Original article

Acquired Immune Deficiency Syndrome mortality rate in Thailand

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Objective Acquired Immune Deficiency Syndrome (AIDS) has been a leading cause of morbidity in Thailand for many years. The objective of this study was to model and forecast the AIDS mortality rate in Thailand using data from death certificate reports.

Methods A retrospective analysis of the AIDS mortality rate was conducted. The data were obtained from the national vital registration database for a 10-year period, from 2000 to 2009, provided by the Ministry of the Interior, and coded as cause-of-death using ICD-10 by the Ministry of Public Health. Multivariate linear regression was used for modeling and forecasting age-specific AIDS mortality rates in Thailand.

Results AIDS mortality increased with increasing age in each gender and it also was higher in the northern and southern provinces. The trend of AIDS mortality remained stable in most age groups, but decreased in others after 2003. AIDS mortality was highest in males aged 30-39 years.

Conclusion The multivariate linear regression model was suitable for modeling and forcasting AIDS mortality in Thailand. There is a need for a sustained and long-term AIDS control measures to deal with a high AIDS burden rate in Thailand. **Chiang Mai Medical Journal 2012;51(3):79-86.**

Keywords: forecasting, mortality, multivariate linear regression, AIDS

Introduction

Acquired Immune Deficiency Syndrome (AIDS) is decease resulting from damage to the human immune system caused by the human immunodeficiency virus (HIV) [1]. HIV is transmitted through direct contact of a mucous membrane or the bloodstream with a bodily fluid containing HIV, such as blood, semen, vaginal fluid, preseminal fluid, and breast milk [2]. According to the new data in the 2009 AIDS epidemic update, new HIV infections have been reduced by 17% over the past eight years. The World Health Organization (WHO) estimated that there are 33.4 million people worldwide living with HIV/AIDS, with 2.7 million new HIV infections per year and 2.0 million annual deaths due to AIDS [3]. The disease causes a major health problem in many parts of the world, and is considered a pandemic. The disease

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outbreak that is not only present over a large area, but also actively spreading [3]. In 2007, UNAIDS estimated: 33.2 million people worldwide were HIV positive; AIDS killed 2.1 million people in the course of that year, including 330,000 children, and 76% of those deaths occurred in sub-Saharan Africa [4].

Statistics regarding AIDS cases occurring in Thailand between 1985 and 2006 (data from the Thailand A2 Team cited in AIDS Thailand, 2007) estimated that 1,102,628 people (adults and children) were infected with HIV, and 558,578 died of AIDS-related complications [5]. The first case of an AIDS patient in northern Thailand was reported in 1987, thus marking the outbreak of the epidemic [6].

Thailand is a country located at the centre of the Indochina peninsula in Southeast Asia. It is divided into 77 provinces, which are gathered into 4 groups of regions [7]: central, north, north-east and south. The country is bordered in the north by Myanmar and Laos, to the east by Laos and Cambodia, to the south by the Gulf of Thailand and Malaysia, and to the west by the Andaman Sea and the southern extremity of Myanmar. The Department of Provincial Administration estimates a total Thai population of 65,479,453 [8].

Sriwattanapongse et al in 2010, [9] investigated the epidemic patterns of hospital-diagnosed HIV/AIDS incidence by year, district and age group for Chiang Mai; a northern province of Thailand. The linear regression model was used to forecast HIV/AIDS incidence rates by district and age group in order to prevent disease epidemics that are likely to occur soon in this area. The model obtained an r^2 of 0.74. This study also found that the average incidence rate of AIDS appeared to be highest at 2.10 per 10,000 people per year in Hang Dong district. Having a model that gives such forecasts of disease outbreaks can provide a useful basis for allocating resources in disease prevention.

AIDS has been recognized as a critical problem that leads to increased adult and child mortality in Thailand. Consequently, the objective of this study was to modeling and forcasting the AIDS mortality rate in Thailand using data from death certificate reports.

