

# **Miscoding and misclassification of ischaemic heart disease mortality**

**Rafael Lozano,  
Christopher J. L. Murray,  
Alan D. Lopez ,  
Toshi Satoh**

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# 1. Introduction

Ischaemic heart disease (IHD) is estimated to be the leading cause of mortality in the world and in high-income countries it is also the leading cause of premature mortality and disability (1). Each year IHD kills an estimated 7 million people representing 13% of all male deaths and 12% of all female deaths. Moreover, 56% of those deaths occur before age 75 years (2). Recent recorded death rates from IHD vary widely across countries; age-standardized rates for males for the population aged over 30 range from more than 900 per 100,000 in some Eastern European countries (Turkmenistan, Republic of Moldova, Belarus, Ukraine) to 84 per 100,000 in Japan; for females the corresponding range is from more than 500 per 100,000 in Turkmenistan, Republic of Moldova and Ukraine to less than 50 per 100,000 in France and Japan (see Table 1).

Understanding the huge variation in IHD mortality has been the focus of intense study in the last 20 years (3, 4, 5, 6, 7, 8). An example of the interest generated by the cross-national variation in IHD mortality rates is the so called "French Paradox" - where France has a relatively high prevalence of the major risk factors for IHD such as Tobacco and fat intake but low reported IHD mortality rates (9, 10, 11). Many descriptive and analytical epidemiological studies have been inspired by the large variation in IHD mortality rates across countries (12). Not only has the cross-sectional pattern of IHD been an important stimulus to hypothesis formulation in this area but the recorded rise in many high income countries in IHD mortality rates in the 1950s and 1960s followed by declines in age-specific death rates has led to a vast body of research to understand the broader determinants of IHD incidence, case-fatality rates and mortality rates (13, 14, 15, 16, 17, 18).

Doubts have, however, been raised about the validity of cross-national comparisons and trends within countries in IHD mortality because of variation in coding practices across countries (19, 20, 21, 22, 23, 24). There are a number of cardiovascular codes in the International Classification of Diseases Ninth and Tenth Revisions (25, 26) that may be used by physicians in different countries to assign deaths that are actually due to IHD (see Table 2). These include heart failure, ventricular dysrhythmias, generalized atherosclerosis and ill-defined descriptions and complications of heart disease. IHD deaths may be assigned to these ill-defined cardiovascular codes because of insufficient clinical information at the time of death, local medical diagnostic practices or simply by error.

Figure 1 illustrates that there is enormous variation across countries in coding practice with respect to these ill-defined cardiovascular codes. For each country, the fraction of cardiovascular deaths (excluding stroke) that are assigned to IHD (ICD-9 codes 410-414 or in I20-I25 ICD-10) is shown on the x-axis. On the y-axis the fraction of cardiovascular deaths (excluding stroke) that are assigned to the ill-defined cardiovascular codes is measured. The strong negative relation between IHD mortality and that from the ill-defined cardiovascular disease (CVD) codes ( $r^2=0.90$ ) strongly supports the suggestion that the quality of CVD death certification varies substantially across countries. On the upper left side of the curve are those countries where doctors certified, on average, more ill-defined CVD than IHD deaths, and in the bottom right corner are those countries where doctors assign, on average, a small proportion of ill-defined CVD deaths.

**Table 1. Age standardized IHD mortality rate for ages 30 years and over, selected countries, latest available year, 1994-1998.**

