# GEOGRAPHICAL VARIATIONS IN ALL-CAUSE MORTALITY IN THAILAND

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**Abstract.** In this study, we examined age-specific death rates among men and women from various districts in Thailand using mortality data from 1999 to 2001. A Poisson generalized linear model was used for analysis. To adjust for large variations in resident populations among 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 for these data. The fitted mortality rates among the 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 colors signifying each superdistrict's mortality rate compared to the mean. Northeastern Thailand had higher than average mortality for both males and females. 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 Nong Chok and Lat Krabang Districts. This modeling and mapping approach is a useful preliminary tool enabling public health planners to determine statistically valid geographical variations in mortality and to develop effective interventions.

**Key words:** all-cause mortality, Poisson regression, Thailand

## INTRODUCTION

Some studies have investigated all-cause mortality for the whole population (Myklebost, 1981; Nerbrand *et al*, 1985; Lee and Yoon, 1991; Langford and Bentham, 1996), while some studies have focused on cause-specific mortality, such as cardiovascular diseases (Fulton *et al*, 1978; Starrin *et al*, 1988; Douglas *et al*, 1990; Andersen and Commons, 2002; Filate *et al*, 2003), cancers (Hoogendoorn, 1983; Chen *et al*, 2003), traffic accidents (Clark and Cushing, 1999), and homicide (Vega-Lopez *et al*, 2003). Some studies have focused on causes of childhood mortality (Pattnayak and Shai, 1995; Treurniet *et al*, 2000; Laskar and Harada, 2005).

In Thailand, several studies have investigated regional variations in all-cause and cause-specific mortality. Faramnuayphol *et al* (2008) studied age-specific, cause-specific and all-cause mortality ratios at the district level. They found clustering of cause-specific mortality rates (SMR) in a

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single region for liver cancer (northeastern Thailand) and chronic obstructive pulmonary disease (northern Thailand). A study by Lotrakul (2006) during 1998–2003 found suicide mortality rates were highest in northern, followed by central, southern, and northeastern Thailand.

Because the number of deaths is a non-negative integer valued random variable, the Poisson regression model has been used to analyse mortality data (Lovett *et al*, 1986; Frome *et al*, 1990; Marsh *et al*, 1992; Vacchino, 1999). Brouhns *et al* (2002) analyzed Belgian mortality data using a generalized linear model, substituting the Poisson random variation for the number of deaths using an additive error term for the logarithm of the mortality rate. Delwarde *et al* (2006) used a Poisson log-bilinear projection model for mortality data in G5 countries (France, Germany, Japan, UK and USA).

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 the age group and region are incorporated as factors. The estimated mortality rates and their 95% confidence intervals were used to produce thematic maps, so valid statistical conclusions can be made. Our illustrations begin with all-cause mortality in Bangkok, then we extended the method to all of Thailand.

## MATERIALS AND METHODS

Gender-age-specific mortality data for 926 districts throughout Thailand during 1999-2001 were obtained from the vital registration database. This database was 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 in Thailand were taken from the 2000 population and housing census conducted by the National Statistical Office (2002).

The district populations in Thailand vary substantially, ranging from 2,088 (in King Ko Kut, Trat Province) to 451,447 (Samut Prakan City). Therefore, we grouped contiguous districts into "superdistrict" with an approximate total population of 200,000 persons per "superdistrict". The districts were grouped into 235 superdistricts, with numbers ranging from one superdistrict covering 14 provinces (Ang Thong, Sing Buri, Chai Nat, Nakhon Nayok, Trat, Samut Songkham, Amnat Charoen, Mukdahan, Uthai Thani, Phang-Nga, Phuket, Ranong, Krabi and Satun) to 24 superdistricts in Bangkok Province.

### Poisson model

The number of deaths ($D_{ij}$) per 100,000 population ($E_{ij}$) per superdistrict ($i$) ($i$ = 1, 2, 3, ..., 235) by age group ($j$) ($j$ = <1, 1-4, 5-9, ..., 80-84 years), were modeled using the Poisson generalized linear model (Venables and Ripley, 2002). This gave the following model:

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

where $\alpha_i$ is the district specific parameter, and $\beta_j$ is the age-group parameter, one of which is redundant.

The contrast matrix used in the model was a "sum contrast"; each parameter estimate has a standard error enabling comparison with the mean (Venables and Ripley, 2002; Tongkumchum and McNeil, 2009).