Methods

Data for registered deaths due to AIDS were obtained from the National Vital Registration Database for a 10-year period from 2000 to 2009.The database was provided by the Ministry of the Interior and coded as cause-of-death using ICD-10: B20-B24 by the Bureau of Policy and Strategy, Ministry of Public Health.

Age, gender, residential area by region in Thailand and year were selected as explanatory variables in studying the mortality rates of AIDS. Age was divided into nine subgroups (0-9, 10-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79 and over 80 yrs). Various approaches have been developed to improve forecasting morbidity and mortality rates. This study focused on the model proposed by Lee and Carter [10] and Lee and Miller [11], which was used initially for projections of age-specific mortality rates in the United States. Lee-Carter-based modeling frameworks are viewed in the current literature as among the most efficient and transparent methods of modeling and projecting mortality improvements [12]. This method also is regarded as the state-of-the-art in mortality forecasting and has become increasingly popular for long-term forecasts of age-specific mortality rates.

Since AIDS death counts are based on small cells, zero cases often occur. Therefore, to make necessary adjustments and transform 0, this study replaced zero counts with a suitably chosen small constant that was greater than 0. The method used to define the mortality rate was

$$m_{x,t} = \left(\frac{(0.5+n_{x,t})}{P} \times 100{,}000 \right)^{1/3}$$ x, is the age group, "t" is the year, (1)

where $n_{x,t}$ is the number of AIDS death cases in the cell and P is the project population size at risk.

Regarding each region and gender combination; the multivariate linear regression model was used to investigate and forecast AID mortality by age group and year. The original principal component of the Lee -Carter model was expressed as

$$\log(m_{x,t}) = a_x + b_x k_t + \varepsilon_{x,t},$$

"x" is the age group, "t" is the year, (2)

where $m_{x,t}$ is the central death rate (per 100,000) in age group *x* and year *t* for each specific gender and geographical region . The factors a_x and b_x describe the level and annual increase of the age-specific mortality rate, respectively, and kt is the year that Lee - Carter chose for ε_x constraints as follows: $\sum k_t = 0$, where is the set of random disturbances.

Table 1. AIDS mortality cases in each gender and region in Thailand from 2000 to 2009

Age Group	Male				Female				Total
	Central	Northeast	Northern	Southern	Central	Northeast	Northern	Southern	
0	354	430	377	135	299	374	343	150	2,462
10	116	121	104	49	139	149	168	50	896
20	3,886	3,147	2,611	1,953	2,814	2,859	2,710	950	20,930
30	9,980	7,802	7,672	3,895	4,165	4,124	4,549	1,317	43,504
40	4,940	2,330	3,640	1,354	1,882	1,323	1,868	510	17,847
50	1,351	507	846	274	570	268	426	120	4,362
60	374	95	187	71	153	71	89	24	1,064
70	91	32	60	14	39	21	42	7	306
80	30	9	30	4	23	17	32	5	150
Total	21,122	14,473	15,527	7,749	10,084	9,206	10,227	3,133	91,521