<b>Rank</b>	<b>Males</b>	<b>Year</b>	<b>Age std rate 30+</b>	<b>Ratio*</b>	<b>Females</b>	<b>Year</b>	<b>Age std rate 30+</b>	<b>Ratio*</b>
1	Turkmenistan	94	976	11.6	Turkmenistan	94	789	18.5
2	Republic of Moldova	98	967	11.5	Republic of Moldova	98	674	15.8
3	Belarus	98	934	11.1	Ukraine	98	562	13.2
4	Ukraine	98	919	10.9	Azerbaijan	97	475	11.1
5	Kazakhstan	97	876	10.4	Kazakhstan	97	464	10.9
6	Azerbaijan	97	833	9.9	Belarus	98	459	10.8
7	Estonia	98	780	9.3	Armenia	97	429	10.1
8	Latvia	98	775	9.2	Estonia	98	412	9.7
9	Russian Federation	97	751	8.9	Latvia	98	396	9.3
10	Kyrgyzstan	98	658	7.8	Lithuania	98	391	9.2
11	Lithuania	98	645	7.6	Kyrgyzstan	98	384	9.0
12	Armenia	97	613	7.3	Russian Federation	97	383	9.0
13	Slovakia	95	587	7.0	Slovakia	95	329	7.7
14	Hungary	98	531	6.3	Trinidad & Tobago	94	314	7.4
15	Mauritius	97	487	5.8	Romania	98	303	7.1
16	Romania	98	470	5.6	Hungary	98	288	6.8
17	Bulgaria	98	448	5.3	Mauritius	97	286	6.7
18	Ireland	96	438	5.2	Kuwait	97	277	6.5
19	Finland	96	434	5.1	Bulgaria	98	266	6.2
20	UK North Ireland	97	428	5.1	Cuba	96	256	6.0
21	Croatia	98	424	5.0	Croatia	98	230	5.4
22	Czech Republic	98	419	5.0	Czech Republic	98	216	5.1
23	UK Scotland	98	405	4.8	Venezuela	94	213	5.0
24	Trinidad & Tobago	94	393	4.7	Ireland	96	205	4.8
25	New Zealand	96	360	4.3	Scotland	98	203	4.8
26	UK	97	354	4.2	North Ireland	97	199	4.7
27	Cuba	96	347	4.1	Finland	96	193	4.5
28	UK England & Wales	97	345	4.1	Singapore	97	188	4.4
29	Kuwait	97	343	4.1	New Zealand	96	175	4.1
30	Norway	95	341	4.1	Costa Rica	95	172	4.0
31	Venezuela	94	329	3.9	UK	97	166	3.9
32	Sweden	96	324	3.8	Colombia	94	164	3.8
33	Austria	98	312	3.7	England & Wales	97	160	3.8
34	Australia	95	305	3.6	Australia	95	160	3.8
35	Denmark	96	302	3.6	USA	97	158	3.7
36	Germany	98	299	3.6	Austria	98	158	3.7
37	USA	97	291	3.5	Germany	98	153	3.6
38	Singapore	97	288	3.4	Denmark	96	148	3.5
39	Costa Rica	95	276	3.3	Sweden	96	146	3.4

(continued)

**Table 1 (continued). Age standardized IHD mortality rate for ages 30 years and over, selected countries, latest available year, 1994-1998.**

Rank	Males	Year	Age std rate 30+	Ratio*	Females	Year	Age std rate 30+	Ratio*
40	Canada	97	267	3.2	Mexico	95	140	3.3
41	Slovenia	98	259	3.1	Norway	95	140	3.3
42	Poland	96	257	3.0	Slovenia	98	135	3.2
43	Macedonia	97	245	2.9	Canada	97	133	3.1
44	Colombia	94	244	2.9	Israel	96	132	3.1
45	Netherlands	97	226	2.7	Brazil	95	129	3.0
46	Israel	96	223	2.6	Macedonia	97	117	2.8
47	Switzerland	94	219	2.6	Chile	94	112	2.6
48	Luxembourg	97	210	2.5	Switzerland	94	100	2.4
49	Brazil	95	210	2.5	Netherlands	97	97	2.3
50	Mexico	95	204	2.4	Poland	96	93	2.2
51	Greece	97	199	2.4	Luxembourg	97	91	2.1
52	Chile	94	199	2.4	Belgium	94	87	2.0
53	Belgium	94	189	2.2	Greece	97	86	2.0
54	Italy	96	181	2.2	Italy	96	85	2.0
55	Argentina	96	167	2.0	Portugal	98	78	1.8
56	Spain	96	161	1.9	Argentina	96	71	1.7
57	Portugal	98	159	1.9	Spain	96	69	1.6
58	France	97	116	1.4	France	97	46	1.1
59	Japan	97	84	1.0	Japan	97	43	1.0

Source: WHO, Mortality Database

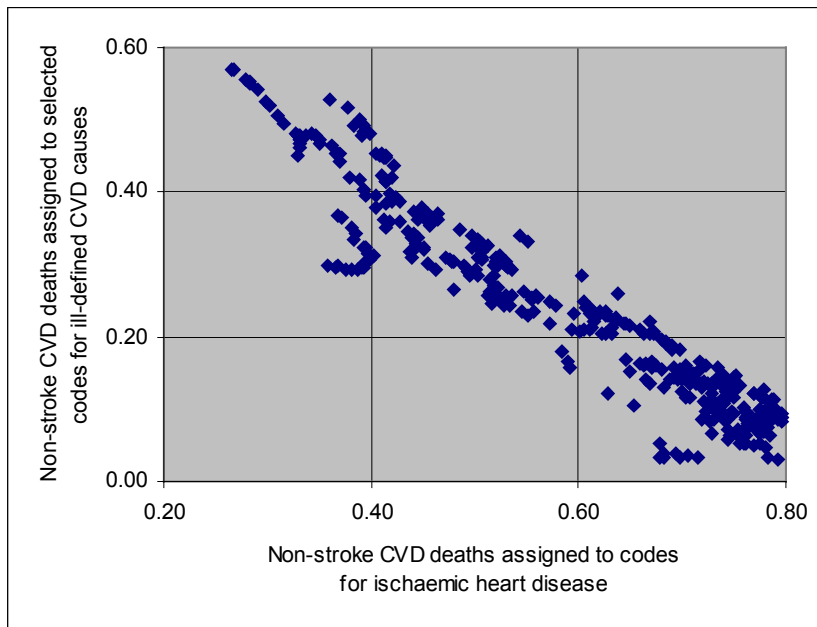
- Ratio of death rates compared with Japan

