of the virus.[65]

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[63] Allan, *loc. cit*., in fn. 42; B.H. Heng and K.K. Tan. 'Three Decades of Tuberculosis in Singapore', *Bulletin of the International Union against Tuberculosis and Lung Disease*, **66** (1991), pp.125-128.

[64] Data on mortality from hepatitis do not shed any light on this issue because the death rate from this cause is generally low (e.g., typically less than one-twentieth as high as from cirrhosis) and because hepatitis B cannot be distinguished in our data from other forms of infectious hepatitis.

[65] La Vecchia et al., *loc. cit*., in fn. 39; D.-S. Chen, J.-L. Sung and M.-Y. Lai, 'A Seroepidemiologic Study of Hepatitis B Virus Infection in Taiwan', *Journal of the Formosan Medical Association*, **77** (908-918) (1996), pp. 36-46.

Table 1: *The Ten Leading Causes of Death Associated with the Initial Sex Difference and the Decline in the Sex Difference: Hong Kong*

Contribution to Sex Difference in 1960-62		Contribution to Decline in Sex Difference, 1960-89	
Cause of Death	p_i	Cause of Death	b_i
Ages 30-49			
1. Respiratory tuberculosis	0.330	1. Respiratory tuberculosis	0.440
2. Other respiratory diseases	0.114	2. Diseases of digestive system	0.103
3. Cancer, other & unspecified	0.111	3. Accidents & injuries	0.091
4. Accidents & injuries	0.105	4. Ill-defined & senility	0.088
5. Diseases of digestive system	0.079	5. Liver cirrhosis	0.082
6. Cancer, buccal cavity & pharynx	0.067	6. Other respiratory diseases	0.076
7. Liver cirrhosis	0.066	7. Suicide	0.055
8. Ill-defined & senility	0.063	8. Cancer, stomach	0.039
9. Ischemic heart disease	0.050	9. Other circulatory diseases	0.037
10. Suicide	0.046	10. Cancer, buccal cavity & pharynx	0.025
Ages 50-69			
1. Respiratory tuberculosis	0.198	1. Respiratory tuberculosis	0.355
2. Cerebrovascular disease	0.141	2. Ill-defined & senility	0.183
3. Ill-defined & senility	0.135	3. Cerebrovascular disease	0.163
4. Other respiratory diseases	0.090	4. Hypertension	0.077
5. Ischemic heart disease	0.072	5. Other circulatory diseases	0.075
6. Hypertension	0.059	6. Ischemic heart disease	0.054
7. Cancer, other & unspecified	0.056	7. Diseases of digestive system	0.053
8. Other circulatory diseases	0.051	8. Other respiratory diseases	0.037
9. Cancer, lung	0.031	9. Diseases of genito-urinary system	0.031
10. Liver cirrhosis	0.029	10. Other infectious diseases & Cancer, stomach[1]	0.023

Note: p_i denotes the proportion of the sex difference in mortality that can be attributed to cause i in 1960-62; b_i denotes the proportion of the *change* in the sex difference in death rates from cause i between 1960 and 1989.

[1] These two causes have the same b_i values.

Table 2: *The Ten Leading Causes of Death Associated with the Initial Sex Difference and the Decline in the Sex Difference: Singapore*

Contribution to Sex Difference in 1963-65		Contribution to Decline in Sex Difference, 1963-89	
Cause of Death	p_i	Cause of Death	b_i
Ages 30-49			
1. Ischemic heart disease	0.283	1. Ischemic deart disease	0.190
2. Accidents & injuries	0.257	2. Accidents & injuries	0.173
3. Respiratory tuberculosis	0.150	3. Respiratory tuberculosis	0.156
4. Liver cirrhosis	0.079	4. Cancer, other & unspecified	0.104
5. Ill-defined & senility	0.073	5. Diseases of digestive system	0.101
6. Diseases of digestive system	0.054	6. Cancer, breast	0.082
7. Cancer, other & unspecified	0.053	7. Liver cirrhosis	0.070
8. Other infectious diseases	0.051	8. Cancer, stomach	0.062
9. Suicide	0.048	9. Cancer, intestine	0.044
10. Cerebrovascular disease	0.042	10. Ill-defined & senility	0.042
Ages 50-69			
1. Respiratory tuberculosis	0.224	1. Respiratory tuberculosis	0.354
2. Ischemic heart disease	0.120	2. Ill-defined & senility	0.191
3. Other respiratory diseases	0.110	3. Other respiratory diseases	0.094
4. Ill-defined & senility	0.105	4. Other circulatory diseases	0.083
5. Cancer, lung	0.066	5. Diseases of digestive system	0.081
6. Cancer, stomach	0.057	6. Cancer, other & unspecified	0.073
7. Cancer, other & unspecified	0.051	7. Cancer, stomach	0.056
8. Other circulatory diseases	0.048	8. Hypertension	0.037
9. Diseases of digestive system	0.046	9. Suicide	0.034
10. Accidents & injuries	0.038	10. Other infectious diseases	0.033