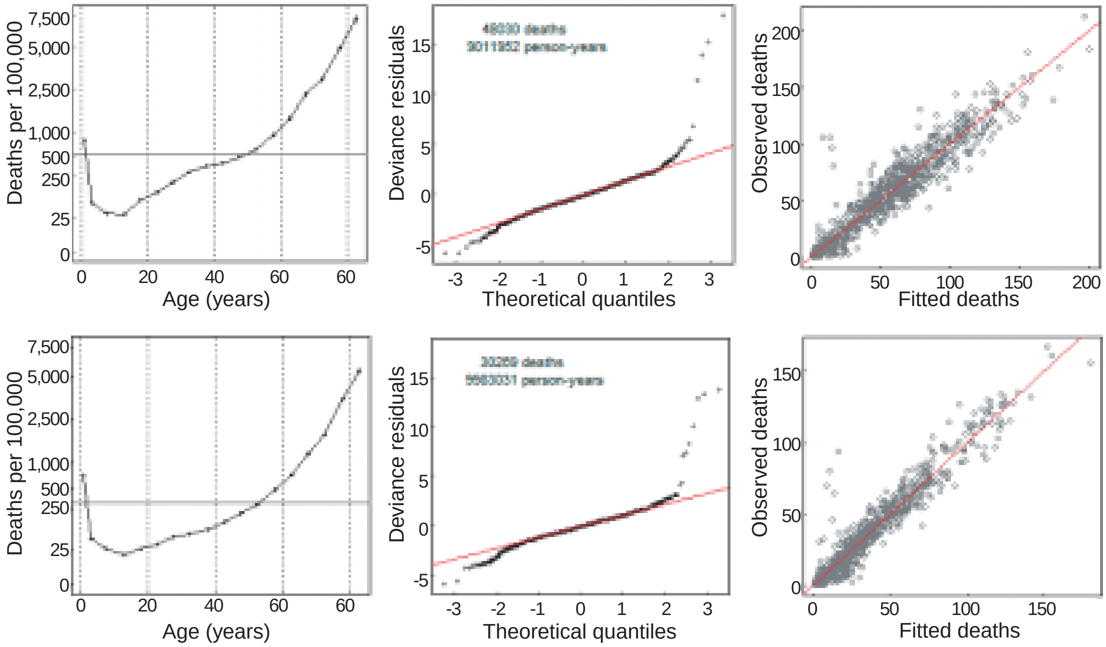



Fig 1–Model results for all-cause mortality for males and females aged 0-84 years in Bangkok, 1999-2001.

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 for all such areas in the sample were then classified into three groups, according to whether the confidence interval was: 1. completely above the mean, 2. crossing the mean, or 3. completely below the mean. A thematic map was used to display this information using corresponding colors: red, orange, and blue. Statistically valid conclusions can be made using this map; the mortality rate for each red-colored district was greater than the average mortality, and the mortality rate for each blue-colored district was less than the average mortality.