**Table 2. III-defined cardiovascular diseases, ICD-9 and ICD-10**

Disease	ICD-9	ICD-10
Paroxysmal ventricular tachycardia	427.1	I47.2
Ventricular fibrillation and flutter	427.4	I49.0
Cardiac arrest	427.5	I46
Heart failure	428	I50
Myocarditis, unspecified	429.0	I51.4
Myocardial degeneration	429.1	I51.5
Cardiovascular disease, unspecified	429.2	I51.6
Complications of heart disease, unspecified	429.9	I51.9
Atherosclerosis, generalized and unspecified	440.9	I70.9

Source: WHO 1977, WHO 1992.

**Figure 1. Proportion of CVD deaths (excluding stroke) assigned to selected I11-defined causes and directly to ischaemic heart disease, for selected countries (1979-1998)**



The first group of countries includes Japan<sup>1</sup>, France, Spain and Portugal while the second group includes New Zealand, Australia, Scotland, Finland, Norway and Canada. We refer to these two groups of countries as the “High ill-defined coding” and “Low ill-defined coding” groups. In addition to the problems of miscertification, part of the variation in reported IHD mortality rates (ICD-9 codes 410-414 or ICD-10 I20-I25) among countries may well be due to variations in the medical part of the death certificate, as well as miscoding.

In order to correct for the likely under-registration of IHD in countries such as Japan, France or Spain in the Global Burden of Disease Study, Murray and Lopez (29) developed an algorithm based on the assumption that the cluster of countries comprising Canada, Finland, Norway and New Zealand, where ill-defined coding was low, would define the "standard" coding practice. For all other countries, the percentage of cardiovascular deaths (excluding stroke) assigned to these codes in excess of this "standard" percentage was then assumed to be largely miscertified IHD. The regression equations developed to estimate the proportion of deaths to be extracted from ill-defined heart diseases codes and assigned to IHD was calculated by age group with the added constraint that the percentage of CVD deaths with ill-defined codes did not exceed the average of the standard countries mentioned above. A similar procedure, with some local adaptations, has been used in different National Burden of Diseases Studies such as Mexico (30), Chile (31), Australia (32) and the USA.

<sup>1</sup> In Japan nearly 60 percent of cardiovascular deaths are assigned to the ill-defined codes whereas in the United Kingdom, New Zealand and Finland less than 1.0 percent are assigned to these codes. Since 1995, when ICD-10 was introduced with some modifications to the death certificate, with the proportion of ill-defined CVD deaths Japan has declined to 30% in males and 35% in females. For a more detailed discussion of these modifications see Oomi et al., 1997; Hirako et al 1999 (27, 28).

In this paper, we propose and test, on a cross-national dataset, a revised method to estimate the fraction of IHD deaths that are assigned to ill-defined cardiovascular codes. Corrected IHD mortality rates are calculated for each country using the results of this analysis. Corrections for miscertification substantially narrows the range in death rates across countries and changes the relative ranks of countries as well.

## 2. Methods

In the absence of a multi-country autopsy study using standardized methods, the challenge is to estimate the fraction of deaths assigned to ill-defined cardiovascular codes that are in reality due to IHD. If a set of variables can be identified that are strongly related to the true death rate from IHD, this relationship can be exploited to estimate the fraction of deaths assigned to ill-defined cardiovascular codes that should have been assigned to IHD. We begin by noting that the true IHD death rate ( $I_T$ ) can be divided into the observed IHD death rate ( $I_O$ ) and the miscoded IHD death rate ( $I_M$ ), as follows:

$$I_T = I_O + I_M \quad (1)$$

This equation can be rewritten so that the measurable quantity,  $I_O$ , is on the left-hand side:

$$I_O = I_T - I_M \quad (2)$$

Neither  $I_T$  nor  $I_M$  can be directly observed, but if a set of variables that can predict  $I_T$  are known, then  $I_M$  can be estimated through OLS regression. The other observable is the death rate from ill-defined cardiovascular codes, which can be separated into components due to IHD and other causes as follows:

$$G_O = G_T + I_M \quad (3)$$

where  $G_O$  is the observed death rate from ill-defined cardiovascular causes,  $G_T$  is the true death rate from ill-defined cardiovascular codes that are not due to IHD and  $I_M$  is as defined as above.

