Chapter 3

Results

3.1 Studies completed

The statistical models were applied to both overall and cause-specific mortality, and presented in two studies. The first study was concerned with developing a statistical method for comparing all-cause mortality rates across geographical regions. The method involves first fitting a statistical model based on the Poisson distribution in which age group and superdistrict are incorporated as factors.

The statistical model used in the first study could also be applied to analyse cause-specific mortality. However, a more appropriate model for comparing cause-specific mortality across a region is based on the proportions of cause-specific deaths to all-cause deaths, and the methods used in this study can be extended straightforwardly to this situation by using logistic instead of Poisson regression. A benefit of this method is that the population denominators are not needed.

In the second study, we report on the use of statistical graphics and models to investigate geographic variations in the proportions of ill-defined and unknown cause mortality in order to examine the cause-of-death data quality across administrative districts in Thailand.

3.2 Preliminary results

Study 1: Geographical variation of mortality in Thailand

Age-specific death rates (per 100,000) for males and females in Thailand during 1999-2001 are shown in Figure 3.1. There appears to be higher mortality in males than females in every age group. The crude death rate was 537 per 100,000 population as indicated by the horizontal dotted line in the Figure 3.1

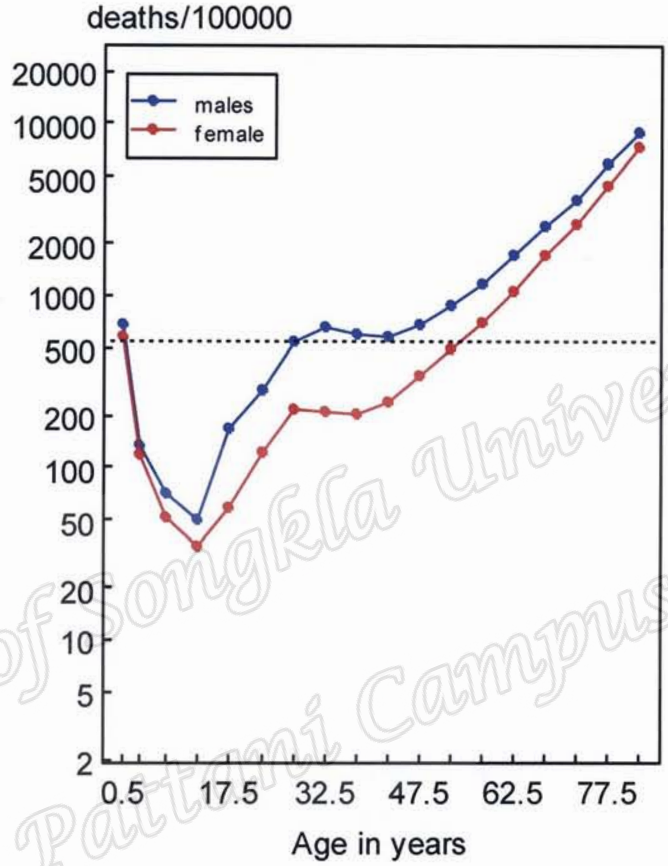

Figure 3.1: Mortality patterns for males and females in Thailand, 1999-2001

Figure 3.2 shows the crude death rates for Thai males and females aged 0-84 years during 1999-2001. Residents in the north had higher mortality rates than those in other regions. Bangkok and the southern region had lower mortality for both sexes.

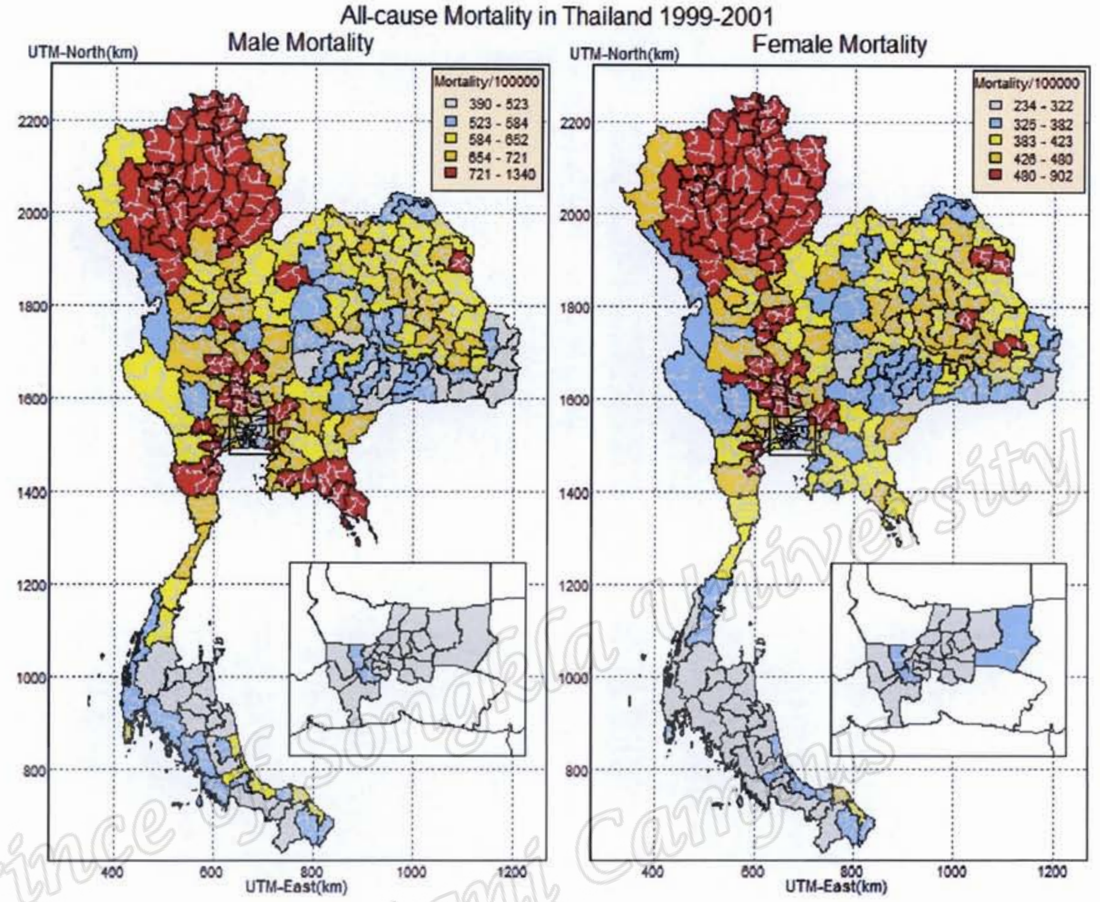

Figure 3.2: Observed mortality rates for males and females aged less than 85 years in Thailand, 1999-2001

Study 2: Geographical variation of ill-defined mortality in Thailand

Deaths were diagnosed as ill-defined and unknown cause mortality for 32% of males and for 42% for females aged 0-84 during 1999-2001. Figure 3.3 shows a graphical comparison.

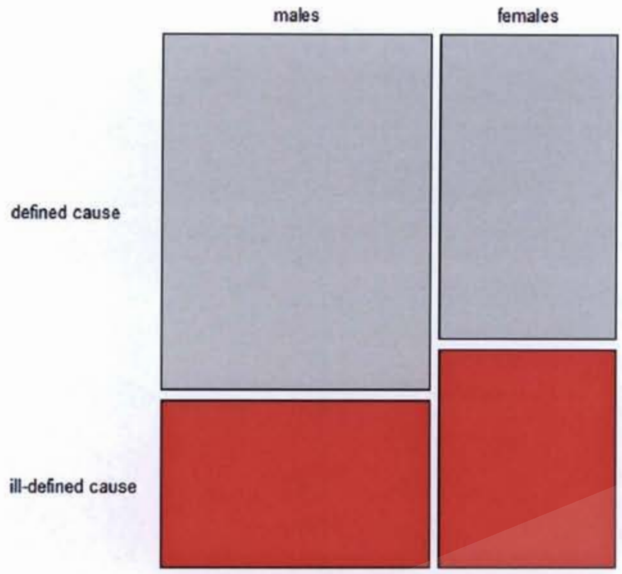

Figure 3.3: Mosaic plot for ill-defined deaths for males and females aged 0-84 in Thailand, 1999-2001

The proportions of ill-defined deaths among males and females aged 0-84 years in 235 superdistricts of Thailand are shown in Figure 3.4. The higher percentages mostly occurred in age greater than 65 years old for both sexes.