Note: p_i denotes the proportion of the sex difference in mortality that can be attributed to cause i in 1963-65; b_i denotes the proportion of the *change* in the sex difference in death rates from cause i between 1963 and 1989.

Table 3: *The Ten Leading Causes of Death Associated with the Initial Sex Difference and the Decline in the Sex Difference: Taiwan*

Contribution to Sex Difference in 1971-73		Contribution to Decline in Sex Difference, 1971-90	
Cause of Death	p_i	Cause of Death	b_i
	Ages 50-69		
1. Respiratory tuberculosis	0.164	1. Respiratory tuberculosis	0.374
2. Cerebrovascular disease	0.163	2. Cerebrovascular disease	0.253
3. Other respiratory diseases	0.099	3. Diseases of digestive system	0.243
4. Diseases of digestive system	0.094	4. Ill-defined & senility	0.133
5. Cancer, other & unspecified	0.085	5. Other respiratory diseases	0.099
6. Accidents & injuries	0.085	6. Cancer, stomach	0.094
7. Liver cirrhosis	0.081	7. Liver cirrhosis	0.088
8. Cancer, stomach	0.069	8. Endocrine & metabolic diseases	0.054
9. Ill-defined & senility	0.051	9. Hypertension	0.046
10. Other circulatory diseases	0.041	10. Suicide	0.036

Note: p_i denotes the proportion of the sex difference in mortality that can be attributed to cause i in 1971-73; b_i denotes the proportion of the *change* in the sex difference in death rates from cause i between 1971 and 1990.

Appendix A. *Reclassification of Causes of Death, Based on the 7th, 8th, and 9th Revisions of the International Classification of Diseases*

Cause	ICD7 A Codes	ICD8 A Codes	ICD9 B Codes
1 Respiratory tuberculosis	A001	A006	B020-B021
2 Other tuberculosis	A002-A005	A007-A010	B022-B025, B077
3 Infectious hepatitis	A034	A028	B046
4 Other infectious diseases	A006-A033, A035-A043	A001-A005, A011-A027, A029-A044	B01, B03, B040-B045, B047, B048, B05, B06, B070-B076, B078
5 Cancer, lung	A050	A051	B101
6 Cancer, stomach	A046	A047	B091
7 Cancer, buccal cavity & pharynx	A044	A045	B08
8 Cancer, esophagus & larynx	A045, A049	A046, A050	B090, B100
9 Cancer, intestine	A047, A048	A048, A049	B092-B094
10 Cancer, bone & skin	A055, A056	A052, A053	B110-B112
11 Cancer, lymphatic & hematopoietic	A058, A059	A059, A060	B14
12 Cancer, other & unspecified	A057	A058	B13, B125, B126, B095, B096, B16
13 Cancer, breast	A051	A054	B113
14 Cancer, cervix, uterus, prostate	A052-A054	A055-A057	B120-B124
15 Benign neoplasms	A060	A061	B15, B17
16 Endocrine & metabolic diseases	A061-A063	A062-A064, A066	B18
17 Nutritional deficiency & blood disease	A064, A065	A065, A067, A068	B19, B20
18 Mental disorders	A067-A069	A069-A071	B21
19 Diseases of nervous system	A071-A078	A072-A079	B22-B24
20 Rheumatic fever & heart disease	A079, A080	A080, A081	B25
21 Hypertension	A083, A084	A082	B26
22 Ischemic heart disease	A081	A083	B27
23 Cerebrovascular disease	A070	A085	B29
24 Other circulatory diseases	A082, A085, A086	A084, A086-A088	B28, B30
25 Other respiratory diseases	A066, A087-A097	A089-A096	B31-B32
26 Liver cirrhosis	A105	A102	B347
27 Diseases of digestive system	A098-A104, A106, A107	A097-A101, A103, A104	B33, B340-B346, B348
28 Diseases of genito-urinary system	A108-A114	A105-A111	B35-B37
29 Pregnancy-related complications	A115-A120	A112-A118	B38-B41
30 Diseases of musculoskeletal system	A121-A126	A119-A125	B42, B43
31 Other (congenital & perinatal)	A127-A135	A126-A135	B44, B45
32 Ill-defined & senility	A136, A137	A136, A137	B46
33 Suicide	A148	A147	B54
34 Accidents & injuries	A138-A147, A149, A150	A138-A146, A148-A150	B47-B53, B55, B56