By multiplying and dividing  $I_M$  by  $G_O$  in equation 2 and rearranging, the following expression is obtained:

$$I_O = I_T - (I_M/G_O) \cdot G_O \quad (4)$$

The ratio of  $I_M$  to  $G_O$  is the fraction of observed deaths assigned to the ill-defined cardiovascular codes that are actually due to IHD. This is the quantity of interest.

Next, if there is a set of variables ( $X_i$ ) that might predict the true IHD death rate ( $I_T$ ) then we can write:

$$I_T = f(X_i \dots)$$

Substituting into equation (4):

$$I_0 = f(X_i, \dots) - (I_M/G_0) \cdot G_0$$

If we define the following dummy variables for *low ill-defined coding* countries:

$$F_{Low} = I_M / (G_T + I_M)$$

and for *high ill-defined coding* countries:

$$F_{High} = F_{Low} + C \cdot D_{High}$$

where  $D_{High}$  is a dummy variable that is 1 for *high ill-defined coding* countries and 0 for *low ill-defined coding* countries, then the latter equation can be estimated empirically using OLS regression if a set of variables,  $X_i$ , are known and their functional relationship to  $I_T$  specified. For example, if there is only one variable  $X_I$  and the relationship with  $I_T$  is linear, the following regression equation could be estimated:

$$I_0 = \beta_1 X_I + \beta_2 G_0 + \beta_3 G_0 D_{High} + \varepsilon$$

$\beta_2$  and  $\beta_3$  are then the empirically estimated fraction of deaths assigned to ill-defined cardiovascular codes that are actually due to IHD, depending on the dummy variable. If the theory elaborated here is correct, this regression coefficient should be negative and have a value between 0 and 1.

We have applied this approach using ICD-9 and ICD-10 4-digit vital registration data available in the World Health Organization mortality database. This yielded 372 country-years with complete vital registration and medical certification of causes of death (see Table 3). While the composition of deaths assigned to each of the four clusters of ill-defined cardiovascular codes clearly varies across countries, we have combined all of these ill-defined codes into one aggregate for the purpose of this analysis. For risk factors predicting IHD mortality, we have used the method developed by Peto and Lopez (33). They found that variations in the lung cancer death rate in these industrialized countries can largely be attributed to differences in the cumulative effects of tobacco exposure. Lung cancer death rates in excess of non-smoker lung cancer death rates in an age group was considered as a biological assay of the cumulative effects of tobacco exposure. As tobacco is a powerful risk factor for IHD (see, for example, USDHHS, 1989; Doll et al, 1994 (34, 35)), we have used the lung cancer death rate as the primary variable predicting true IHD death rates. Regression equations have been developed for each sex and age-group separately as we expect the fraction of deaths assigned to ill-defined cardiovascular codes to rise with age and differ by sex.

For each age and sex group, the following equation has been estimated using OLS regression:

$$I_0 = \beta_1 SIR + \beta_2 G_0 + \beta_3 G_0 D_{High} + \varepsilon \tag{5}$$

where SIR (Smoking Impact Ratio), is the predictor (the relative excess of the lung cancer death rate in an age-group  $x$  over and above non-smoker levels). Once the first estimate of  $I_0$  was obtained, an iterative process was followed for the second and subsequent rounds according to the following model

$$I_0 = \beta_1 IHD_C + \beta_2 G_0 + \beta_3 G_0 D^{Na} + \varepsilon \quad (6)$$

where  $IHD_C$  is the predictor variable, taken from the previous iteration.

The set of estimated  $\beta_{G,x}$  for each age-sex group has then been used as the estimates of miscoded IHD to calculate corrected IHD death rates for each country.

**Table 3. Country-years used for estimating model**

Country	Years	Period	Dummy*
Canada	12	1986-97	0
USA	19	1979-97	0
Israel	2	1995-96	0
Japan	19	1979-97	1
Austria	19	1980-98	0
Belgium	10	1980-94	1
Czech Republic	13	1986-98	1
Finland	8	1989-96	0
France	19	1979-97	0
Germany	4	1995-98	0
Germany, Former FRG	12	1979-90	0
Greece	11	1987-97	0
Hungary	20	1979-98	1
Iceland	7	1979-95	0
Ireland	17	1979-95	0
Italy	18	1979-96	1
Netherlands	19	1979-97	0
Norway	10	1986-95	0
Portugal	15	1984-98	1
Spain	17	1980-96	1
Sweden	10	1987-96	0
England & Wales	19	1979-97	0
N. Ireland	19	1979-97	0
Scotland	20	1979-98	0
Australia	15	1979-95	0
New Zealand	18	1979-96	0
<b>Total</b>	<b>372</b>		

\* Dummy: 0 Low ill-defined coding countries, 1: High ill-defined coding countries



### 3. Results

Table 4 shows the results of the third round of regression analysis. In all age-groups and for both sexes, the  $\beta_G$  are positive because we ran the model with negative signs in STATA. In all cases the coefficients are between zero and one. The interactive process was stopped after the third cycle since the  $r^2$  values by age and sex did not change (see Table 5).