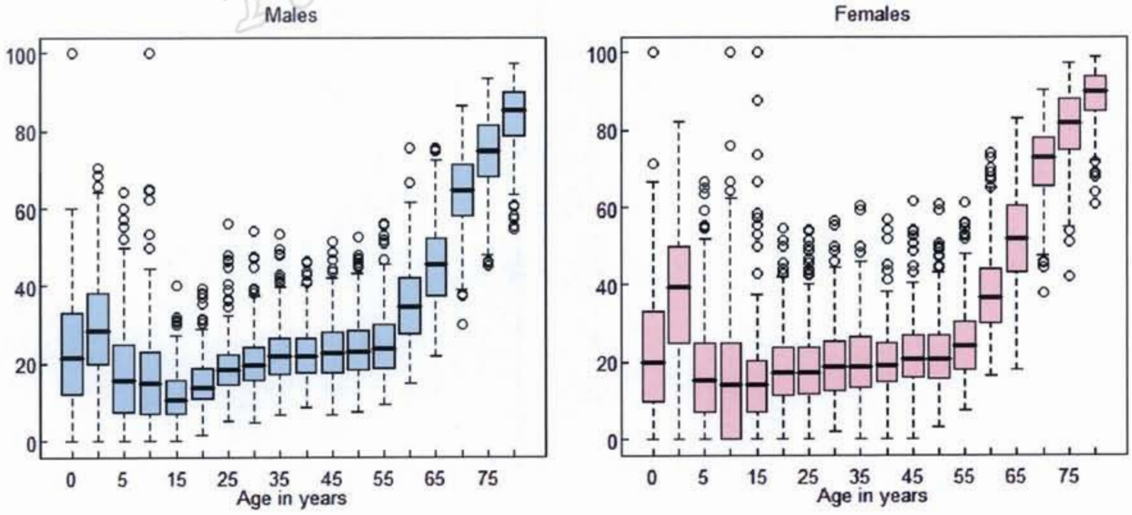

Figure 3.4: Boxplots of percentage of ill-defined mortality for males and females in Thailand, 1999-2001

3.3 Manuscripts

3.3.1 Geographical variations of morality in Thailand

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Geographical Variations of All-cause Mortality in Thailand

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Abstract

In this study, we examine the variation in age-specific death rates in men and women across administrative districts in Thailand based on mortality data during 1999-2001. A Poisson generalized linear model was used in the analysis. To adjust for large variations of resident populations among the districts, the 926 districts in Thailand were reduced to 235 "superdistricts" based on a minimum population of 200,000. The Poisson model incorporating additive factors for age-group and superdistrict generally provided a good fit to these data. The fitted mortality rates among 235 superdistricts were compared with the overall means for each gender (637 per 100,000 for males and 415 per 100,000 for females). Thematic maps were created with three different colours signifying each superdistrict's mortality rate compared to the mean. The North-Eastern region had higher than average mortality for both males and females. In contrast, lower than average death rates were found in Southern Thailand with the exception of Phuket and Narathiwat, and in Bangkok except for females in the superdistrict containing NongChok and LatKrabang districts. This modeling and mapping approach is a useful preliminary tool enabling public health planners to determine statistically valid geographical variations in mortality and thus to target effective intervention.

Keywords: all-cause mortality, Poisson regression

Introduction

Studies on the regional variations in mortality give insight on how mortality different across the country worldwide. Some studies investigate all-cause mortality for the whole population [1-4], while some studies focus on specific-cause mortality, such as cardiovascular diseases [5-9], cancers [10-11], traffic accidents [12-13], and homicide [14]. Some studies focus on variations of child mortality [15-17] as measures of development.

In Thailand, several studies have investigated regional variations of both all-cause and cause-specific mortality. Faramnuayphol et al [18] presented age-specific mortality rates and cause-specific and all-cause standardized mortality ratios at the district level. They found clustering of cause-specific SMR in a single region for liver cancer (in the upper northeast region) and chronic obstructive pulmonary disease (in the upper north region). A study by Lotrakul [19] during the 1998–2003 period found that the suicide mortality rates were highest in the northern region, followed by the central, south, and north-east regions.

Because the number of deaths is a non-negative integer valued random variable, Poisson regression models have been used to analyse mortality data [20-23]. Brouhns et al [24] analyzed Belgian mortality data using a generalized linear model, substituting the Poisson random variation for the number of deaths by an additive error term on the logarithm of mortality rates. Delwarde et al [25] used a Poisson log-bilinear projection model for mortality data in the G5 countries (France, Germany, Japan, UK and US).

In this study, we have developed a statistical method for comparing mortality rates across geographical regions. The method involves first fitting a statistical model based on the Poisson distribution in which age group and region are incorporated as factors. The estimated mortality rates and their 95% confidence intervals were then used to produce thematic maps, so that valid statistical conclusions could be made. Our illustrations begin with all-cause mortality in Bangkok, and then we extend the method to the whole of Thailand.

Data and Methodology

Gender-age-specific mortality for 926 districts over Thailand in years 1999-2001 were obtained from the vital registration database. This database is provided by the Bureau of Registration Administration, Ministry of the Interior and coded as cause-of-death using the tenth International Classification of Diseases (ICD-10) by the Bureau of Policy and Strategy, Ministry of Public Health.

The population denominators for gender, age group and district for Thailand was taken from the 2000 population and housing census conducted by the National Statistical Office [26].

Since populations of districts in Thailand vary substantially, with the total resident populations in 2000 ranging from a minimum of 2,088 (in King-Ko-Kut in Trat province) to a maximum of 451,447 (in Samut-Prakan City), we also analyzed the mortality incidence rates in aggregated districts called "superdistricts", defined as regions comprising contiguous districts in the same province with a total population of at least 200,000 if possible. We thus obtained 235 superdistricts, with numbers varying from just one superdistrict in 14 provinces (Angthong, Singburi, Chainat, Nakhon-Nayok, Trat, Samut-Songkam, Amnat-Charoen, Mukdahan, Uthai-Thani, Phangnga, Phuket, Ranong, Krabi and Satun) to 24 in Bangkok province.

Poisson model

The number of deaths D_{ij} per 100,000 population E_{ij} in district i and age group j, may be modeled using the Poisson generalized linear model [27]. For an additive model, this distribution has mean

$$\lambda_{ij} = E_{ij} \exp(\alpha_i + \beta_j) \ , \tag{1}$$

where α_i are district specific parameters, and β_j are age-group parameters, one of which is redundant.

The contrast matrix used in the model was "sum contrasts" so that each parameter estimate has a standard error enabling comparison with the mean [27-28].

A thematic map was produced based on the model results. Gender-specific death rates were used for comparison of mortality between geographical areas. The mortality rates from all such areas in the sample were then classified into three groups, according to whether the confidence interval was (a) totally above the mean, (b) crossing the mean, or (c) totally below the mean. A thematic map was used to display this information using corresponding colours, (a) red (darkest shade), (b) orange (intermediate shade), and (c) blue (lightest shade). Statistically valid conclusions can be made using this map, that is, the mortality in each red-coloured district is greater than the average mortality, and the mortality in each blue-coloured district is less than the average mortality.

All statistical modeling and graphical displays used R commands [29].

Results

The different age- and gender-specific mortality rates for Bangkok and the four regions of Thailand during 1999-2001 are shown in Table 1. The average observed mortality rates were higher in males than females in all age groups.

Figure 1 shows results of fitting model (1) to all-cause mortality for males and females aged 0 to 84 in Bangkok province. It is clear from the district-adjusted mortality rates for age-groups (as shown in the left panel of Figure 1) that age group 80-84 had highest mortality. The residuals plots in the middle panel of Figure 1 indicate that the models fitted reasonably well apart from 4 outliers for males and 7 outliers for females. The high outliers in both males and females occurred in the babies aged less than 1 year in PathumWan, RatThewi, Kannayao and KhlongSan district. The fitted and observed numbers of deaths are also plotted in the right panel of Figure 1.

Table 1: Mortality rates (per 100,000 populations) by gender, age and region, Thailand, 1999-2001

Gender	Age	Region					National
		Bangkok	Central	Northeastern	Northern	Southern	
Males	0	1002	717	613	605	745	683
	1-4	86	167	114	153	141	134
	5-9	42	70	71	91	65	72
	10-14	40	57	45	56	54	51
	15-19	105	181	174	191	163	170
	20-24	150	270	313	386	265	285
	25-29	250	552	533	846	477	544
	30-34	370	680	592	1010	529	653
	35-39	457	640	506	810	470	590
	40-44	506	623	513	736	445	578
	45-49	614	728	643	813	512	681
	50-54	773	924	908	992	669	887
	55-59	1150	1166	1216	1245	940	1171
	60-64	1725	1724	1767	1767	1398	1705
	65-69	2814	2554	2480	2600	2139	2508
	70-74	3672	3627	3727	3932	3208	3674
	75-79	5985	5900	5502	6268	5332	5788
	80-84	8878	9081	8593	9577	8009	8867
Male aged 0-84		533	697	609	852	547	659
Females	0	942	603	488	532	598	571
	1-4	74	144	95	151	120	118
	5-9	33	52	48	73	45	52
	10-14	20	38	32	41	37	35
	15-19	32	62	57	76	54	58
	20-24	47	116	130	223	96	124
	25-29	77	190	215	464	148	220
	30-34	98	197	201	373	161	213
	35-39	121	204	196	305	162	207
	40-44	175	250	239	317	178	244
	45-49	258	354	351	418	254	344
	50-54	375	485	538	576	355	495
	55-59	604	687	778	804	480	711
	60-64	945	1029	1193	1212	749	1078
	65-69	1588	1590	1818	1958	1287	1710
	70-74	2379	2479	2780	2969	2034	2612
	75-79	4472	4371	4414	4937	3617	4419
	80-84	6794	7423	7510	8300	6084	7375
Female aged 0-84		303	424	410	565	316	419
Person aged 0-84		412	558	509	707	431	537