Sources: World Health Organization. 1957. *Manual of the International Statistics Classification of Diseases, Injuries and Causes of Death. Seventh Revision.* Geneva: World Health Organization; World Health Organization. 1967. *Manual of the International Statistics Classification of Diseases, Injuries and Causes of Death. Eighth Revision.* Geneva: World Health Organization; World Health Organization. 1978. *Manual of the International Statistics Classification of Diseases, Injuries and Causes of Death. Ninth Revision*. Geneva: World Health Organization.

Appendix B. *Proportionate Contributions to the Sex Difference in Mortality in the Initial Period (p_i), by Cause of Death and Age Group: Hong Kong, Singapore and Taiwan*

	Hong Kong	Hong Kong	Singapore	Singapore	Taiwan
	1960-62	1960-62	1963-65	1963-65	1971-73
	30-49	*50-69*	*30-49*	*50-69*	*50-69*
1 Respiratory tuberculosis	0.330	0.198	0.150	0.224	0.164
2 Other tuberculosis	0.003	0.003	0.001	0.002	0.000
3 Infectious hepatitis	0.001	0.000	0.003	0.000	0.000
4 Other infectious diseases	0.033	0.024	0.051	0.028	0.010
5 Cancer, lung	0.006	0.031	0.016	0.066	0.022
6 Cancer, stomach	0.018	0.023	0.005	0.057	0.069
7 Cancer, buccal cavity & pharynx	0.067	0.018	0.035	0.009	0.017
8 Cancer, esophagus & larynx	0.018	0.028	0.015	0.034	0.032
9 Cancer, intestine	0.007	0.003	0.010	0.009	0.006
10 Cancer, bone & skin	0.003	0.002	0.006	0.000	0.000
11 Cancer, lymphatic & hematopoietic	0.000	0.000	0.032	0.006	0.003
12 Cancer, other & unspecified	0.111	0.056	0.053	0.051	0.085
13 Cancer, breast	-0.051	-0.021	-0.091	-0.020	-0.015
14 Cancer, cervix, uterus, prostate	-0.094	-0.035	-0.108	-0.038	-0.061
15 Benign neoplasms	-0.001	0.001	-0.007	0.001	-0.002
16 Endocrine & metabolic diseases	-0.004	0.004	0.001	-0.002	-0.018
17 Nutritional deficiency & blood disease	0.001	0.003	-0.028	0.006	0.001
18 Mental disorders	0.000	0.001	-0.001	0.002	0.004
19 Diseases of nervous system	0.005	0.005	0.030	0.007	0.004
20 Rheumatic fever & heart disease	-0.035	-0.001	-0.039	-0.002	-0.005
21 Hypertension	0.026	0.059	0.022	0.026	0.021
22 Ischemic heart disease	0.050	0.072	0.283	0.120	0.023
23 Cerebrovascular disease	0.031	0.141	0.042	0.013	0.163
24 Other circulatory diseases	0.032	0.051	0.017	0.048	0.041
25 Other respiratory diseases	0.114	0.090	0.031	0.110	0.099
26 Liver cirrhosis	0.066	0.029	0.079	0.023	0.081
27 Diseases of digestive system	0.079	0.027	0.054	0.046	0.094
28 Diseases of genito-urinary system	0.013	0.022	0.008	0.010	0.003
29 Pregnancy-related complications	-0.044	0.000	-0.055	0.000	0.000
30 Diseases of musculoskeletal system	0.000	0.000	0.001	-0.003	-0.003
31 Other (congenital & perinatal)	0.000	0.000	0.004	0.000	0.000
32 Ill-defined & senility	0.063	0.135	0.073	0.105	0.051
33 Suicide	0.046	0.013	0.048	0.026	0.024
34 Accidents & injuries	0.105	0.019	0.257	0.038	0.085

Note: See equation (1) for estimation of p_i.