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

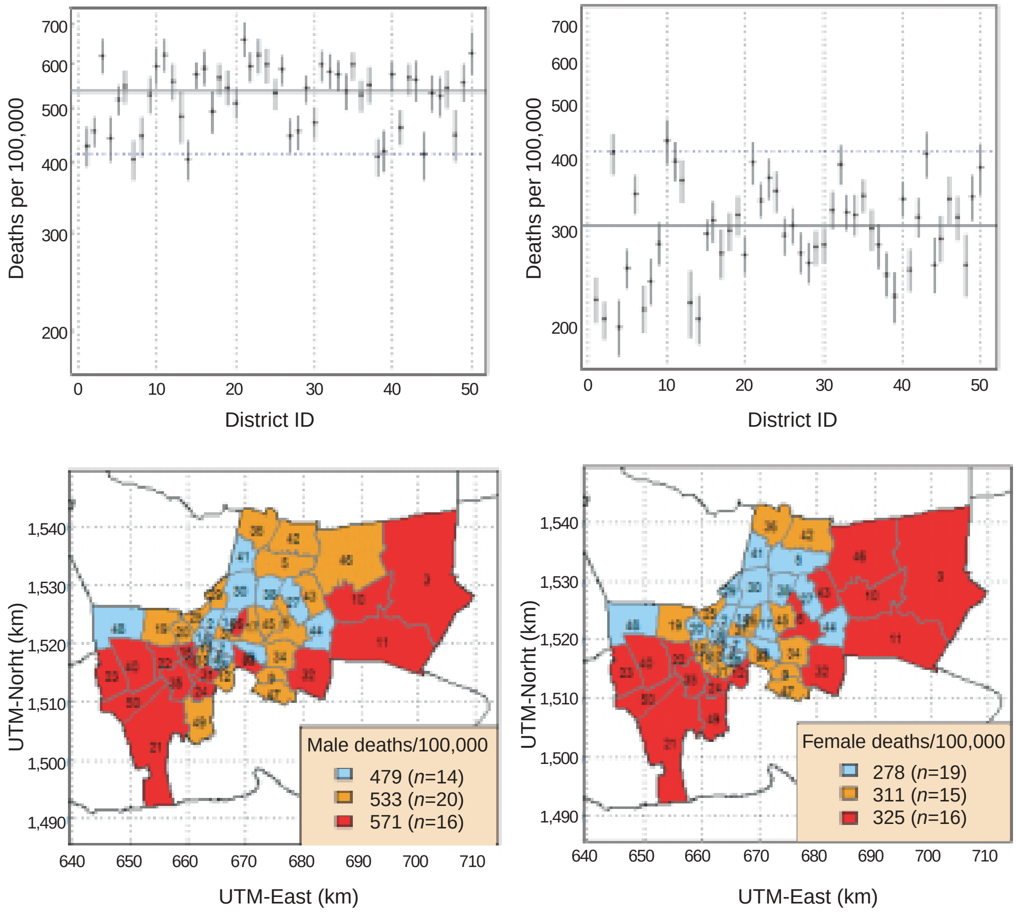
## RESULTS

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.

Fig 1 shows the results of fitting model (1) to all-cause mortality for males and females aged 0 to 84 years in Bangkok Province. It is clear from the district-adjusted mortality rates by age-group (as shown in the left panel of Fig 1) the 80-84 year old age group had the highest mortality rate. The residual plots in the middle panel of Fig 1 indicate the models fit reasonably well, apart from 4 outliers in males and 7 outliers in females. The outliers in both males and females occurred in babies aged less than 1 year in Pathum Wan,

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

| Gender | Age in years | Regions | | | | | National |
|---|---|---|---|---|---|---|---|
| | | Bangkok | Central | Northeast | North | South | |
| Males | <1 | 1,002 | 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 | 1,010 | 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 | 1,150 | 1,166 | 1,216 | 1,245 | 940 | 1,171 |
| | 60-64 | 1,725 | 1,724 | 1,767 | 1,767 | 1,398 | 1,705 |
| | 65-69 | 2,814 | 2,554 | 2,480 | 2,600 | 2,139 | 2,508 |
| | 70-74 | 3,672 | 3,627 | 3,727 | 3,932 | 3,208 | 3,674 |
| | 75-79 | 5,985 | 5,900 | 5,502 | 6,268 | 5,332 | 5,788 |
| | 80-84 | 8,878 | 9,081 | 8,593 | 9,577 | 8,009 | 8,867 |
| Male aged | 0-84 | 533 | 697 | 609 | 852 | 547 | 659 |
| Females | <1 | 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 | 1,029 | 1,193 | 1,212 | 749 | 1,078 |
| | 65-69 | 1,588 | 1,590 | 1,818 | 1,958 | 1,287 | 1,710 |
| | 70-74 | 2,379 | 2,479 | 2,780 | 2,969 | 2,034 | 2,612 |
| | 75-79 | 4,472 | 4,371 | 4,414 | 4,937 | 3,617 | 4,419 |
| | 80-84 | 6,794 | 7,423 | 7,510 | 8,300 | 6,084 | 7,375 |
| Female aged | 0-84 | 303 | 424 | 410 | 565 | 316 | 419 |
| Person aged | 0-84 | 412 | 558 | 509 | 707 | 431 | 537 |