As expected, the extent of miscoding at every age, for both males and females was systematically higher in *high ill-defined coding* countries compared with *low ill-defined coding* populations. The correction factors typically decreased with age, from less than 5% below age 50 to almost 95% males aged 55-59 in *high ill-defined coding* countries. Indeed, for these populations our methods suggest that 50-95% of ill-defined CVD codes should be reassigned to ischaemic heart disease.

Taking the suggested proportions from ill-defined CVD deaths by age and sex and adding to the observed IHD deaths, age-standardized death rates were recalculated for the 26 countries.

**Table 4. Correction factors (Beta values) by age and sex, Low and high ill-defined coding countries**

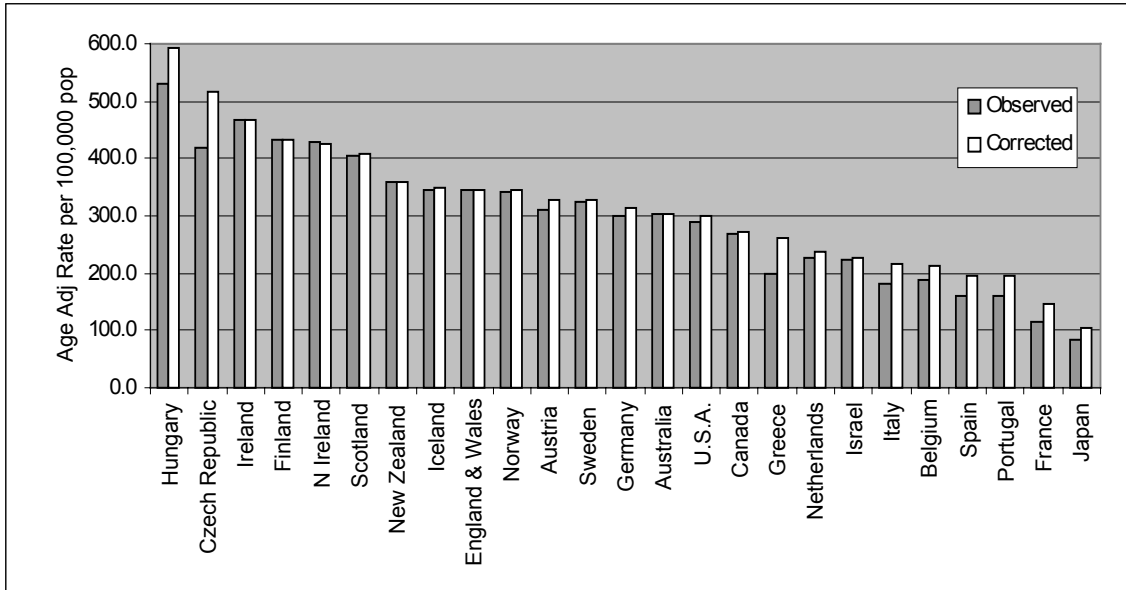
Age group	Males		Females	
	Low ill-defined coding	High ill-defined coding	Low ill-defined coding	High ill-defined coding
35-39	0.000	0.000	0.000	0.000
40-44	0.107	0.107	0.000	0.000
45-49	0.039	0.273	0.000	0.041
50-54	0.040	0.696	0.101	0.446
55-59	0.203	0.941	0.139	0.689
60-64	0.160	0.754	0.119	0.660
65-69	0.253	0.827	0.251	0.615
70-74	0.264	0.732	0.202	0.469
75-79	0.233	0.576	0.170	0.358
80+	0.030	0.242	0.060	0.198