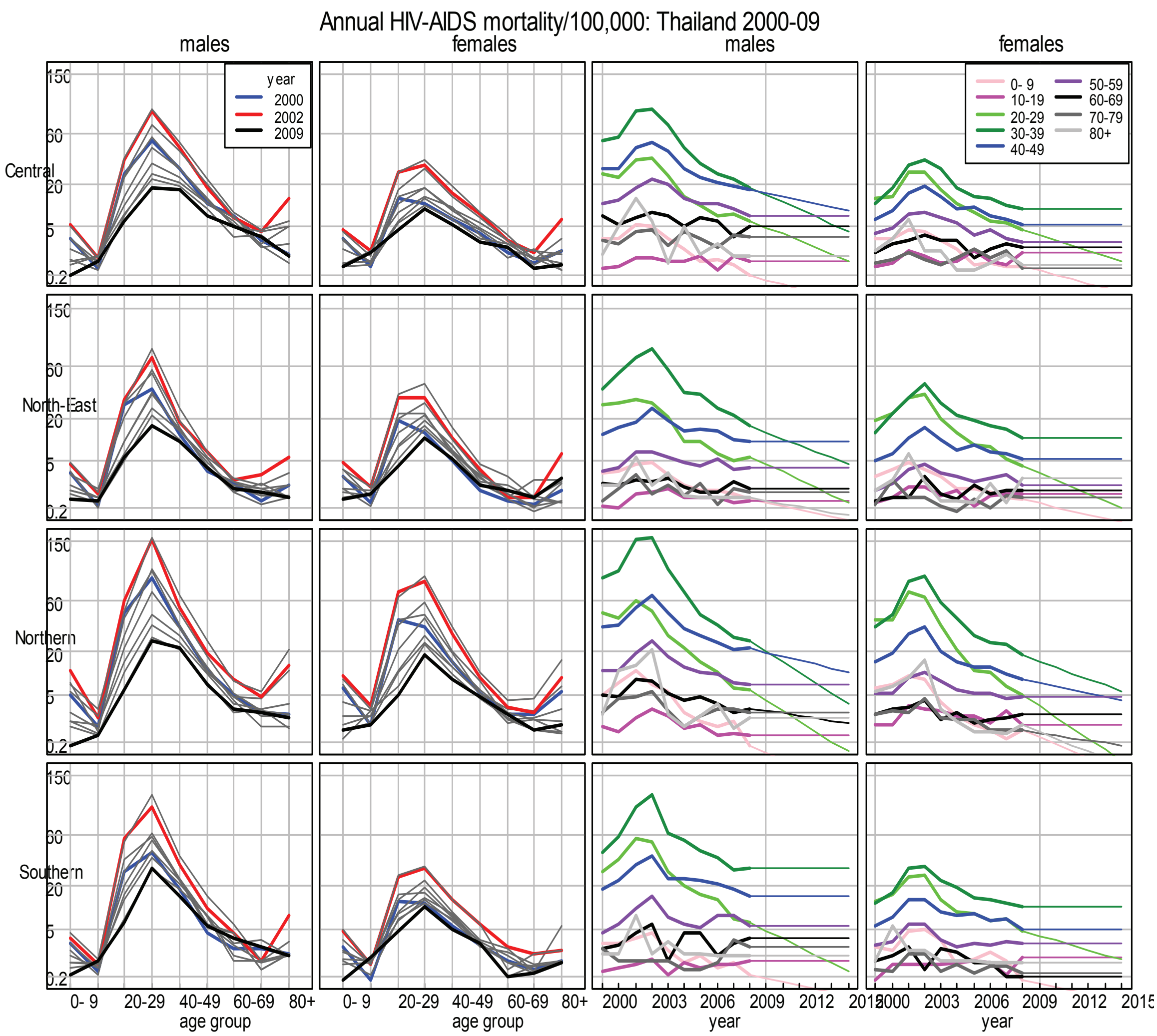

Figure 1. Plot of AIDS mortality rates by age group for each year (right-hand panels) and trend with forecasts for each age group (left-hand panels) for the four regions of Thailand.

Since some cells had no reported cases to allow log-transformation, zero counts were replaced by a suitably chosen small constant, without changing any value of $m_{x,t}$ greater than 0. The multivariate linear regression model takes into account correlation in the data between age groups. The R program was used for all statistical analysis and graphs [13].

Results

The results from demographic variables showed that, from 91,521 AIDS cases in Thailand, 64.32% of AIDS deaths were male and 35.68% were female; also, 47.53% of AIDS death cases were aged 30-39 years (Table 1).

The average mortality rate of AIDS in Thailand appeared to be highest in the northern region, with 2.2 deaths per 100,000 people per year in males, and lowest in the south, with 1.47 deaths per 100,000 people per year in females. This study found that the highest age-specific AIDS mortality rates were in the northern male group aged 30-39 years (4.17 deaths per 100,000 people per year). The lowest age-specific AIDS mortality rate was in the north-east, with 0.80 deaths per 100,000 people per year in females aged 70-79 years. Most death were resident males in the central region. The trend of the AIDS mortality rate has decreased approximately more in females than males. AIDS mortality decreased in most of the age groups, especially adults age group of 30-39 year old, followed by 40-49 year, and 10-19 year children, consecutively.