Appendix C. *Proportionate Contributions to Changes in the Sex Difference in Mortality over Relevant Time Period (b_i), by Cause of Death and Age Group: Hong Kong, Singapore and Taiwan*

	Hong Kong	Hong Kong	Singapore	Singapore	Taiwan
	1960-89 *30-49*	1960-89 *50-69*	1963-89 *30-49*	1963-89 *50-69*	1971-90 *50-69*
1 Respiratory tuberculosis	0.440	0.355	0.156	0.354	0.374
2 Other tuberculosis	0.012	0.000	0.004	0.008	0.002
3 Infectious hepatitis	-0.003	0.000	-0.003	-0.001	0.000
4 Other infectious diseases	0.022	0.023	0.032	0.033	0.000
5 Cancer, lung	-0.022	-0.098	-0.006	-0.060	-0.083
6 Cancer, stomach	0.039	0.023	0.062	0.056	0.094
7 Cancer, buccal cavity & pharynx	0.025	-0.007	-0.031	-0.005	-0.043
8 Cancer, esophagus & larynx	0.007	-0.018	-0.001	0.024	0.009
9 Cancer, intestine	0.015	-0.001	0.044	-0.005	-0.008
10 Cancer, bone & skin	0.000	0.000	-0.008	0.003	0.003
11 Cancer, lymphatic & hematopoietic	-0.006	-0.005	0.000	-0.004	-0.009
12 Cancer, other & unspecified	0.021	-0.006	0.104	0.073	-0.072
13 Cancer, breast	-0.007	-0.003	0.082	0.017	0.022
14 Cancer, cervix, uterus, prostate	-0.081	-0.015	-0.001	-0.009	-0.018
15 Benign neoplasms	-0.003	0.001	0.013	0.003	-0.038
16 Endocrine & metabolic diseases	-0.001	0.009	0.022	0.018	0.054
17 Nutritional deficiency & blood disease	0.004	0.003	-0.019	0.006	0.007
18 Mental disorders	0.002	0.001	0.000	0.003	-0.014
19 Diseases of nervous system	0.002	0.007	0.026	0.010	0.008
20 Rheumatic fever & heart disease	-0.039	0.005	-0.019	0.000	0.000
21 Hypertension	0.016	0.077	0.011	0.037	0.046
22 Ischemic heart disease	0.023	0.054	0.190	-0.126	-0.051
23 Cerebrovascular disease	0.023	0.163	0.025	0.008	0.253
24 Other circulatory diseases	0.037	0.075	-0.058	0.083	-0.013
25 Other respiratory diseases	0.076	0.037	-0.007	0.094	0.099
26 Liver cirrhosis	0.082	0.022	0.070	0.023	0.088
27 Diseases of digestive system	0.103	0.053	0.101	0.081	0.243
28 Diseases of genito-urinary system	0.012	0.031	0.025	0.022	0.001
29 Pregnancy-related complications	-0.049	0.000	-0.062	0.000	0.000
30 Diseases of musculoskeletal system	0.014	0.003	0.016	0.001	-0.003
31 Other (congenital & perinatal)	0.000	0.000	0.013	0.000	0.000
32 Ill-defined & senility	0.088	0.183	0.042	0.191	0.133
33 Suicide	0.055	0.012	0.002	0.034	0.036
34 Accidents & injuries	0.091	0.016	0.173	0.028	-0.121

Note: See equation (2) for estimation of b_i.

Appendix D. *Proportionate Contributions to Changes in Male and Female Mortality over Relevant Time Period (d_i), by Cause of Death and Age Group: Hong Kong, Singapore and Taiwan*