**Table 5. Correlation Coefficient ( $r^2$ ) by age, sex and iterative cycle**

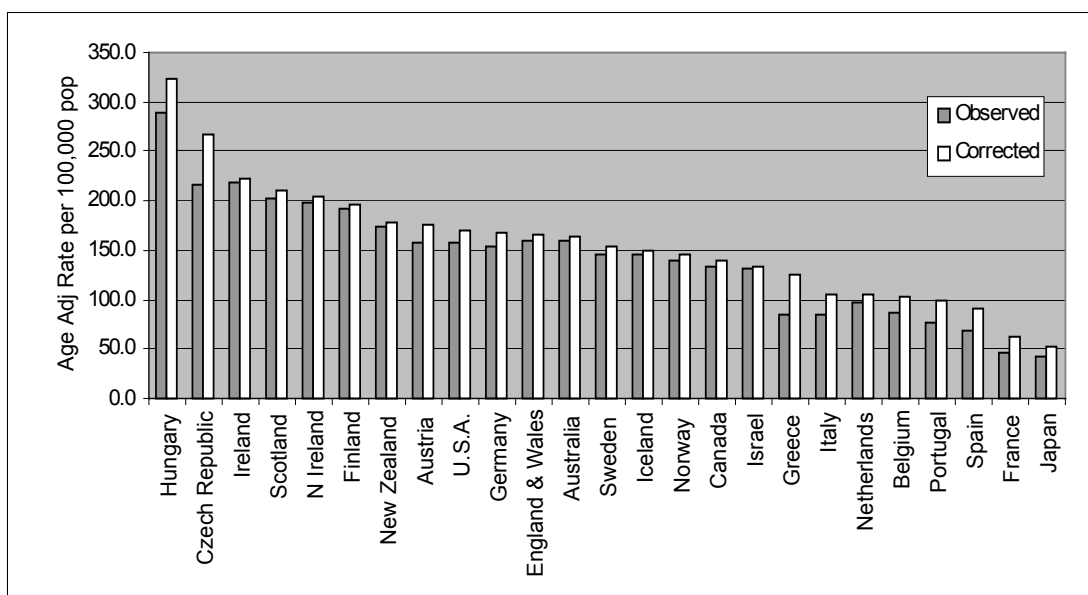
Age group	Males					Females				
	1st	2nd	3rd	4th	5th	1st	2nd	3rd	4th	5th
35-39	.35	.61	<b>.61</b>	.61	.61	.61	.61	<b>.61</b>	.61	.61
40-44	.25	.79	<b>.79</b>	.79	.79	.80	.80	<b>.80</b>	.80	.80
45-49	.26	.80	<b>.80</b>	.80	.80	.80	.80	<b>.81</b>	.81	.81
50-54	.42	.87	<b>.88</b>	.88	.88	.84	.84	<b>.88</b>	.88	.88
55-59	.49	.90	<b>.90</b>	.90	.90	.87	.87	<b>.90</b>	.90	.90
60-64	.48	.91	<b>.92</b>	.92	.92	.88	.88	<b>.92</b>	.92	.92

65-69	.43	.94	<b>.94</b>	.94	.94	.93	.93	<b>.94</b>	.94	.94
70-74	.40	.95	<b>.95</b>	.95	.95	.93	.93	<b>.94</b>	.94	.94
75-79	.34	.95	<b>.95</b>	.95	.95	.94	.94	<b>.95</b>	.95	.95
80+	.22	.95	<b>.95</b>	.95	.95	.95	.95	<b>.95</b>	.95	.95

**Figure 2a. Mortality Rates from Ischaemic Heart Disease in Males over 30 years old, selected countries circa 1997, before and after correction.**



**Figure 2b. Mortality Rates from Ischaemic Heart Disease in Females over 30 years old, selected countries circa 1997, before and after correction.**



Figures 2a and 2b show, for males and females respectively, the corrected and uncorrected age-standardized death rates from IHD for the population aged 30 and over for the 26 countries included in this study (latest year available). With correction, the age-standardized death rates increased in all countries, but most notably in France (27% in males and 35% in females), Japan (26% in males and 24% in females) and Greece (32% in males and 47% in females). Less in Spain, Belgium, Portugal, Italy, Czech Republic and Hungary (12-25% in average for males and females), with only small changes in USA, Austria, Netherlands and Germany (about 5%). In other countries, including Ireland, Finland, UK (Scotland and North Ireland), New Zealand, Australia, Norway and Canada, no corrections were suggested by this analysis.

With correction, the ratio of death rates from IHD between Japan (lowest) and Finland or Ireland (countries with the highest death rates without correction) decreased from 5 to 4 in both males and females. The coefficient of variation also declined in both sexes.

After correcting the rates, there were several changes in the rank order of countries. The Czech Republic, Austria, Germany, Greece and Italy had higher rankings compared to the uncorrected order. On the other hand, the correction procedure did not affect the ranking of countries with low IHD mortality such as Spain, France or Japan. In the case of Japan, at least, the introduction of ICD-10 has eliminated a substantial fraction of IHD miscoding. Indeed, prior to the introduction of ICD-10, corrected rates were over 80% higher in males and around 70% greater in females, compared with what was recorded in the vital statistics.

## 4. Comparison with estimated IHD miscoding in the MONICA project

For some selected countries in our dataset and in MONICA, it is possible to compare the results of this correction algorithm to that from the MONICA data on IHD fatality rates, with minor modifications to the definition of IHD. In the MONICA project, the registered fatal

cases of IHD were classified into four categories: "Definite" (F1), "Probable" (F2), "unclassified" (F9), and "no myocardial infarction or coronary death" (F4) (36) For the main analysis of the MONICA study, the "true" IHD definition was based on the sum of the first three categories. For comparison purposes, we have limited the analysis to the same age groups as MONICA (35-64 years), the same time period (1982-1993), and have only modified the MONICA definition F9: "unclassified" IHD, excluding those fatal cases for which the cause of death was not a cardiovascular death (i.e. sudden death, injuries, etc).