To log-transform the counts, the zeros were replaced with 0.5 before fitting the model. The 2 left-hand panels of Figure 1 show the AIDS mortality rates plotted by age group for each year in each gender; and the 2 right-hand panels show trends for the period, 2000-2009 for each age group in each gender, together with forecasts based on the model.

Figure 1 shows that the mortality increased in the 30-39 year old age group and decreased slightly before increasing in the higher age group of 70-79 year, with the exception of the north-east region, which increased in the 60-69 year old males. However, the time trends shown in the 2 right-hand panels indicate that AIDS mortality decreased over a-7-year period after 2003 in all age groups.

This figure found that in 2000 the mortality rate was highest in the northern male age group of 30-39 year, and increased slightly in the group of 60-69 year. In the ten-year period (2000 to 2009), the trend of AIDS mortality fluctuated in most age groups, but decreased in 2000-2003 and decreased after 2003. There was a pronounced bulge in mortality in the north and the south among males aged between 30 and 39 years. In addition, there was an increased fluctuation of AIDS mortality rate in most age groups of between 60 and 79 years in both males and females.

Figure 1 and Table 2 found that mortality rates from 2009 to 2015 in some age groups are constant because the model is not significant.

Discussion

Gender and age affect the mortality rate. Rhucharoenpornpanich and Chamratrithirong has shown that the impact of AIDS on the demographic process in Thailand can be illustrated by population size, annual growth rates and mortality indicators such as the crude death rate, age-specific death rate, infant mortality rate, child mortality rate and life expectancy at birth [14].

After 2003, the AIDS mortality rate declined in all age groups, due to the Bureau of Policy and Strategy, Ministry of Public Health having strong control and prevention measures of AIDS morbidity over the previous 10 years. The data was interpreted accurately and objectively for this investigation. Therefore The Ministry of Public Health could use the result of this study to continue observation and surveillance of the AIDS disease, especially in risk areas.

Although the Lee-Carter model is used often for forecasting, this non-linear device cannot fit with ordinary regression methods, and thus, does not provide standard errors routinely for estimated parameters. Booth et al [15] used the Lee-Carter method with Australian data, which was compromised by significant departures from lin-

Table 2. Results from multivariate linear models of mortality rate by region in Thailand and gender for each age group