UTM = Universal Transverse Mercator

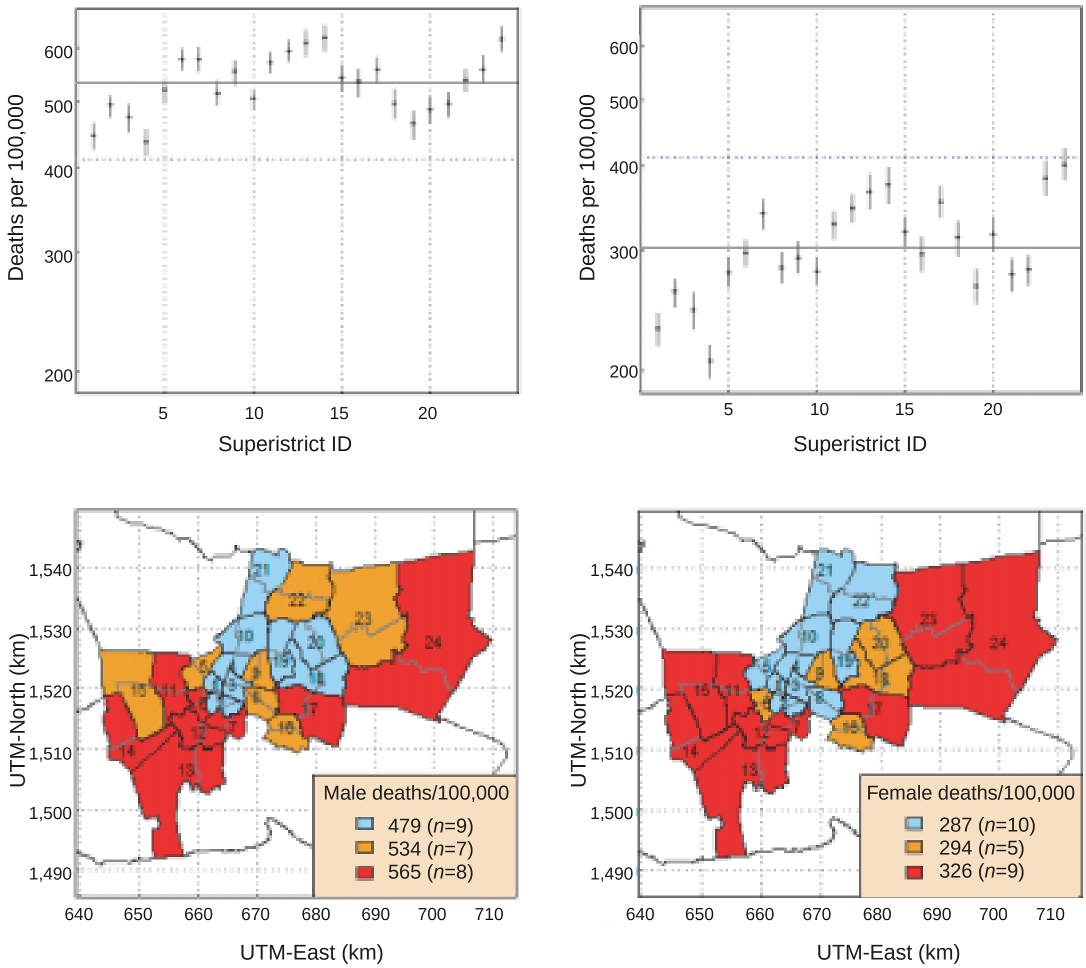
Districts in Bangkok

1 Phra Nakhon
2 Dusit
3 Nong Chok
4 Bang Rak
5 Bang Khen
6 Bang Kapi
7 Pathum Wan
8 Pom Prap Sattru Phai
9 Pra Kanong
10 Min Buri
11 Lat Krabang
12 Yan Nawa
13 Samphanthawong
14 Phaya Thai
15 Thon Buri
16 Bangkok Yai
17 Huai Khwang
18 Khlong San
19 Taling Chan
20 Bangkok Noi
21 Bang Khun Thian
22 Phasi Charoen
23 Nong Khaem
24 Rat Burana
25 Bang Phlat
26 Din Daeng
27 Bueng Kum
28 Sathon
29 Bang Sue
30 Chatuchak
31 Bang Kho Laem
32 Prawet
33 Khlong Toei
34 Suan Luang
35 Chom Thong
36 Don Mueang
37 Ratchathewi
38 Lat Phrao
39 Watthana
40 Bang Khae
41 Lak Si
42 Sai Mai
43 Khan Na Yao
44 Saphan Sung
45 Wang Thonglang
46 Khlong Sam Wa
47 Bang Na
48 Thawi Watthana
49 Thung Khru
50 Bang Bon

Fig 2–All-cause mortality for males and females aged less than 85 years in Bangkok, Thailand 1999-2001.

Ratchathewi, Khan Na Yao and Khlong San districts. The fitted and observed numbers of deaths are plotted in the right panel of Fig 1.