Table 6 shows the relationship between the implied MONICA corrections and those from the method that has been proposed in this paper for males and females in some selected sites. For this comparison, we used the ratio of age-standardized mortality rates from IHD. The first two columns give the ratio between the corrected IHD death rate and that observed from Vital Registration for those countries where MONICA had site. In the right-hand columns of the table we present the ratio of the MONICA "true" IHD death rate to that observed from Vital Registration. For those countries where we used the dummy variable in the prediction, the results are less consistent (Italy, Belgium, Spain and Italy) with MONICA. De Henauw et al. (37) validated the Belgium vital statistics for IHD by linking fatal cases of Acute Myocardial Infarction (AMI) in the MONICA register to the corresponding death certificate. They found that 15-20% of F1 ("definite") and F2 ("possible") AMI events among the MONICA cases were actually coded to sudden death and other totally unrelated ICD codes (for example, neoplasm). They did not include F9 (insufficient) AMI in their study. If F9 had been included, the percentage of the MONICA events coded to sudden death and other totally unrelated ICD codes would be even higher. This finding for Belgium may explain much of the difference in the comparison of both methods. For the other countries studies which validate each fatal case against death certificates are not available, although in France, Richard et al. (38) reported that rates of the diagnostic categories "Definitive" and "possible" MI were probably underestimated by around 25%.

Clearly, true IHD deaths may be coded to ill-defined codes other than cardiovascular deaths. Ill-defined deaths coded to Chapter XVI in ICD-9 are another possible source of true IHD deaths. Chapter XVI includes "symptoms, signs, abnormal results of laboratory or other investigative procedures, and ill-defined conditions regarding which no diagnosis classifiable elsewhere is recorded" such as senility and sudden death. The MONICA study found that in France, Poland and Belgium, sudden death (ICD code 798) and "other ill-defined and unknown causes of morbidity and mortality" (799) tend to be coded instead of IHD (39).

In other countries, such as Finland, the UK (Scotland, Northern Ireland), Iceland and Canada, our results support the MONICA findings that miscertification is rare. In cases where the difference observed is large, such as in the Stanford MONICA site in the USA compared with the national correction factor from our algorithm, at least part of the discrepancy may be due to the atypical nature of the MONICA site. Comparisons with MONICA in such cases are probably too restrictive to be informative.

**Table 6. Correction factors for IHD deaths from algorithm and for selected MONICA sites , males and females**

Country	Year	Males	Females	Monica Site	Males	Females
Australia	1984-93	1.002	1.005	Newcastle	1.060	1.170
				Perth	1.036	1.083
Belgium	1983-92	1.250	1.314	Charleroi	1.215	1.418
				Ghent	1.280	1.301

Canada	1986-93	1.007	1.012	Halifax County	1.100	0.970
Czech Republic	1986-93	1.033	1.038	Czech Republic	1.000	0.959
Finland	1989-92	1.001	1.002	Kuopio Province	1.033	1.038
				North Karelia	1.023	1.001
				Turku/Loimaa	1.037	1.042
France	1985-93	1.187	1.265	Lille	1.442	1.854
				Strasbourg	1.433	1.506
				Toulouse	1.313	1.534
Italy	1984-93	1.129	1.217	Area Brianza	1.061	1.143
				Friuli	1.096	1.060
New Zealand	1983-91	1.001	1.003	Auckland	1.020	1.021
Spain	1985-94	1.198	1.349	Catalonia	1.130	1.264
Sweden	1987-94	1.004	1.008	Gothenburg	1.042	1.116
				Northern Sweden	1.035	1.16
Scotland	1985-94	1.002	1.004	Glasgow	1.092	1.070
N. Ireland	1983-93	1.002	1.006	Belfast	0.993	0.999
U.S.A.	1980-92	1.021	1.031	Stanford	1.210	1.340

## 5. Discussion

Because IHD is one of the major contributors to premature mortality and disability in the world, our finding that mortality rates in some countries such as Japan, Greece or France need to be corrected by 30% or so, has potentially important implications for national health policy formulation and cross-national evaluations of the determinants of IHD mortality. The statistical model developed in this paper appears to provide plausible estimates of the fraction of deaths assigned to ill-defined cardiovascular codes in ICD-9 that are actually deaths from IHD. The estimated fraction of ill-defined cardiovascular deaths that are IHD according to the OLS regression equations rises with age. This result is consistent with our prior expectations since the prevalence of idiopathic causes of ventricular dysrhythmias and heart failure are higher in younger ages, while the prevalence of IHD is lower.