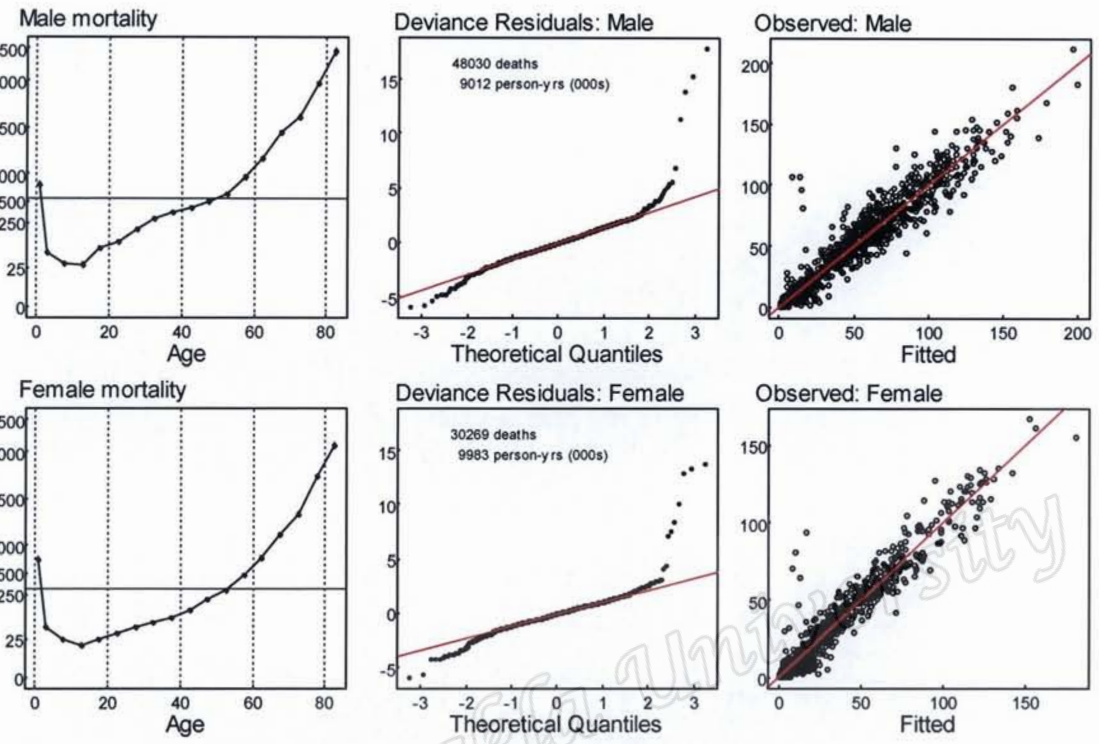
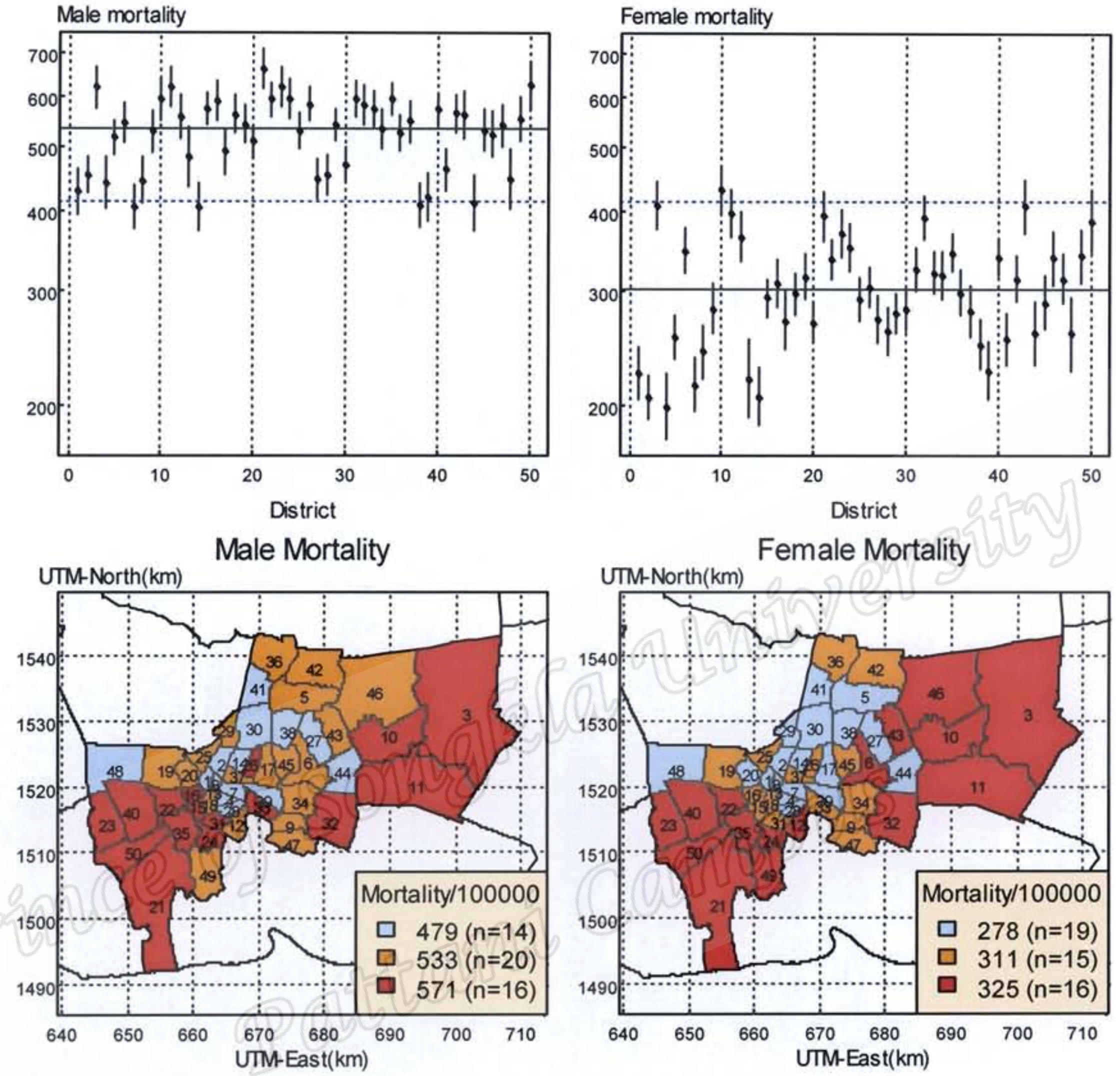


Figure 1: Model results of all-cause mortality for males and females aged 0-84 years in Bangkok, 1999-2001

The age-adjusted male and female mortality rates and their 95% confidence intervals for each district are shown in the top panel of Figure 2, where the horizontal solid lines denote the average mortality rates (533 per 100,000 for males and 303 per 100,000 for females). The horizontal dotted lines correspond to the overall morality rates for males and females combined (412 per 100,000). The maps of 50 districts in Bangkok for male and female mortality (lower panel of Figure 2) show how the confidence intervals classify the districts, that is, if the confidence interval is entirely above the gender-specific mean then the district is coloured red (dark shade), if the confidence interval crosses the gender-specific mean, the district is coloured orange (medium shade), and if the confidence interval is entirely below the mean, the district coloured blue (light shade). There were eleven districts (NongChok, Minburi, LatKrabang, Prawet, Ratburana, ChomThong, PhasiCharoen, BangKhae, Nongkheam, BangBon and Bangkhuntien) in Bangkok where mortality rates were significantly higher than the average for both males and females.

Figure 3 shows the same results as Figure 2 using superdistricts instead of districts, after the 50 districts in Bangkok were reduced to 24 superdistricts.