	Age	ax	bx	RSE	R-squared	F-statistic$^{(1, 8)}$	*p*-value
Central region males	0	1.73817	-0.11447	0.21680	0.74190	22.99000	0.00136
	10	0.84185	0.01164	0.12340	0.08401	0.73370	0.41660
	20	3.31466	-0.16139	0.28640	0.76610	26.20000	0.00091
	30	4.37400	-0.17420	0.41880	0.64080	14.27000	0.00540
	40	3.47807	-0.08635	0.29770	0.46460	6.94200	0.02995
	50	2.57898	-0.04636	0.23590	0.28480	3.18600	0.11210
	60	1.99417	-0.03331	0.14590	0.34960	4.30000	0.07181
	70	1.45991	-0.00098	0.14610	0.00047	0.00375	0.95270
	80	1.74086	-0.07336	0.46570	0.20370	2.04700	0.19040
Central region females	0	1.65148	-0.10223	0.17570	0.77720	27.91000	0.00074
	10	0.91104	0.00970	0.14490	0.04414	0.36940	0.56020
	20	2.84778	-0.12180	0.31480	0.60690	12.35000	0.00791
	30	2.92253	-0.06737	0.38820	0.23700	2.48500	0.15360
	40	2.35222	-0.04325	0.27490	0.20330	2.04100	0.19090
	50	1.89410	-0.04256	0.21750	0.28320	3.16000	0.11330
	60	1.31735	-0.00794	0.16650	0.02294	0.18780	0.67620
	70	0.95329	0.00434	0.15690	0.00783	0.06312	0.80800
	80	1.41843	-0.07327	0.29860	0.38310	4.96700	0.05641
North-east region males	0	1.64260	-0.08647	0.15500	0.76240	25.68000	0.00097
	10	0.78411	0.00837	0.15210	0.03026	0.24960	0.63080
	20	3.29604	-0.18142	0.21170	0.88330	60.56000	0.00005
	30	4.10120	-0.14827	0.40750	0.57720	10.92000	0.01078
	40	2.62851	-0.03679	0.21230	0.23640	2.47700	0.15410
	50	1.70229	-0.00636	0.17400	0.01361	0.11040	0.74830
	60	1.22530	-0.01825	0.11530	0.20520	2.06500	0.18860
	70	1.03560	-0.00697	0.22500	0.00978	0.07903	0.78580
	80	1.38712	-0.06643	0.25510	0.41140	5.59300	0.04561
North-east region females	0	1.60949	-0.08796	0.14700	0.78680	29.53000	0.00062
	10	0.89272	0.00233	0.15310	0.00239	0.01917	0.89330
	20	3.17111	-0.16213	0.32500	0.71970	20.54000	0.00192
	30	3.04712	-0.06213	0.38080	0.21540	2.19600	0.17660
	40	2.07752	-0.01607	0.24740	0.04168	0.34790	0.57160
	50	1.31010	0.00093	0.19330	0.00024	0.00190	0.96630
	60	0.88999	0.01642	0.16780	0.08991	0.79040	0.39990
	70	0.86215	-0.01473	0.20870	0.04886	0.41090	0.53940
	80	1.24360	-0.03687	0.36520	0.09511	0.84080	0.38600

earity in the time component and changes over time in the age component. The model also expanded to take account of age-time interactions by incorporating additional terms, but these were not incorporated readily into forecasts. Delwarde et al [16] studied a model to forecast future mor-

Table 2. (continued)

	Age	ax	bx	RES	R-squared	F-statistic$^{(1, 8)}$	*p*-value
Northern region	0	2.19772	-0.16303	0.27280	0.78650	29.47000	0.00062
males	10	1.13406	-0.03427	0.19210	0.24700	2.62400	0.14390
	20	3.99547	-0.24224	0.26860	0.89350	67.12000	0.00004
	30	5.27387	-0.24612	0.52400	0.69460	18.20000	0.00274
	40	3.73326	-0.09545	0.32410	0.47220	7.15600	0.02814
	50	2.63984	-0.06258	0.27440	0.34910	4.29100	0.07205
	60	1.91439	-0.05622	0.18920	0.47660	7.28500	0.02711
	70	1.54836	-0.03324	0.22800	0.17970	1.75300	0.22210
	80	2.10904	-0.11854	0.58760	0.29560	3.35800	0.10430
Northern region	0	2.18256	-0.16846	0.24890	0.82530	37.78000	0.00028
females	10	1.19720	-0.00015	0.18550	0.00001	0.00005	0.99440
	20	4.08068	-0.25559	0.43060	0.78410	29.06000	0.00065
	30	4.10227	-0.13910	0.49670	0.44710	6.46900	0.03452
	40	2.97093	-0.08549	0.31330	0.43430	6.14100	0.03822
	50	1.98511	-0.03055	0.19820	0.19680	1.96000	0.19910
	60	1.38202	-0.02744	0.14490	0.26990	2.95800	0.12380
	70	1.42134	-0.05946	0.15450	0.60430	12.22000	0.00813
	80	2.13375	-0.15849	0.39960	0.61870	12.98000	0.00695
Southern region	0	1.52939	-0.08855	0.17140	0.73360	22.03000	0.00155
males	10	0.77146	0.01380	0.10690	0.14680	1.37600	0.27450
	20	3.70299	-0.19154	0.38340	0.72020	20.59000	0.00191
	30	4.29102	-0.11590	0.49000	0.36590	4.61600	0.06392
	40	3.05076	-0.04148	0.26590	0.20050	2.00700	0.19440
	50	1.94228	-0.00012	0.27510	0.00000	0.00001	0.99700
	60	1.40956	-0.00053	0.28930	0.00003	0.00027	0.98720
	70	0.94280	0.01643	0.23950	0.04627	0.38810	0.55060
	80	1.37445	-0.03352	0.29690	0.11620	1.05100	0.33520
Southern region	0	1.55009	-0.08400	0.27820	0.48460	7.52300	0.02534
females	10	0.73904	0.02280	0.14690	0.19910	1.98800	0.19620
	20	2.78280	-0.11254	0.28560	0.61550	12.81000	0.00720
	30	2.83494	-0.05139	0.32710	0.20290	2.03600	0.19140
	40	2.14728	-0.02621	0.22860	0.11940	1.08400	0.32820
	50	1.54534	-0.02148	0.19790	0.10830	0.97160	0.35320
	60	1.16240	-0.05070	0.21670	0.36090	4.51700	0.06628
	70	0.89838	-0.01649	0.17580	0.08320	0.72600	0.41900
	80	1.31658	-0.05381	0.22430	0.37240	4.74700	0.06099