	Ages 30-49			
	Hong Kong	Hong Kong	Singapore	Singapore
	Male 1960-89	Female 1960-89	Male 1963-89	Female 1963-89
1 Respiratory tuberculosis	0.322	0.205	0.157	0.119
2 Other tuberculosis	0.015	0.017	0.006	0.007
3 Infectious hepatitis	-0.002	-0.001	0.001	0.004
4 Other infectious diseases	0.024	0.021	0.039	0.032
5 Cancer, lung	-0.014	0.000	-0.008	0.004
6 Cancer, stomach	0.022	0.009	0.055	0.060
7 Cancer, buccal cavity & pharynx	0.025	0.028	-0.016	0.007
8 Cancer, esophagus & larynx	0.006	0.007	0.011	0.015
9 Cancer, intestine	-0.002	-0.010	-0.004	-0.021
10 Cancer, bone & skin	0.002	0.002	0.005	0.008
11 Cancer, lymphatic & hematopoietic	-0.003	0.000	-0.005	-0.010
12 Cancer, other & unspecified	0.040	0.052	0.094	0.091
13 Cancer, breast	0.000	0.006	0.000	-0.030
14 Cancer, cervix, uterus, prostate	0.000	0.068	0.000	0.019
15 Benign neoplasms	0.004	0.007	0.011	0.011
16 Endocrine & metabolic diseases	0.002	0.007	0.006	-0.006
17 Nutritional deficiency & blood disease	0.005	0.007	0.011	0.033
18 Mental disorders	0.001	0.000	0.003	0.002
19 Diseases of nervous system	0.004	0.006	0.026	0.015
20 Rheumatic fever & heart disease	0.018	0.062	0.015	0.045
21 Hypertension	0.018	0.016	0.057	0.061
22 Ischemic heart disease	0.020	0.017	0.065	0.013
23 Cerebrovascular disease	0.035	0.045	0.074	0.085
24 Other circulatory diseases	0.051	0.058	0.013	0.054
25 Other respiratory diseases	0.071	0.065	0.053	0.096
26 Liver cirrhosis	0.045	0.018	0.044	0.018
27 Diseases of digestive system	0.089	0.072	0.101	0.088
28 Diseases of genito-urinary system	0.022	0.025	0.038	0.034
29 Pregnancy-related complications	0.000	0.044	0.000	0.047
30 Diseases of musculoskeletal system	0.002	-0.007	0.002	-0.017
31 Other (congenital & perinatal)	0.000	0.000	0.001	-0.005
32 Ill-defined & senility	0.090	0.093	0.108	0.130
33 Suicide	0.035	0.024	-0.010	-0.016
34 Accidents & injuries	0.056	0.039	0.053	0.008

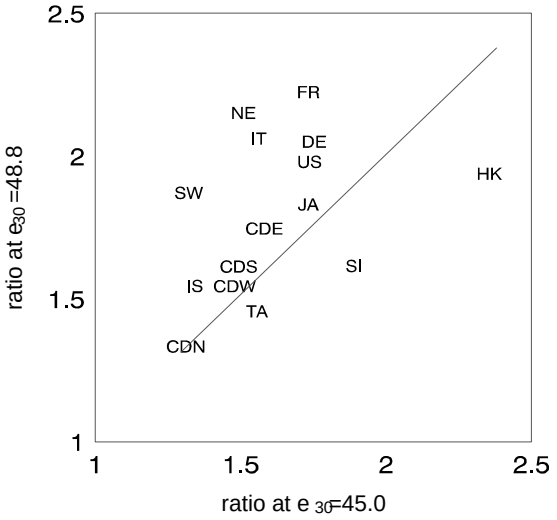
Note: See equation (3) for estimation of d_i

Appendix D. *Proportionate Contributions to Changes in Male and Female Mortality over Relevant Time Period (d_i), by Cause of Death and Age Group: Hong Kong, Singapore and Taiwan (continued)*