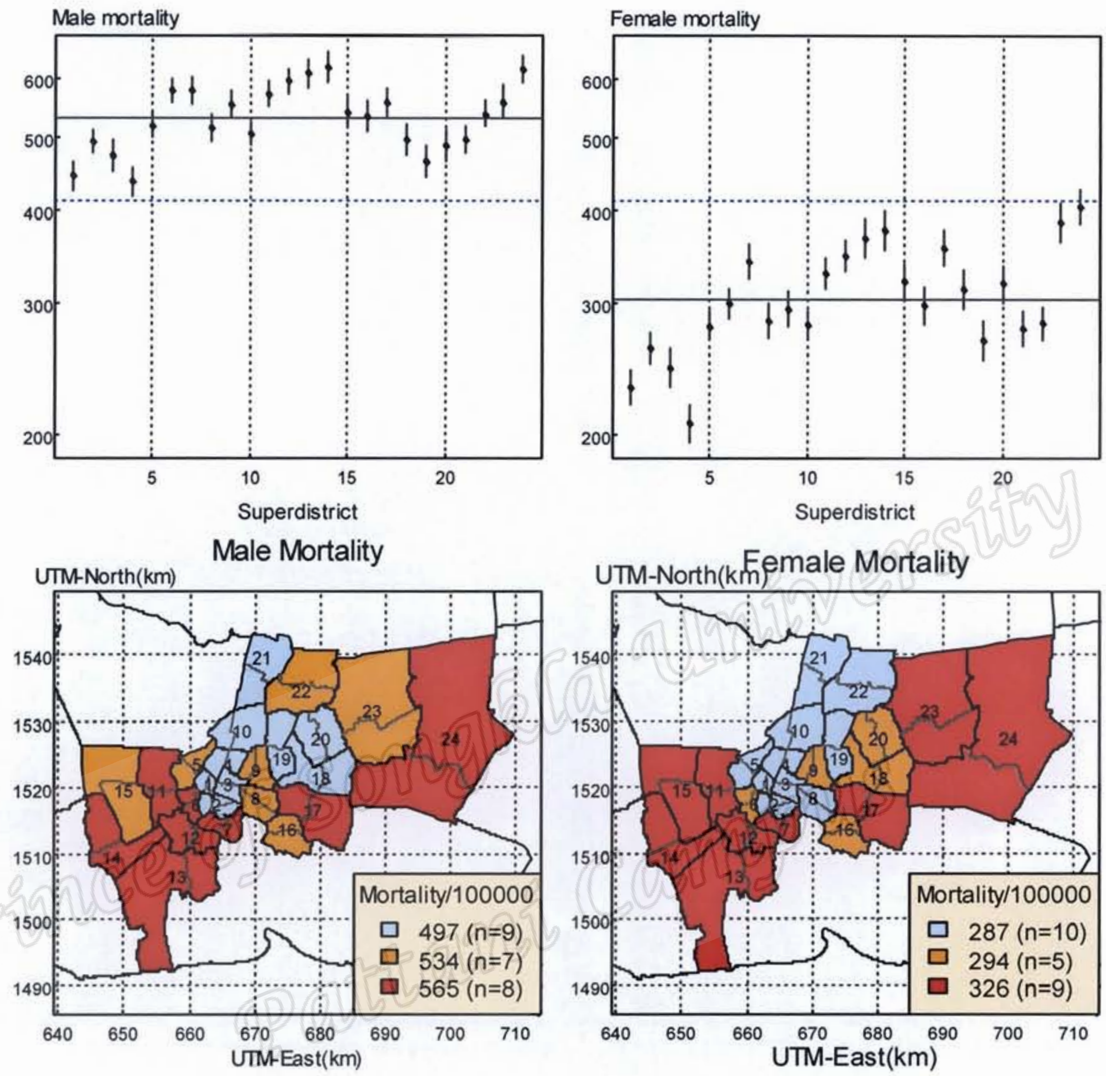
The 95% confidence intervals of age-adjusted mortality rates for the 24 superdistricts, as shown in the upper panel of Figure 3) are smaller than those in Figure 2. Maps in the lower panel of Figure 3 indicate that there were seven superdistricts located in the eastern and southwestern Bangkok having higher mortality than the gender-specific mean for both males and females.



Districts in Bangkok

1 PhraNakhon	11 LatKrabang	21 Bangkhuntien	31 BangKhoLaem	41 LakSi
2 Dusit	12 Yannawa	22 PhasiCharoen	32 Prawet	42 Saimai
3 NongChok	13 Samphanthawong	23 Nongkheam	33 KhlongToei	43 Kannayao
4 BangRak	14 PhayaThai	24 Ratburana	34 SuanLuang	44 Saphansung
5 BangKhen	15 ThonBuri	25 BangPlad	35 ChomThong	45 WangThonglang
6 BangKapi	16 BangkokYai	26 DinDaeng	36 DonMuang	46 KhlongSamWa
7 PathumWan	17 HuaiKhwang	27 BungKum	37 RatThewi	47 BangNa
8 PomPrapSattruPhai	18 KhlongSan	28 Sathorn	38 LatPhrao	48 ThawiWattana
9 Prakanong	19 TalingChan	29 Bangsue	39 Wattana	49 Thungkru
10 Minburi	20 BangkokNoi	30 Chatuchak	40 BangKhae	50 BangBon

Figure 2: All-cause mortality for males and females aged less than 85 in Bangkok, Thailand 1999-2001



Superdistricts in Bangkok

1 PhraNakhon, PomPrapSattruPhai, Samphanthawong
2 BangRak, KhlongSan, Sathorn
3 PathumWan, RatThewi
4 Dusit, PhayaThai
5 BangkokNoi, BangPlad
6 ThonBuri, BangkokYai
7 Yannawa, BangKhoLaem
8 KhlongToei, Wattana
9 HuaiKhwang, DinDaeng
10 Bangsue, Chatuchak
11 TalingChan, PhasiCharoen
12 Ratburana, ChomThong
13 Bangkhuntien, Thungkru
14 Nongkheam, BangBon
15 ThawiWattana, BangKhae
16 Prakanong, BangNa
17 Prawet, SuanLuang
18 BangKapi, Saphansung
19 LatPhrao, WangThonglang
20 BungKum, Kannayao
21 DonMuang, LakSi
22 BangKhen, Saimai
23 Minburi, KhlongSamWa
24 NongChok, LatKrabang

Figure 3: All-cause mortality for males and females aged less than 85 across 24 superdistricts in Bangkok, Thailand 1999-2001

Figure 4 shows the district-adjusted mortality rates, residuals plots and plots of observed and fitted deaths after fitting the Poisson model to all-cause mortality for the whole of Thaialnd, with 926 districts reduced to 235 superdistricts. The highest residuals for both males and females occurred in babies aged less than 1 year in the superdistrict in Bangkok containing Pathum-Wan and Rat-Thewi districts.

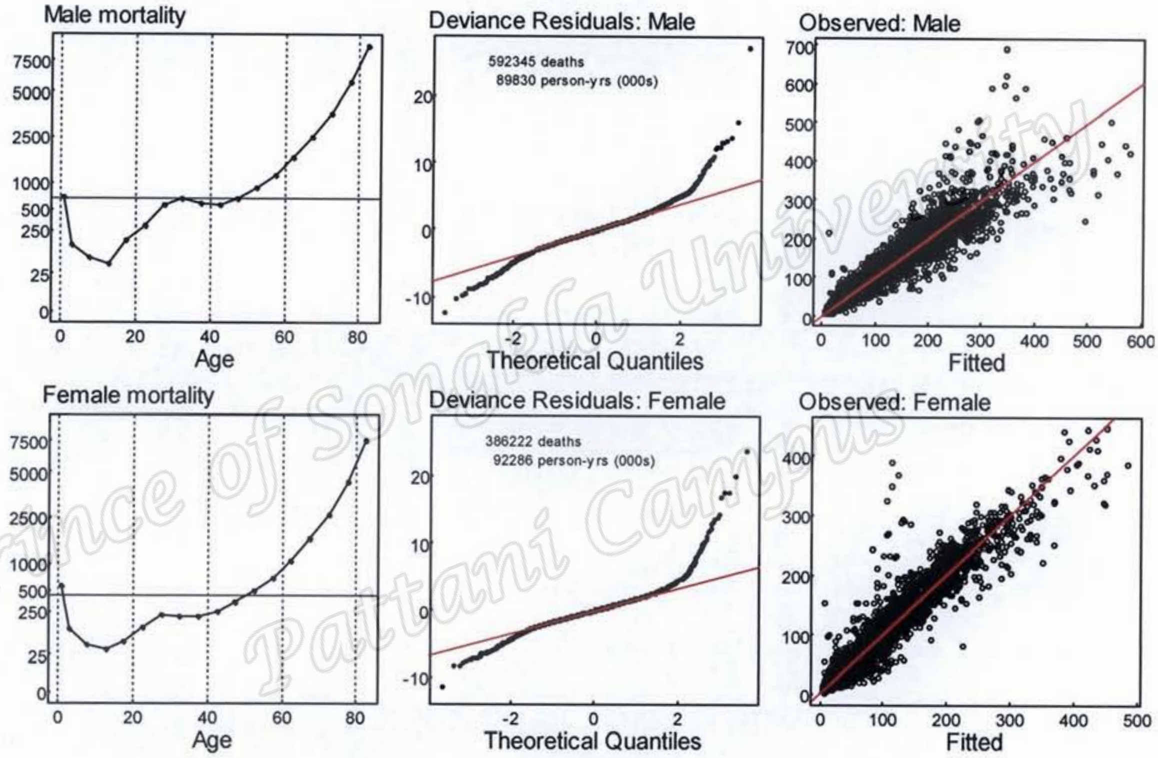


Figure 4: Model results of all-cause mortality for males and females aged less than 85 across 235 superdistricts in Thailand, 1999-2001

The 95% confidence intervals of age-adjusted mortality rates in the 235 superdistricts were compared with the averages (659 per 100,000 for males and 418 per 100,000 for females) to produce the thematic maps in Figure 5. Most superdistricts in the northern region and some superdistricts in the upper part of the northeastern region had higher mortality than the average for both males and females. The superdistricts in Southern Thailand have lower than average mortality except for Phuket and Narathiwat. All superdistricts in Bangkok have lower mortality than the average except for females in the superdistrict containing Nong-Chok and Lat-Krabang districts.