tality rates.The result showed that it was possible to smooth the estimated βx's in the Lee–Carter and Poisson log-bilinear models for mortality projection. Finally, penalized least-squares or maximum likelihood analysis was performed. The optimal value of the smoothing parameter was selected with the help of cross validation.

Conclusion

The multivariate linear regression was a suitable model for AIDS mortality in Thailand, as it has the additional advantage of taking account of correlations between data in different age groups. Therefore, this method was used to forecast disease mortality.

The graphical method provides an informative display of the variation in mortality by gender, age group and region. Public health authorities can use such graphs for applying preventive measures to control AIDS outbreaks by focusing on high risk groups.

The limitation of this research was its data with many zero cases in small cells (23,590 of 42,300 (55.77%) cells). In further study, other methods will be used for analysis such as the multiple imputations technique to solve this limitation [17].

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อัตราการตายโรคเอดส์ในประเทศไทย

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วัตถุประสงค์ โรคเอดส์เป็นสาเหตุของภาวการณ์เจ็บป่วยอันดับต้นๆ ในประเทศไทยมานาน วัตถุประสงค์ของการศึกษานี้เพื่อหาตัวแบบและพยากรณ์อัตราการตายเนื่องจากโรคเอดส์ในประเทศไทยโดยใช้รายงานมรณะบัตร

วิธีการวิจัย โดยมีการวิเคราะห์ย้อยหลังอัตราการตาย ข้อมูลได้มาจากฐานข้อมูลผู้เสียชีวิตของประเทศไทย ในช่วงเวลา 10 ปี ตั้งแต่ปี พ.ศ.2543 ถึง 2552 ของกระทรวงมหาดไทย การถดถอยเชิงเส้นพหุถูกนำมาใช้เป็นตัวแบบและพยากรณ์อัตราการตายตามกลุ่มอายุ

ผลการศึกษา อัตราการตายโรคเอดส์เพิ่มขึ้นตามอายุที่เพิ่มขึ้นในแต่ละเพศ มีอัตราสูงในจังหวัดภาคเหนือและภาคใต้ แนวโน้มการเพิ่มขึ้นยังคงที่ในทุกกลุ่มอายุและลดลงหลังจากปี พ.ศ. 2546 อัตราการตายโรคเอดส์สูงสุดในเพศชาย ช่วงอายุ 30-39 ปี

สรุปผลการศึกษา ตัวแบบการถดถอยเชิงเส้นพหุคูณเหมาะสมกับอัตราการตายโรคเอดส์ในประเทศไทย ทั้งนี้ต้องมีมาตรการควบคุมเพื่อให้อัตราการตายเนื่องจากโรคเอดส์คงที่และแนวโน้มในระยะยาวไม่มีอัตราการระบาดสูงขึ้น **เชียงใหม่เวชสาร 2555;51(3):79-86.**

คำสำคัญ: การพยากรณ์ อัตราการตาย การถดถอยเชิงเส้นพหุ โรคเอดส์