The age-adjusted male and female mortality rates and their 95% confidence intervals for each district are shown in the top panel of Fig 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




UTM = Universal Transverse Mercator

Superdistrict in Bangkok

1 Phra Nakhon, Pom Prap Sattru Phai, Samphanthawong
2 Bang Rak, Khlong San, Sathon
3 Pathum Wan, Ratchathewi Din Daeng
4 Dusit, PhayaThai
5 Bangkok Noi, Bang Phlat
6 Thon Buri, Bangkok Yai
7 Yan Nawa, Bang Kho Laem
8 KhlongToei, Watthana
9 Huai Khwang, Bang Khae
10 Bang Sue, Chatuchak
11 Taling Chan, Phasi Charoen
12 Rat Burana, Chom Thong
13 Bang Khun Thian, Thung Khru
14 Nong Kheam, Bang Bon
15 Thawi Watthana,
16 Phra Kanong, Bang Na
17 Prawet, Suan Luang
18 Bang Kapi, Saphan Sung
19 Lat Phrao, Wang Thonglang
20 Bueng Kum, Khan Na Yao
21 Don Mueang, Lak Si
22 Bang Khen, Sai Mai
23 Min Buri, Khlong Sam Wa
24 Nong Chok, Lat Krabang

Fig 3–All-cause mortality for males and females aged less than 85 years across 24 superdistricts in Bangkok, Thailand 1999-2001.

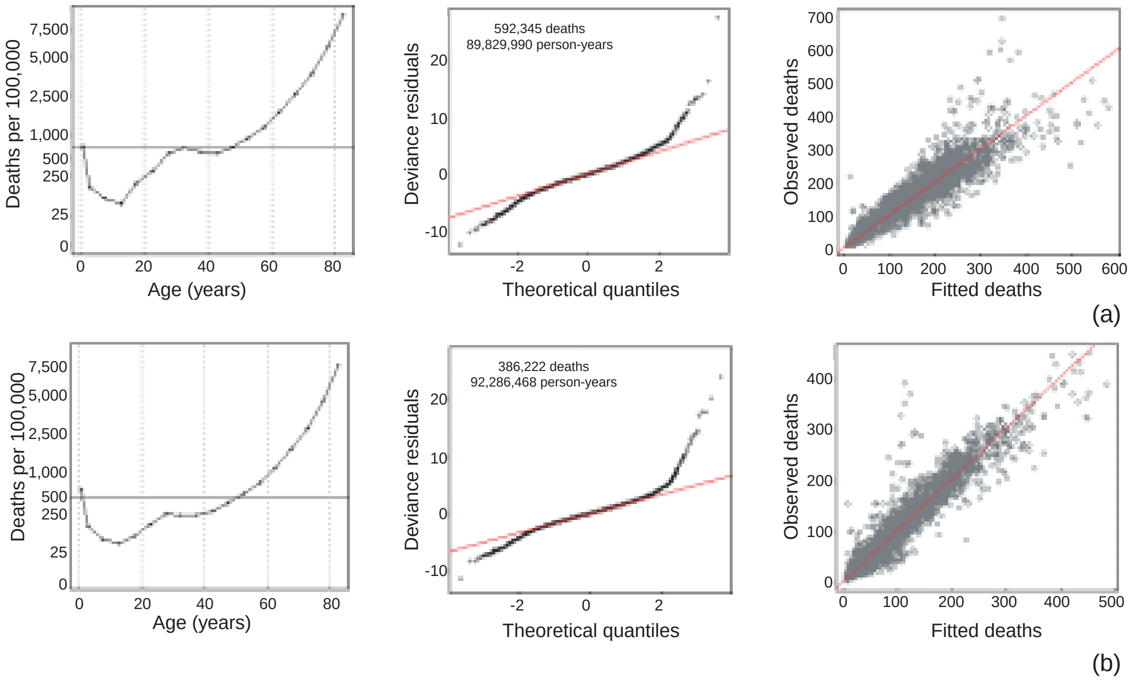



Fig 4–Model results for all-cause mortality for (a) males and (b) females aged less than 85 years across 235 superdistricts in Thailand, 1999-2001.

morality rates for males and females combined (412 per 100,000). The maps of 50 districts in Bangkok show male and female mortality (lower panel of Fig 2); the confidence intervals classify the districts. If the confidence interval was entirely above the gender-specific mean then the district is red, if the confidence interval crosses the gender-specific mean, the district is orange, and if the confidence interval is entirely below the mean, the district is blue. There were eleven districts (Nong Chok, Min Buri, Lat Krabang, Prawet, Rat Burana, Chom Thong, Phasi Charoen, Bang Khae, Nong Khaem, Bang Bon and Bang Khun Thian) in Bangkok where mortality rates were significantly higher than average for both males and females.