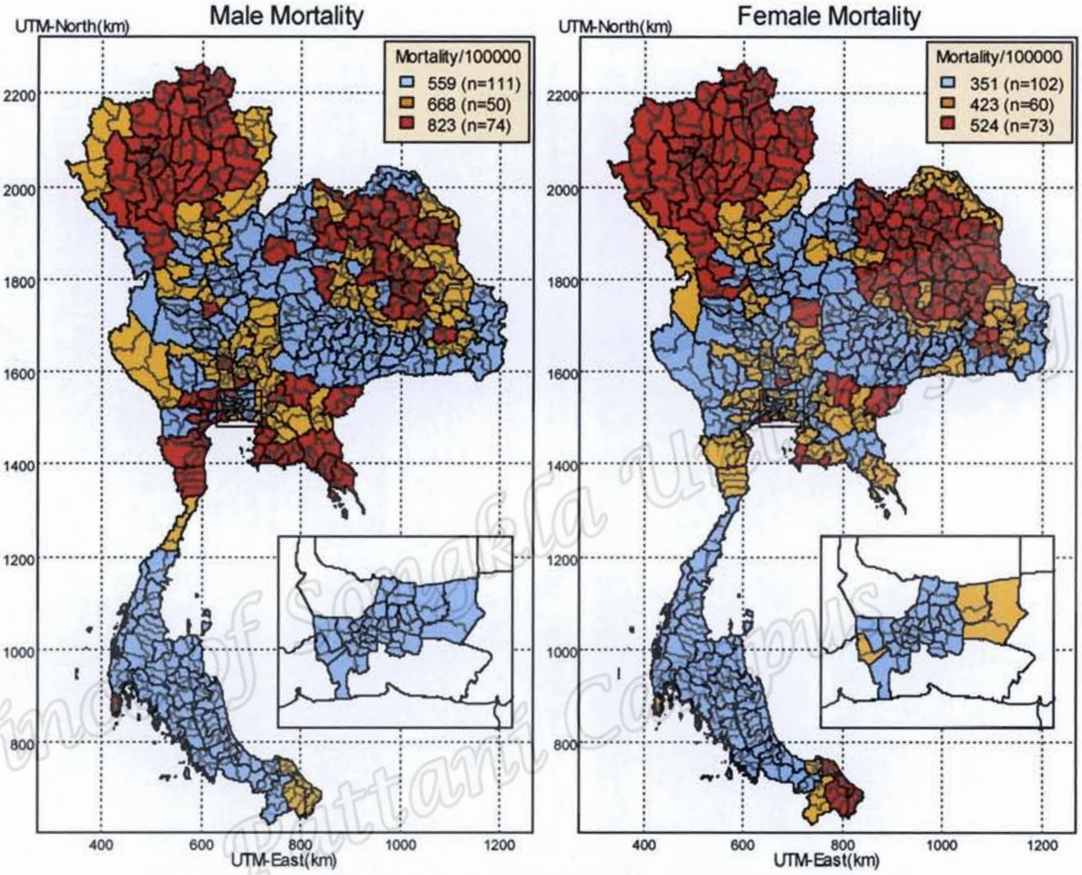


Figure 5: All-cause mortality rates for males and females aged less than 85 in Thailand, 1999-2001

The highest mortality rate for males occurred in the superdistrict in Chiang Rai containing Phan, MaeSa-ruai and WiangPaPao districts, and the superdistrict in Chiang Rai containing WiangChai, Thoeng, PaDaet, PhayaMengrai and KhunTan district had highest mortality rate among females in Thailand. The top ten superdistricts with highest age-adjusted mortality rates for males and females are shown in Table 3 *(individual rankings of superdistricts available from the author)*.

Table 3: Top 10 superdistricts with highest age-adjusted mortality rates in males and females, Thailand 1999-2001

Rank	Males Superdistrict	Males Mortality per 100,000 (95% CI)	Females Mortality per 100,000 (95% CI)	Females Superdistrict
1	5703 Phan, MaeSa-ruai, WiangPaPao (Chiang Rai)	1127 (1096,1159)	844 (813,876)	5702 WiangChai, Thoeng, PaDaet, PhayaMengrai, KhunTan (Chiang Rai)
2	5601 MuangPhayao, DokKhamTai, MaeChai, PhuKamYao (Phayao)	1106 (1076,1137)	836 (804,869)	5003 Fang, MaeAi, ChaiPrakarn (Chiang Mai)
3	5003 Fang, MaeAi, ChaiPrakarn (Chiang Mai)	1095 (1061,1131)	807 (778,838)	5602 Chun, ChiangKham, ChiangMuan, Pong, PhuSang (Phayao)
4	5602 Chun, ChiangKham, ChiangMuan, Pong, PhuSang (Phayao)	1089 (1056,1123)	799 (773,827)	5703 Phan, MaeSa-ruai, WiangPaPao (Chiang Rai)
5	5702 WiangChai, Thoeng, PaDaet, PhayaMengrai, KhunTan (Chiang Rai)	1083 (1049,1117)	759 (730,790)	5004 ChiangDao, MaeTaeng, Phrao, WiangHaeng (Chiang Mai)
6	5006 MaeRim, Samoeng, SanSai (Chiang Mai)	1081 (1045,1118)	753 (724,783)	5701 MuangChiangRai, MaeLao (Chiang Rai)
7	5401 MuangPhrae, RongKwang, Song, NongMuangKhai (Phrae)	1075 (1045,1107)	744 (719,770)	5601 MuangPhayao, DokKhamTai, MaeChai, PhuKamYao (Phayao)
8	5701 MuangChiangRai, MaeLao (Chiang Rai)	1070 (1037,1105)	744 (711,778)	5705 ChiangKhong, ChiangSaen, WiengKaen, WiengChiangRung, DoiLuang (Chiang Rai)
9	5007 SanPaTong, HangDong, MaeWang, DoiLo (Chiang Mai)	1066 (1034,1100)	710 (685,736)	5005 DoiSaket, SanKamphaeng, Saraphi, MaeOn (Chiang Mai)
10	5004 ChiangDao, MaeTaeng, Phrao, WiangHaeng (Chiang Mai)	1050 (1017,1084)	710 (680,741)	5006 MaeRim, Samoeng, SanSai (Chiang Mai)

Conclusion and Discussion

The Poisson model incorporating additive factors for age-group and district generally provides a good fit to mortality data in Thailand. This study illustrates the applications of the Poisson GLM to all-cause mortality rates in Bangkok in the district and superdistrict levels. Superdistricts are more effective regional divisions than districts because they provide cells with approximately equal populations, and thus equalize the standard errors of estimated effects, as shown in the upper panels of Figure 2 and

3. Using 235 superdistricts instead of 926 districts decreases the standard errors by nearly a factor of 2. Finally, the 926 districts for the whole of Thailand are difficult to distinguish, whereas 235 superdistricts provide a clearer schematic map.

The statistical model used in this study can be applied to analyse cause-specific mortality. However, a more appropriate model for comparing cause-specific mortality across a region is based on the proportions of cause-specific deaths to all-cause deaths, and the methods used in this study can be extended straightforwardly to this situation by using logistic instead of Poisson regression.

Our finding on the high morality rates in the northern region may be due to chronic obstructive pulmonary disease, similar to the clustering pattern found in the study by Faramnuayphol et al. (2008). They study also found the clustering pattern of liver cancer mortality in the upper northeast that may explain our finding of high mortality in this region.

In this paper we have developed a statistical method for comparing mortality rates across geographical regions. The method involves first fitting a statistical model based on the Poisson distribution in which age group and region are incorporated as factors. This model gives age-adjusted mortality rates for each geographical division, and corresponds to the method of computing standardized mortality rates (SMRs) commonly used in demographic research. Its advantage over the SMR-based method is that it routinely provides standard errors for the adjusted incidence rates, and thus facilitates comparison of both regions and age groups.

The model can also be used to produce colour-coded thematic maps containing just three colours. These are obtained when the model is fitted using sum contrasts, thus giving confidence intervals for comparing the incidence rate in each region with the gender-specific mean incidence rate, and then classifying these regions according to whether their confidence intervals are above, across, or below the mean.

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3.2.3 Geographical variation of ill-defined mortality in Thailand, 1999-2001

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District-level Variations in Quality of Mortality Data in Thailand

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Abstract

Poor quality in cause-of-death diagnosis is of concern in developing countries. Thailand has 95% coverage of death registration, but 75% of annual deaths occur outside the health care setting, and 47% of these deaths are attributed to ill-defined or unknown causes. Improving national mortality statistics requires small-area estimates of quality. In this study, we investigate geographic variations in the proportions of ill-defined and unknown cause mortality in order to examine the cause-of-death data quality across administrative districts in Thailand. Vital registration data from 1999-2001 were used in a logistic regression model to create maps comparing the ill-defined mortality levels by geographical locations. Small-area differences in quality can help direct health policy makers and planners to target their efforts to improve the quality of cause of death diagnosis.

Key words: mortality, ill-defined cause-of-death, death certificates

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Introduction

Different studies on variations of cause-specific mortality provide different policy implications and suggestions. Some findings mirror existing health care and services. Costantini et al (2000) concluded that differences in proportions dying at home for cancer patients across 13 provinces in Italy could not be explained by the known determinants, suggesting inappropriate hospital admission in the terminal phase of cancer. A study on geographical variations in breast cancer mortality in older American women by Goodwin et al (2002) suggested how the quality of breast cancer care could be improved. Some studies suggest further research in specific areas. Vacchino (1999) constructed maps of cancer mortality that found associations of lung cancer with smoking and behaviour in women living in southern Argentinean provinces. An analysis of death rates from Parkinson's disease in Japan during 1977-1985 by Imaizumi (1995) concluded that the age-adjusted death rates from this disease were higher in the south-west than in the north-east, indicating probable environmental risk factors.