The claims about miscertification are supported by the dramatic increase in recorded IHD mortality rates in Japan between 1994 to 1995 (more than 25%) with the change from ICD-9 to ICD-10, whereby physicians were encouraged not to use heart failure as an underlying cause of death (27,28). Other studies have suggested that miscertification of IHD is common in Japan, but have not proposed methods to adjust rates (41, 42, 43). For example, Sekikawa et al (44) compared heart diseases mortality rates in young people in Japan and the US and found that the majority of deaths from heart diseases in Japan were coded to heart failure. Indeed, mortality from heart failure was about three times higher than mortality from CHD. Heart failure was rarely used as a code for vascular deaths in men aged 35-44 in the US.

While the empirical results of applying the recoding model are encouraging, several caveats need to be highlighted. The empirical estimation of the fraction of ill-defined cardiovascular codes that are true cases of IHD depends on identifying a variable or set of variables that are good predictors of the true rate of IHD. If the component of ill-defined cardiovascular deaths not due to IHD is correlated with the predictors of true IHD mortality, the method may over-estimate the fraction that should be re-assigned to IHD. Furthermore, in our model the

fraction of ill-defined cardiovascular deaths that are due to IHD is assumed to be constant across countries. More complicated models in which this fraction varies as a function of other determinants might be more appropriate. Another limitation of using the OLS regression method developed in this paper is that we assume the independent variables including the death rate from ill-defined cardiovascular deaths, are measured without error. The unavoidable measurement error in the recorded rate of ill-defined cardiovascular deaths could be addressed by developing a maximum likelihood procedure around the joint distribution of observed IHD mortality and observed ill-defined cardiovascular mortality. More research is needed to identify a set of good predictors of the true rate of IHD, to empirically test whether the iterative OLS regression procedure used here leads to robust unbiased estimates, and to test the adequacy of this method against the appropriate maximum likelihood procedure.

Because cross-national and temporal trends in IHD mortality have been the focus of so much research and policy attention, the finding that reported rates may need to be corrected by up to 30% may have potentially important implications. Even the changes in the cross-national pattern reported here suggests that the French Paradox is neither uniquely French nor is it quite as great a paradox as suggested by uncorrected mortality rates. Perhaps more importantly, because the fraction of cardiovascular deaths assigned to the ill-defined codes has been steadily declining in different countries, the recorded 'epidemics' of IHD mortality may need to be reinterpreted. For example, in Mexico, 47% of cardiovascular deaths (excluding stroke) in 1980 were due to ill-defined causes and 29% to IHD. Nineteen years later, IHD accounted for 52% of cardiovascular deaths excluding stroke and the ill-defined codes only 18%.

It is unlikely that the epidemiology of the disease could have changed that dramatically in two decades. Similar effects can be observed in Austria, Japan, Spain, Hungary, Italy, France and Greece. In some cases, the implementation of ICD-10 may account for part of the change, as it did in Japan, but other factors, including changes in registration practice may also be relevant. Such artefacts make the interpretation of trend analyses in these countries very difficult.

Much of the apparent increase in IHD mortality rates may simply be due to improvements in the quality of certification and more accurate diagnosis of IHD deaths over the 15 year period. Historical analysis by Preston (46) suggests that when potential miscoding and miscertification of heart disease deaths is taken into account, the long term trend in death rates from major vascular diseases is downwards. This more detailed cause-specific analysis confirms this observation and suggest that where they can be reliably measured, IHD death rates in developing countries have declined with development.

The methods proposed here could be used to correct the miscertification of IHD in countries with 4-digit ICD records, including such Latin American countries such as Chile, Mexico, Brazil, Cuba and Argentina.

Unfortunately, due to the non-standard disease classification used in Russia and other NIS states<sup>2</sup> the method cannot be applied without further evidence from autopsies as to the true cause of vascular deaths. The single most important cause of cardiovascular death in these countries is "coronary atherosclerosis" (093 in the Soviet Classification of Diseases) part of which at least reflects a disease process different to what the term implies elsewhere (47, 48). The use of the code "sudden death" to describe mortality often associated with binge drinking in Russia and neighbouring countries may also conceal true cases of IHD (49).

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<sup>2</sup> The Soviet Classification of Diseases contains 175 categories based on ICD-9.

Despite the amply documented limitations of quality and completeness of mortality data from death certificates, the advantages of the database for public health research continue to make it unique. According to Rosenberg (50), no other health data source exists that is as universal in coverage, as standardized, as uniform, and as timely as mortality data from the vital statistics system. Mortality data continue, therefore to be a key database for epidemiologic, demographic, and historic research and increasingly for public policy. Where they are imperfect, innovative methods such as those proposed in this paper that correct them can greatly increase their utility for health promotion and disease prevention.

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