Fig 3 shows the same results as Fig 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 Fig 3 are smaller than those in Fig 2. Maps in the lower panel of Fig 3 indicate that there were seven superdistricts located in eastern and southwestern Bangkok having higher mortality than the gender-specific mean for both males and females.

Fig 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 Thailand, 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 Ratchathewi Districts.

The 95% confidence intervals of age-adjusted mortality rates in the 235

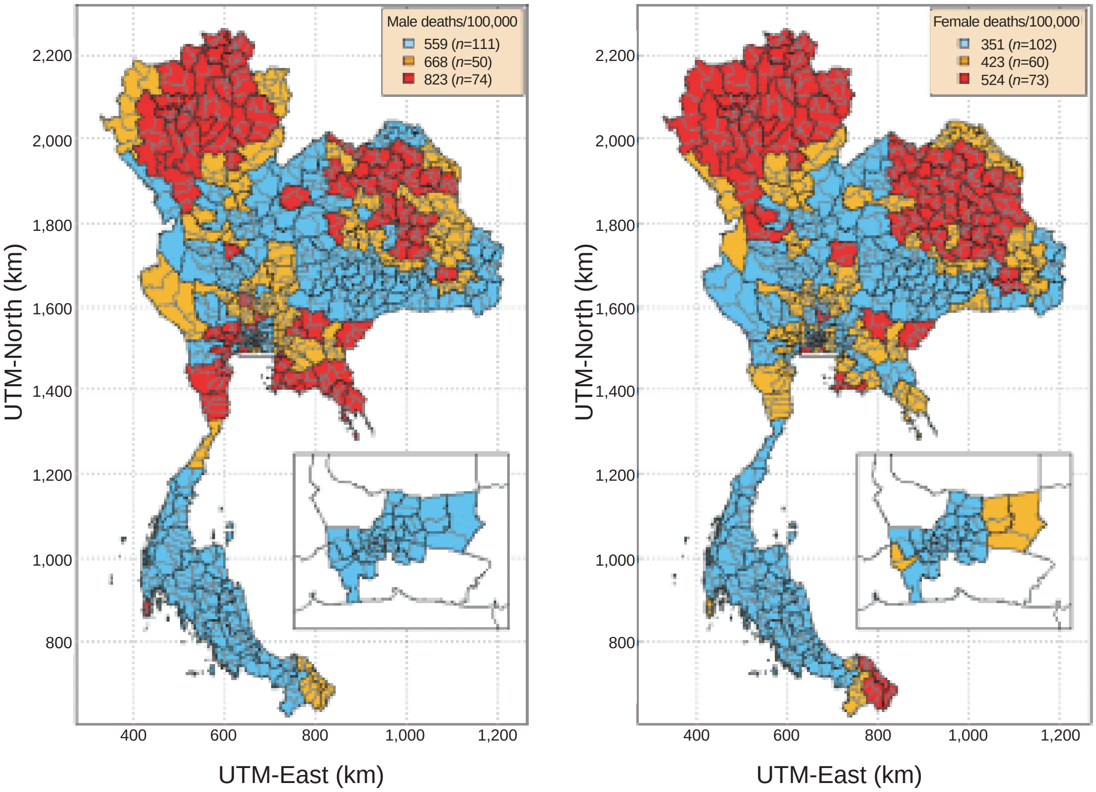



Fig 5–All-cause mortality rates for males and females aged less than 85 years in Thailand, 1999-2001.

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 Fig 5. Most superdistricts in the northern region and some superdistricts in the northern part of the northeastern region had higher mortality than the average for both males and females. The superdistricts in southern Thailand had lower than average mortality except for Phuket and Narathiwat. All superdistricts in Bangkok had lower mortality than average except for females in the superdistrict containing Nong Chok and Lat Krabang Districts.

The highest mortality rate for males occurred in the superdistrict in Chiang Rai containing Phan, Mae Suai and Wiang Pa Pao Districts. The superdistrict in Chiang Rai containing Wiang Chai, Thoeng, Pa Daet, Phaya Mengrai and Khun Tan Districts had the highest mortality rate among females in Thailand. The top ten superdistricts with the highest age-adjusted mortality rates for males and females are shown in Table 2 (individual rankings of superdistricts available from the author).