In Thailand, a study by Lotrakul (2006) of suicide death rates during 1998-2003 found high incidence in the upper northern region where HIV infection was high, and another study of district variation in cause-specific mortality by Faramnuayphol et al (2008) found a clustering of liver cancer deaths in the upper Northeast and chronic obstructive pulmonary disease in the upper North.

However, Mathers et al (2005) recently classified the death registration system in Thailand as of low quality, with 49% of total registered deaths assigned as ill-defined. Tangcharoensathien et al (2006) also evaluated the national death registration system in Thailand and identified two major problems contributing to both under-reporting of death registration and inaccuracy of cause-of-death attribution: problems in recording events or certifying deaths, and problems in transferring information from death certificates to death registers. Although Thailand has verbal autopsy studies (Choprapawan et al, 2001; Choprapawan, 2005) as an assessment tool for cause-of-death validation, a problem is lack of regular quality control (only undertaken every 5 years). During the period 1999-2001, about 40% of total registered deaths in Thailand were assigned as ill-defined and unknown cause mortality.

Thailand introduced the national vital registration system in 1917 under the Ministry of Interior. By law, the death certificate must be issued by the district registrar within 24 hours after occurrence. A medical death certificate is issued by health personnel (physician, nurse or medical coder) for a death occurring in a health institution, while a death notification report is issued by a local registrar (village head or health center personnel) for a death occurring outside a health institution (Rukumnuaykit, 2006). The quality of data on cause of death in the Vital Registration System depends on the attendant at death and the methodology used to identify actual causes of deaths (Rukumnuaykit, 2006). Many deaths are coded by either non-medically trained staff or by health personnel who had little contact with the deceased.

The death registration system partially relies on second hand reports from non-medical persons, unlike other countries that rely primarily on medical or professionally trained coroners. As a consequence, some regions of Thailand rely more on non-medical and non-professional personnel and this may lower the quality of cause of death data at the national level.

In this study, we used a statistical method to estimate where low quality mortality data occur in Thailand. Thai mortality data from 1999 to 2001 were used to model the proportion of ill-defined causes that occurred outside hospital over the 926 districts of Thailand.

Data and Method

Gender-age-cause specific mortality for 926 districts over Thailand in years 1999-2001 were obtained from the vital registration database. This database is provided by the Ministry of the Interior and coded as cause-of-death using ICD-10 by the Bureau of Policy and Strategy, Ministry of Public Health (Ministry of Public Health, 2001).

Ill-defined causes are defined as deaths coded in the International Classification of Diseases, tenth revision (ICD10) by the WHO (1992) as R00-R99 "symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified" when there is unavailable information on cause of death. The proportion of ill-defined deaths is one of the indicators of (poor) quality in a national death registration system (Mathers et al, 2005).

Since populations of districts in Thailand vary substantially, with the total resident populations in 2000 ranging from a minimum of 2,088 (in King-Ko-Kut in Trat province) to a maximum of 451,447 (in Samut-Prakan City), we analyzed the mortality incidence rates in aggregated districts called "superdistricts", defined as regions comprising contiguous districts in the same province with a total population of at least 200,000 (Lim and Choonpradub, 2007). We thus obtained 235 superdistricts, which varied in distribution from just one superdistrict in 14 provinces (Angthong, Singburi, Chainat, Nakhon-Nayok, Trat, Samut-Songkam, Amnat-

Charoen, Mukdahan, Uthai-Thani, Phangnga, Phuket, Ranong, Krabi and Satun) to 24 in Bangkok province.

The adjusted proportions of ill-defined and unknown cause mortality by age group and superdistrict were estimated using a logistic regression model. The probability p_{ij} that a reported death for age group i and superdistrict j is ill-defined is thus modeled as

$$\ln\left(\frac{p_{ij}}{1-p_{ij}}\right) = \mu + \alpha_i + \beta_j \tag{1}$$

where μ is a constant and α_i and β_j are parameters associated with individual age groups and superdistrict, respectively, that sum to 0. These coefficients were estimated from the data and the adequacy of the model was assessed using statistical methods described in Venables and Ripley (2002).

To compare differences in ill-defined and unknown cause mortality across the region of interest, illustrations by graphical method were used. Superdistricts were classified into three groups, according to whether the confidence interval for the proportion was (a) totally above the mean, (b) crossing the mean, or (c) totally below the mean. A thematic map was used to display this information using corresponding colours, (a) red, (b) orange, and (c) blue. Statistically valid conclusions can be made using this map, that is, the mortality in each red-coloured superdistrict is greater than the average mortality, and the mortality in each blue-coloured superdistrict is less than the average mortality.

Statistical modeling and graphical displays used R commands (R Development Core Team, 2008).

Results

During the years 1999-2001, approximately 75% of deaths among the Thai population aged less than 85 years occurred outside hospital each year. About 42% of the total deaths were certified as of ill-defined and unknown cause. Table 1 shows the mortality rates per 100,000 and percentages of ill-defined or unknown cause mortality for Bangkok and the four regions of Thailand. Residents in the Northern region, both males and females, had higher mortality than these living in other regions. Central and Northern regions had lower than average proportions of ill-defined outside hospital deaths.

Figure 1 shows the results after applying model (1) to the proportions of ill-defined/unknown outside hospital mortality in Bangkok by age group and superdistrict for males and females separately. It is clear from the graphs in the left panels of Figure 1 that there were high proportions of ill-defined mortality for persons aged 60 years and over (proportion of ill-defined mortality higher than average in men aged 60 years and over and in women aged 65+ years). The residuals plots on the middle panels of Figure 1 indicate that the model fitted well. The observed and fitted proportions of ill-defined deaths are also plotted in the right panels of Figure 1.

Table 1: Mortality rates and proportions of ill-defined cause mortality for males and females aged less than 85 years in Thailand, 1999-2001

Place/Region	Males		Females		Both sexes	
	*All causes	Ill-defined (%)	*All causes	Ill-defined (%)	*All causes	Ill-defined (%)
Outside hospital						
Bangkok	233	39.8	130	51.5	181	44.1
Central	462	34.8	288	47.9	375	39.9
Northeastern	484	37.6	339	50.1	412	42.7
Northern	657	35.1	450	46.1	553	39.6
Southern	414	41.4	243	53.2	329	45.8
National	**475**	**36.9**	**312**	**48.9**	**393**	**41.7**
In-hospital						
Bangkok	244	21.0	162	22.0	202	21.4
Central	216	18.3	138	19.6	177	18.8
Northeastern	109	19.1	66	20.0	88	19.5
Northern	180	14.5	118	16.2	149	15.2
Southern	115	15.0	67	16.9	91	15.7
National	**162**	**17.8**	**103**	**19.1**	**133**	**18.4**
All places						
Bangkok	477	30.2	292	35.2	383	32.1
Central	678	29.6	426	38.7	552	33.1
Northeastern	593	34.2	405	45.2	499	38.6
Northern	837	30.7	568	39.9	703	34.4
Southern	529	35.7	310	45.4	420	39.3
National	**637**	**32.0**	**415**	**41.6**	**526**	**35.8**