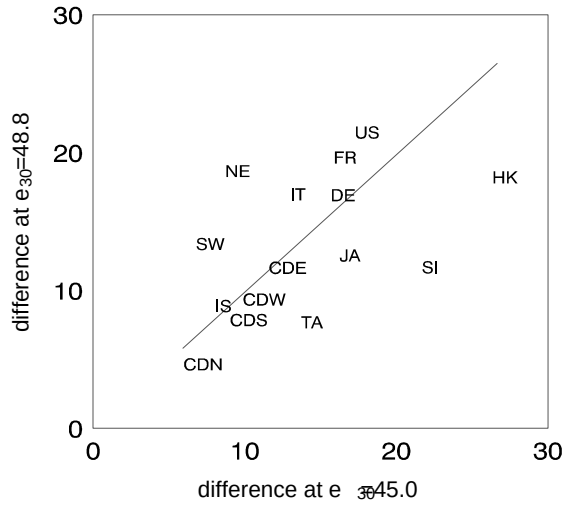
	Ages 50-59					
	Hong Kong	Hong Kong	Singapore	Singapore	Taiwan	Taiwan
	Male 1960-89	Female 1960-89	Male 1963-89	Female 1963-89	Male 1971-90	Female 1971-90
1 Respiratory tuberculosis	0.298	0.188	0.260	0.116	0.227	0.129
2 Other tuberculosis	0.002	0.004	0.006	0.004	0.005	0.007
3 Infectious hepatitis	0.000	-0.001	-0.001	0.000	0.000	0.000
4 Other infectious diseases	0.013	-0.004	0.016	-0.003	-0.004	-0.006
5 Cancer, lung	-0.019	-0.047	-0.044	-0.022	-0.054	-0.035
6 Cancer, stomach	0.029	0.037	0.050	0.042	0.065	0.045
7 Cancer, buccal cavity & pharynx	-0.001	0.011	-0.002	0.003	-0.020	-0.003
8 Cancer, esophagus & larynx	-0.009	0.006	0.023	0.021	0.012	0.013
9 Cancer, intestine	-0.009	-0.022	-0.016	-0.027	-0.002	0.003
10 Cancer, bone & skin	0.001	0.003	0.004	0.005	0.006	0.008
11 Cancer, lymphatic & hematopoietic	-0.008	-0.012	-0.008	-0.011	-0.012	-0.012
12 Cancer, other & unspecified	0.013	0.047	0.071	0.072	-0.008	0.032
13 Cancer, breast	0.000	0.006	0.000	-0.021	0.000	-0.016
14 Cancer, cervix, uterus, prostate	-0.001	0.021	-0.002	0.009	-0.002	0.012
15 Benign neoplasms	0.002	0.004	0.002	0.000	-0.027	-0.016
16 Endocrine & metabolic diseases	0.007	0.007	-0.002	-0.020	-0.061	-0.121
17 Nutritional deficiency & blood disease	0.005	0.009	0.029	0.056	0.012	0.014
18 Mental disorders	0.001	0.001	0.002	0.001	-0.002	0.005
19 Diseases of nervous system	0.003	-0.003	0.028	0.050	0.008	0.007
20 Rheumatic fever & heart disease	0.009	0.017	0.006	0.013	0.017	0.026
21 Hypertension	0.058	0.026	0.063	0.089	0.048	0.051
22 Ischemic heart disease	0.038	0.011	-0.170	-0.201	-0.034	-0.021
23 Cerebrovascular disease	0.146	0.127	0.048	0.106	0.325	0.373
24 Other circulatory diseases	0.106	0.153	0.089	0.092	0.070	0.122
25 Other respiratory diseases	0.065	0.120	0.112	0.137	0.128	0.139
26 Liver cirrhosis	0.020	0.012	0.016	0.007	0.044	0.011
27 Diseases of digestive system	0.070	0.094	0.081	0.076	0.180	0.134
28 Diseases of genito-urinary system	0.001	-0.052	0.016	0.010	0.026	0.040
29 Pregnancy-related complications	0.000	0.000	0.000	0.000	0.000	0.000
30 Diseases of musculoskeletal system	0.003	0.002	-0.001	-0.001	0.002	0.006
31 Other (congenital & perinatal)	0.000	0.001	0.000	-0.002	0.000	0.000
32 Ill-defined & senility	0.195	0.206	0.280	0.376	0.109	0.089
33 Suicide	0.011	0.010	0.023	0.006	0.019	0.011
34 Accidents & injuries	0.016	0.018	0.024	0.016	-0.079	-0.046

Note: See equation (3) for estimation of d_i

Figure 1. Sex differentials in mortality for the age group 65-69 at two levels of e_{30} : Far Eastern populations, Western countries, and Coale and Demeny model life tables[1]



1a. Sex ratio of mortality (male death rate/female death rate)



1b. Sex difference (per thousand population) in mortality (male death rate-female death rate)

CDE=Coale Demeny East	FR=France	NE=Netherlands
CDN=Coale Demany North	HK=Hong Kong	SI=Singapore
CDS=Coale Demeny South	IT=Italy	SW=Sweden
CDW=Coale Demeny West	IS=Israel	TA=Taiwan
DE=Denmark	JA=Japan	US=United States

[1]The two time points correspond to the year in which e_{30}=45.0 (as observed in Taiwan in 1972) on the X-axis and the year in which e_{30}=48.0 (as observed in Taiwan in 1991) on the Y-axis.

1b. Sex difference in mortality (male/female)