## DISCUSSION

The Poisson model incorporating additive factors for age-group and district generally provides a good fit to mortality data in Thailand because the standardized residuals were randomly dispersed along

Table 2
Top 10 superdistricts with highest age-adjusted mortality rates in males and females, Thailand 1999-2001.

| Rank | Males | | Females | |
|---|---|---|---|---|
| | Superdistrict | Mortality per 100,000 (95% CI) | Superdistrict | Mortality per 100,000 (95% CI) |
| 1 | Phan, Mae Suai, Wiang PaPao (Chiang Rai) | 1,127 (1,096-1,159) | Wiang Chai, Thoeng, Pa Daet, Phaya Mengrai, Khun Tan (Chiang Rai) | 844 (813-876) |
| 2 | Mueang Phayao, Dok Khamtai, Mae Chai, Phu Kamyao (Phayao) | 1,106 (1,076-1,137) | Fang, Mae Ai, Chai Prakan (Chiang Mai) | 836 (804-869) |
| 3 | Fang, Mae Ai, Chai Prakan (Chiang Mai) | 1,095 (1,061-1,131) | Chun, Chiang Kham, Chiang Muan, Pong, Phu Sang (Phayao) | 807 (778,838) |
| 4 | Chun, Chiang Kham, Chiang Muan, Pong, Phu Sang (Phayao) | 1,089 (1,056-1,123) | Phan, Mae Suai, Wiang Pa Pao (Chiang Rai) | 799 (773-827) |
| 5 | Wiang Chai, Thoeng, Pa Daet, Phaya Mengrai, Khun Tan (Chiang Rai) | 1,083 (1,049-1,117) | Chiang Dao, Mae Taeng, Phrao, Wiang Haeng (Chiang Mai) | 759 (730-790) |
| 6 | Mae Rim, Samoeng, San Sai (Chiang Mai) | 1,081 (1,045-1,118) | Mueang Chiang Rai, Mae Lao (Chiang Rai) | 753 (724-783) |
| 7 | Mueang Phrae, Rong Kwang, Song, Nong Muang Khai (Phrae) | 1,075 (1,045-1,107) | Mueang Phayao, Dok Khamtai, Mae Chai, Phu Kamyao (Phayao) | 744 (719-770) |
| 8 | Mueang Chiang Rai, Mae Lao (Chiang Rai) | 1,070 (1,037-1,105) | Chiang Khong, Chiang Saen, Wieng Kaen, Wieng Chiang Rung, Doi Luang (Chiang Rai) | 744 (711-778) |
| 9 | San Pa Tong, Hang Dong, Mae Wang, Doi Lo (Chiang Mai) | 1,066 (1,034-1,100) | Doi Saket, San Kamphaeng, Saraphi, Mae On (Chiang Mai) | 710 (685-736) |
| 10 | Chiang Dao, Mae Taeng, Phrao, Wiang Haeng (Chiang Mai) | 1,050 (1,017-1,084) | Mae Rim, Samoeng, San Sai (Chiang Mai) | 710 (680-741) |

a straight line in the deviance residuals plots, as shown in the middle panel of Fig 4.

This study illustrates the applications of the Poisson GLM for all-cause mortality rates in Bangkok at district and superdistrict levels. Superdistricts were more effective regional divisions than districts because they provided cells with approximately equal populations, thus equalizing the standard error of the estimated effects, as shown in the upper panels of Fig 2 and 3. Using 235 superdistricts instead of 926 districts decreased the standard error by a factor of nearly 2. The 926 districts for Thailand were difficult to distinguish, but the 235 superdistricts provided a clearer schematic map.

The statistical model used in this study can be applied to analyze 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 directly to this situation by using logistic instead of Poisson regression.

Our finding of high age-adjusted morality rates in the northern and northeastern regions may be related to socio-economic factors and excessive mortality due to specific causes, such as HIV/AIDS in the northern and liver cancer in the northeastern regions. Regional variations in cause-specific mortality need to be investigated further.

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 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 adjusted incidence rates, and thus facilitates comparison of both regions and age groups. The differences in mortality rates across superdistricts in different age groups reflect underlying factors that need further study. Potential factors worth investigation include risk behavior patterns, levels of health resources, and social determinants of health.

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

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