**deaths per 100,000 population*

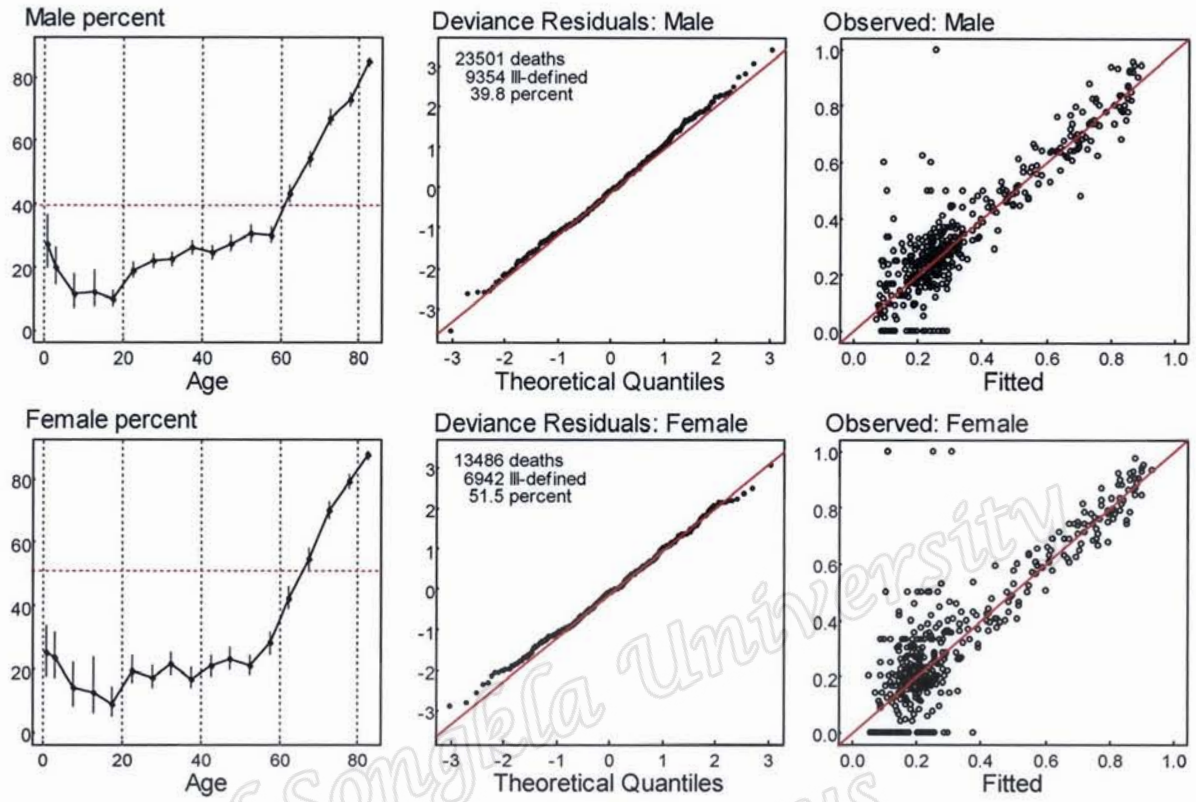
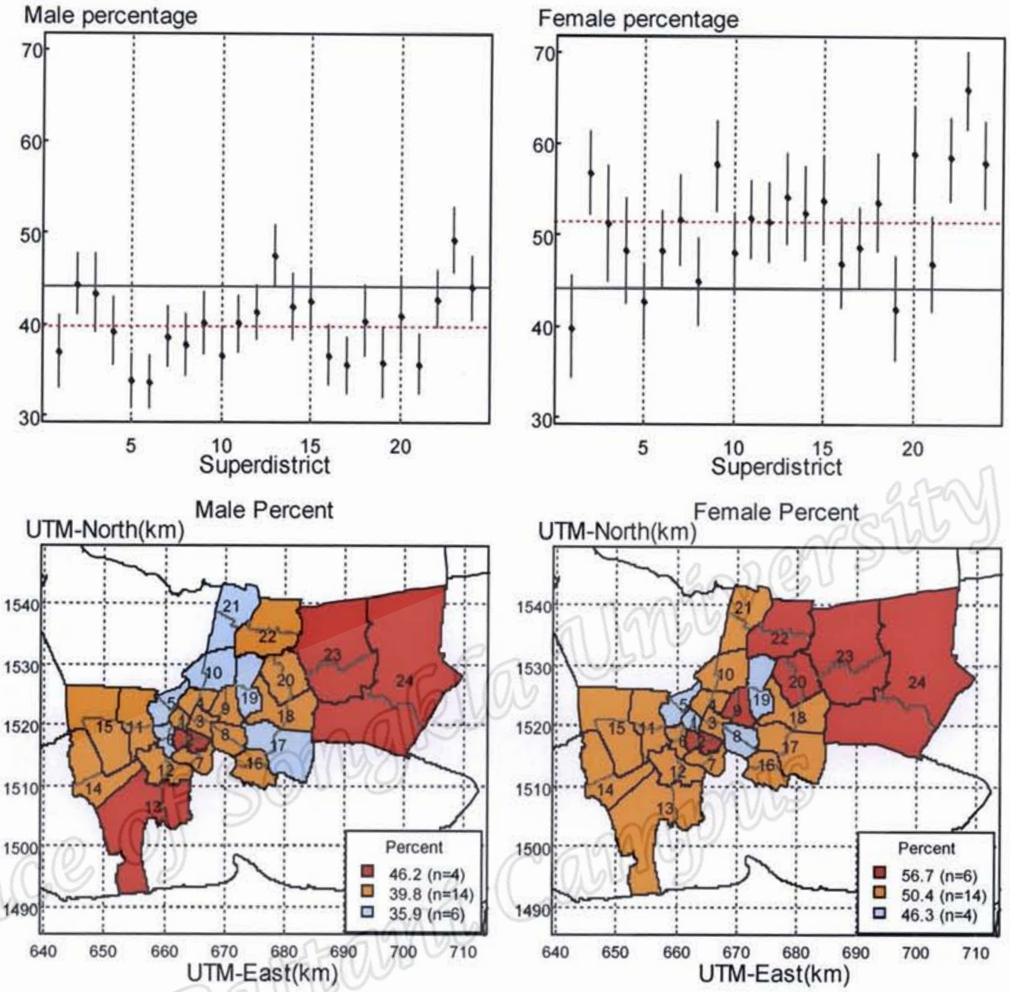


Figure 1: Proportions of ill-defined and unknown cause outside hospital mortality among males and females aged less than 85 in Bangkok, 1999-2001

The adjusted proportions of ill-defined mortality and their confidence intervals for each superdistrict are shown in the top panel of Figure 2, where the horizontal dotted lines denote the average proportions: 39.8% for males and 51.5% for females. The solid horizontal lines correspond to the overall proportion of ill-defined mortality for males and females combined (44.1%). The maps in the lower panel of Figure 2 indicate that there were four superdistricts in Bangkok with higher than average proportions of male mortality. For female mortality, six superdistricts had higher than average proportion.



Superdistricts in Bangkok

1 PhraNakhon, PomPrapSattruPhai, Samphanthawong
2 BangRak, KhlongSan, Sathorn
3 PathumWan, RatThewi
4 Dusit, PhayaThai
5 BangkokNoi, BangPlad
6 ThonBuri, BangkokYai
7 Yannawa, BangKhoLaem
8 KhlongToei, Wattana
9 HuaiKhwang, DinDaeng
10 Bangsue, Chatuchak
11 TalingChan, PhasiCharoen
12 Ratburana, ChomThong
13 Bangkhuntien, Thungkru
14 Nongkheam, BangBon
15 ThawiWattana, BangKhae
16 Prakanong, BangNa
17 Prawet, SuanLuang
18 BangKapi, Saphansung
19 LatPhrao, WangThonglang
20 BungKum, Kannayao
21 DonMuang, LakSi
22 BangKhen, Saimai
23 Minburi, KhlongSamWa
24 NongChok, LatKrabang

Figure 2: Age-adjusted proportions of ill-defined outside hospital mortality for males and females aged less than 85 in Bangkok, 1999-2001

Figure 3 shows the results for applying model (1) to ill-defined outside hospital mortality in the whole of Thailand. The graphs in the left panels of Figure 3 indicate a high percentage for children aged less than 5 years, older males and females aged 60 years and over.

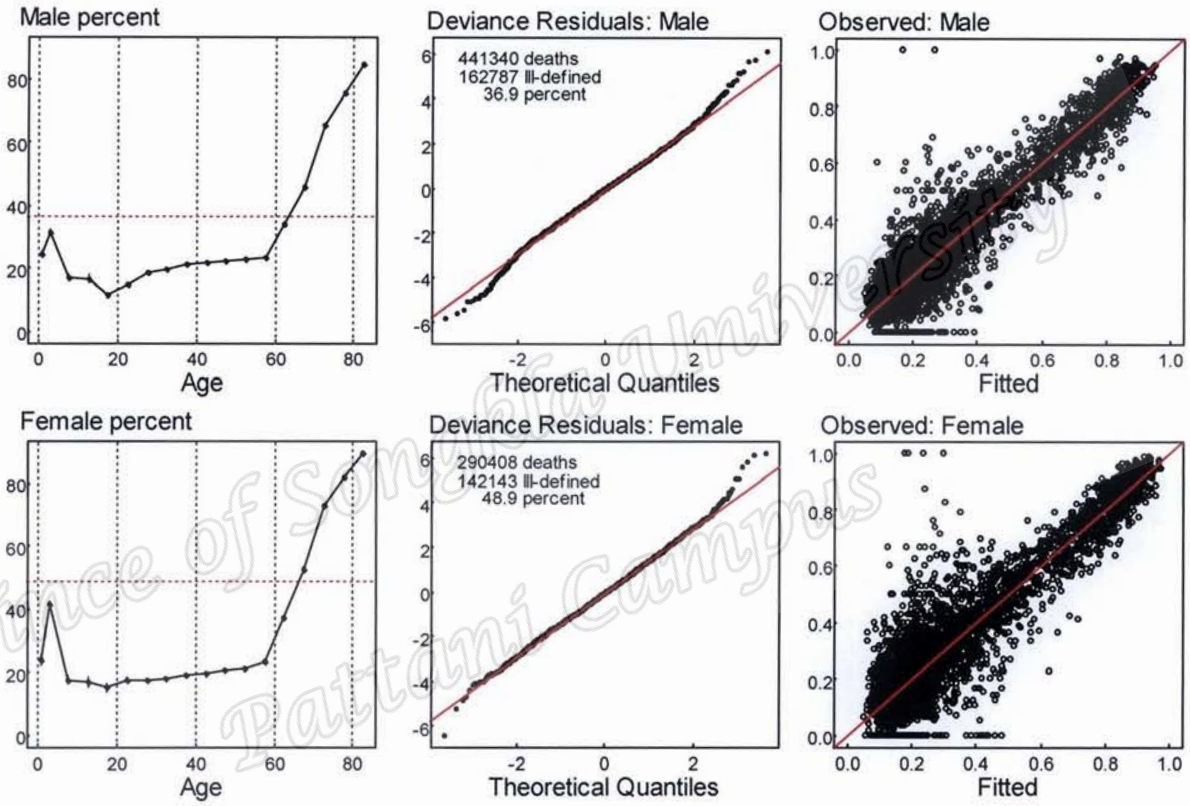


Figure 3: Model results for proportion of ill-defined and unknown cause outside hospital mortality for males and females aged 0-84 years, Thailand 1999-2001

The age-adjusted percentage of ill-defined mortality was then estimated from the model for males and females separately. The 95% confidence intervals of these percentages for the 235 superdistricts were compared with the average (36.9% for males and 48.9% for females) to produce the thematic map in Figure 4. For male mortality, 83 superdistricts with group mean 44.7% had higher than average percentages of ill-defined home deaths, while 82 superdistricts with 56.9% for the group mean had higher than average percentages of ill-defined home deaths among females.

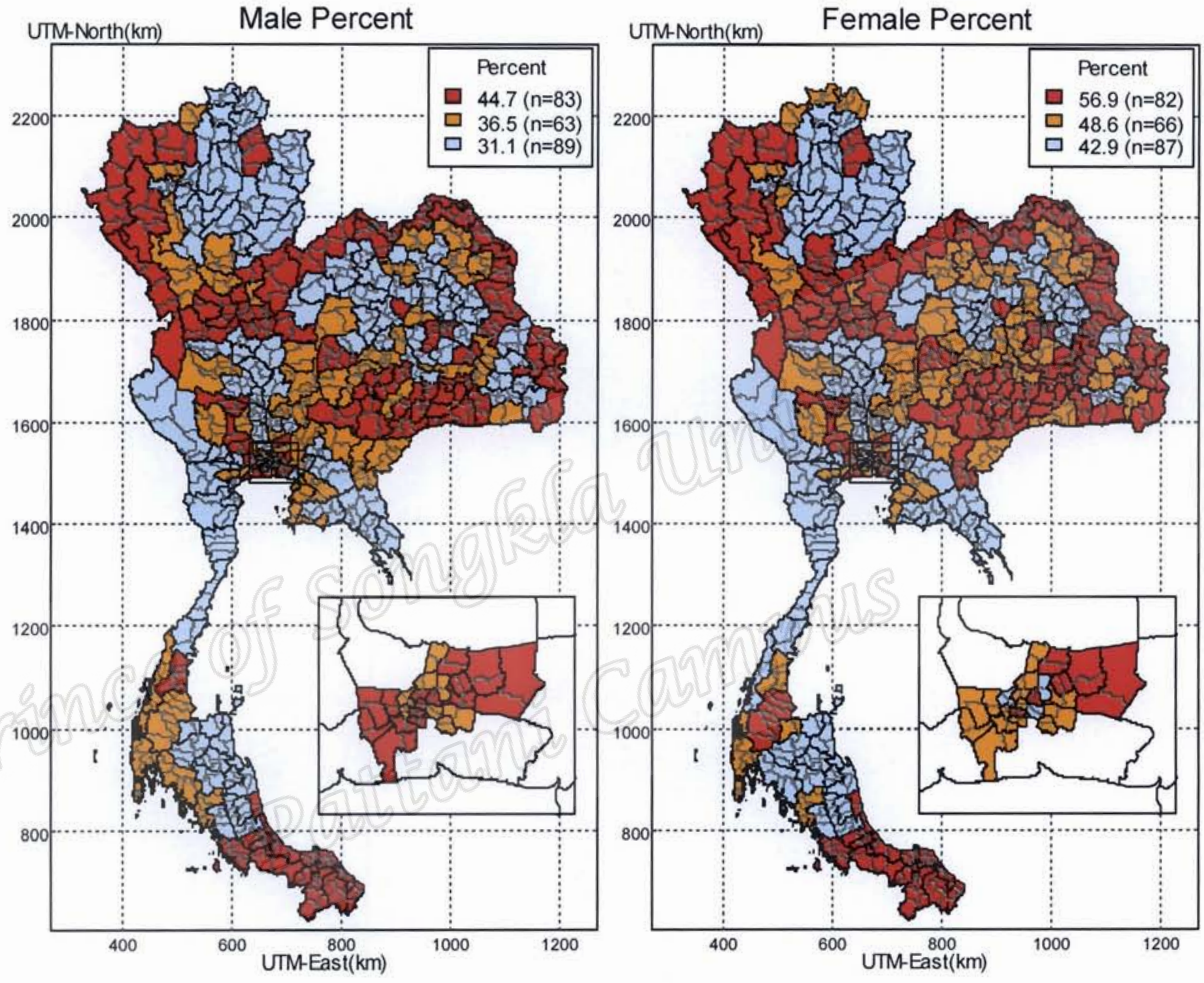


Figure 4: Proportion of ill-defined outside hospital mortality for males and females aged less than 85 in Thailand, 1999-2001

The highest proportion of ill-defined home deaths for males occurred in a superdistrict Ubon Ratchathani containing NaChaluai, NamYun and Buntharik districts. For females, a superdistrict in Pattani containing Panare, Mayo, ThungYangDaeng, SaiBuri, MaiKaen, Yaring and KaPho districts had the highest proportion. The five superdistricts with highest proportions of ill-defined home deaths for males and females are listed in Table 2.

Table 2: Top 5 superdistricts with highest percentages of ill-defined outside hospital mortality for males and females, Thailand 1999-2001.

Rank	Superdistrict (Province)	Percentage (95% CI)
Males		
1	NaChaluai, NamYun, Buntharik (Ubon Ratchathani)	66.8 (64.0,69.5)
2	Panare, Mayo, ThungYangDaeng, SaiBuri, MaiKaen, Yaring, KaPho(Pattani)	65.9 (63.6,68.1)
3	PlaPak, ThatPhanom, RenuNakhon, NaKae, WangYang(Nakhon Phanom)	65.0 (63.1,66.9)
4	MuangLoei, ChiangKhan, PakChom, DanSai, NaHaeo, PhuRua, ThaLi(Loei)	62.8 (60.7,64.8)
5	SiMuangMai, Khemarat, KutKhaoPun, PhoSai, NaTan(Ubon Ratchathani)	59.6 (57.1,62.1)
Females		
1	Panare, Mayo, ThungYangDaeng, SaiBuri, MaiKaen, Yaring, KaPho(Pattani)	79.1 (76.8,81.2)
2	NaChaluai, NamYun, Buntharik (Ubon Ratchathani)	78.7 (75.7,81.3)
3	PlaPak, ThatPhanom, RenuNakhon, NaKae, WangYang(Nakhon Phanom)	77.7 (75.8,79.5)
4	MuangLoei, ChiangKhan, PakChom, DanSai, NaHaeo, PhuRua, ThaLi(Loei)	76.6 (74.3,78.9)
5	MuangKamphaengPhet, KoSamPiNakhon (Kamphaeng Phet)	72.7 (69.9,75.3)

Conclusion and Discussion

Variation of ill-defined mortality across superdistricts in Thailand is reasonably fitted to the logistic regression model as results shown. A number of attributing factors which may relate to the variation were considered in terms of age, gender, and residence. The proportion death in old age in female population was higher than those in men and this seems to contribute to higher percentage of ill-defined cause of death among females as indicated in Table 1.

Senility (ICD10: R54) is the major cause of ill-defined cause of mortality category that account for 58% (50% for males and 66% for females) from the total ill-defined deaths. As deaths at older age were more than half of total deaths, and senility was a major cause of mortality in older age in the vital statistics, high proportions of ill-defined mortality in older age are observed on the left panels of Figure 3.

People in rural area tend to have less access to health institutions which affect their cause of death quality. The superdistricts with highest percentage of ill-defined outside hospital deaths as shown in Table 2 appear to have a high proportion of population living in rural areas, about 80%-100% (NSO, 2002). However, Bangkok which should have better cause diagnosis due to concentration of hospitals and physicians showed high proportion of ill-defined deaths. This may relate to complicate illness condition such as co-morbidity and conditions requiring advance investigation.

The results from our study show that the quality of cause-of-death data varies markedly across Thailand. While Choprapawan (2005) pointed out the need to focus on cause-of-death determination for hospital deaths, this present study analyzes the proportion of ill-defined and unknown cause deaths occurring outside hospital. About 75% of all deaths occurred outside hospitals, but since persons who are not medically trained may not accurately diagnose the cause of death, there is a need to focus on improving these diagnoses.

To do this, Tangcharoensathien et al (2006) recommended that a priority for strengthening mortality statistics is improving cause-of-death attribution by verifying cause-of-death using the verbal assessment algorithm and reviews of medical records by health personnel for home deaths, in collaboration with the district registrar. They suggested that the quality of cause of death data outside hospital could be improved by training more than 70,000 village heads in Thailand, but this could be very costly. Our modeling and mapping approach is a useful preliminary tool for enabling public health researchers to plan investigations in specific areas, possibly only in one-third of the 926 districts.

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