

Time Series Analysis and Forecast of Influenza Cases for Different Age Groups in Phitsanulok Province, Northern Thailand

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Abstract

Influenza is still a major problem in Thailand where the incidence varies among age groups. This descriptive research using retrospective data collection aimed to describe the distribution and synchrony, and to forecast Influenza cases in different age groups in Phitsanulok province, northern Thailand. Influenza cases from January 2009 to December 2016 were obtained from R506, Bureau of Epidemiology. Temporal distribution was visually interpreted from line and decomposed graphs. The synchrony between all pairs of age groups was analyzed using Pearson correlation. The 2017 Influenza cases were forecasted using the seasonal ARIMA model in RStudio version 1.1.419. The results showed that trend of Influenza cases for the three age groups: less than 25 years, 25-64 years, and 65 years and older, slightly decreased from 2011 to 2015 and dramatically increased in 2016. The two peaks were observed, i.e. major peak in September and minor peak in February. The cyclic pattern likely observed major peak in two consecutive years for every five years. All pairs of data series co-varied over time. The best models to forecast Influenza cases were seasonal ARIMA (1,0,1)(0,1,1)¹², seasonal ARIMA (1,0,0)(0,1,1)¹² and seasonal ARIMA (1,0,1)(1,1,1)¹² for age less than 25 years, age 25-64 years and age 65 years and older with the MAPE 15.54, 17.27 and 15.61 respectively. There were 1,698 forecasted cases in age less than 25 years, followed by 1,478 cases in age 65 years and older and 471 cases in age 25-64 years. The major peak in February and minor peak in September were observed in all age groups. In 2017, the forecasted cases were lower than the reported cases in all data series, except for age 65 years and older.

Keywords: Influenza, time series, forecast, seasonal ARIMA, surveillance
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1. Introduction

Influenza is an acute viral infection caused by an Influenza virus, which is one of the prioritized problems in Thailand. There are three types of Influenza virus, i.e. A, B and C. The incubation period is about two days. The virus can spread via droplet, hand and contaminated objects and disperse in schools, nursing homes, businesses or towns [1, 2]. World Health Organization (WHO) reported that epidemics occur mainly during winter in the temperate zone meanwhile Influenza may occur throughout the year, causing outbreaks more irregularly, in tropical regions. An estimated annual rate of Influenza was 5-10% in adults and 20-30% in children. There were about three to five million cases of severe illness, and about 250,000 to 500,000 deaths [2]. In 2014, Thailand had Influenza morbidity rate of 114.4 per 100,000 population in which the northern region had the highest morbidity rate from 2010 to 2014 and Phitsanulok province reported the highest Influenza cases among provinces in the region [3, 4].

Although Influenza occurrence varied in different age groups, most of previous researches regarding the distribution and forecast of Influenza focused on the overall cases or morbidity rates [5-7], which was not specific to age group and the synchrony between different age groups to distinguish the contributed factors were not analyzed. Therefore, the current research aimed to describe the distribution of Influenza in different age groups based on surveillance data (R506) managed by the Bureau of Epidemiology (BOE), Ministry of Public Health, Thailand. The research also aimed to analyze the disease synchrony among age groups to indicate the contribution of endogenous or exogenous factors [8]. Forecasting was also performed for each age group. The finding would be useful for control activities in the optimal time, place and target group, as well as an example for the utilization of data routinely collected.

2. Materials and Methods

2.1 Design and data

The descriptive research using retrospective data routinely collected was carried out in Phitsanulok province, northern Thailand. There were 9 districts with approximately 866,891 population. The reported new Influenza cases by age group from January 2009 to December 2016 were obtained from the national epidemiological surveillance database (R506), Bureau of Epidemiology, Department of Disease Control, Ministry of Public Health, Thailand. R506 is a reporting form in the national surveillance system of Thailand where all governmental hospitals and some private hospitals throughout the country have to report new cases of diseases under surveillance which cover more than 70 items. The monthly Influenza cases from January 2009 to December 2016 of the three age groups; less than 25 years, 25-64 years, and 65 years and older; were processed and analyzed using RStudio version 1.1.419.

2.2 Temporal distribution and synchronicity

Line graphs and the Seasonal Trend Decomposition using Loess (STL) were plotted to identify trend, cyclic and seasonal patterns. The synchrony between all pairs of data series between different age groups was analyzed using Pearson correlation to explore how two continuous signals covary over time. A number (-1) indicates negatively correlated meanwhile (0) indicates not correlated and (1) indicates positively correlated.

2.3 Seasonal ARIMA model development and forecast

Monthly Influenza cases from January 2009 to December 2015 were the training set and the data from January to December 2016 were the validating set for identifying the seasonal ARIMA model. The data were checked for stationarity where non-stationary data were transformed by natural log and seasonal differences. The sample autocorrelation function (ACF) and sample partial autocorrelation function (PACF) were generated to identify the possible ARIMA (p, d, q) (P, D, Q)^s models where: 'p', 'd', and 'q' represented autoregressive (AR) order, differencing order, and moving average (MA) of regular terms and 'P', 'D', and 'Q' referred to AR, differencing and MA of seasonal terms, and 's' represented the span of the periodic seasonal behavior (12 month per year) [6]. Model diagnostic testing to identify the fit models was analyzed using the standardized residuals, residual ACF, p values for Ljung-Box statistic, the cumulative periodogram of residuals, and the Box-Pierce statistic. The model with the lowest Akaike Information Criterion (AIC) and the lowest mean absolute percentage error (MAPE) was the best model. Forecast of the Influenza cases from January to December 2017 was performed using the best model for each series fitted with reported cases from January 2009 to December 2016. The research project was approved as a human ethics exemption by the Ethics Review Committee of Human Research, Faculty of Public Health, Mahidol University, Thailand.

3. Results and Discussion

3.1 Temporal distribution of Influenza

The trend of Influenza cases for the three age groups; less than 25 years, 25-64 years and 65 years and older; had increased from 2009 to 2011, thereafter the trend was slightly decreased and increased in 2016. The major peak occurred in September and minor peak most likely occurred in February. The cyclic pattern likely showed major peak in two consecutive years for every five years. After adjusted seasonal variation, the trend of all three age groups declined from 2011 to 2015 and increased again in 2016 with slightly higher than 2009 (Figures 1 and 2).

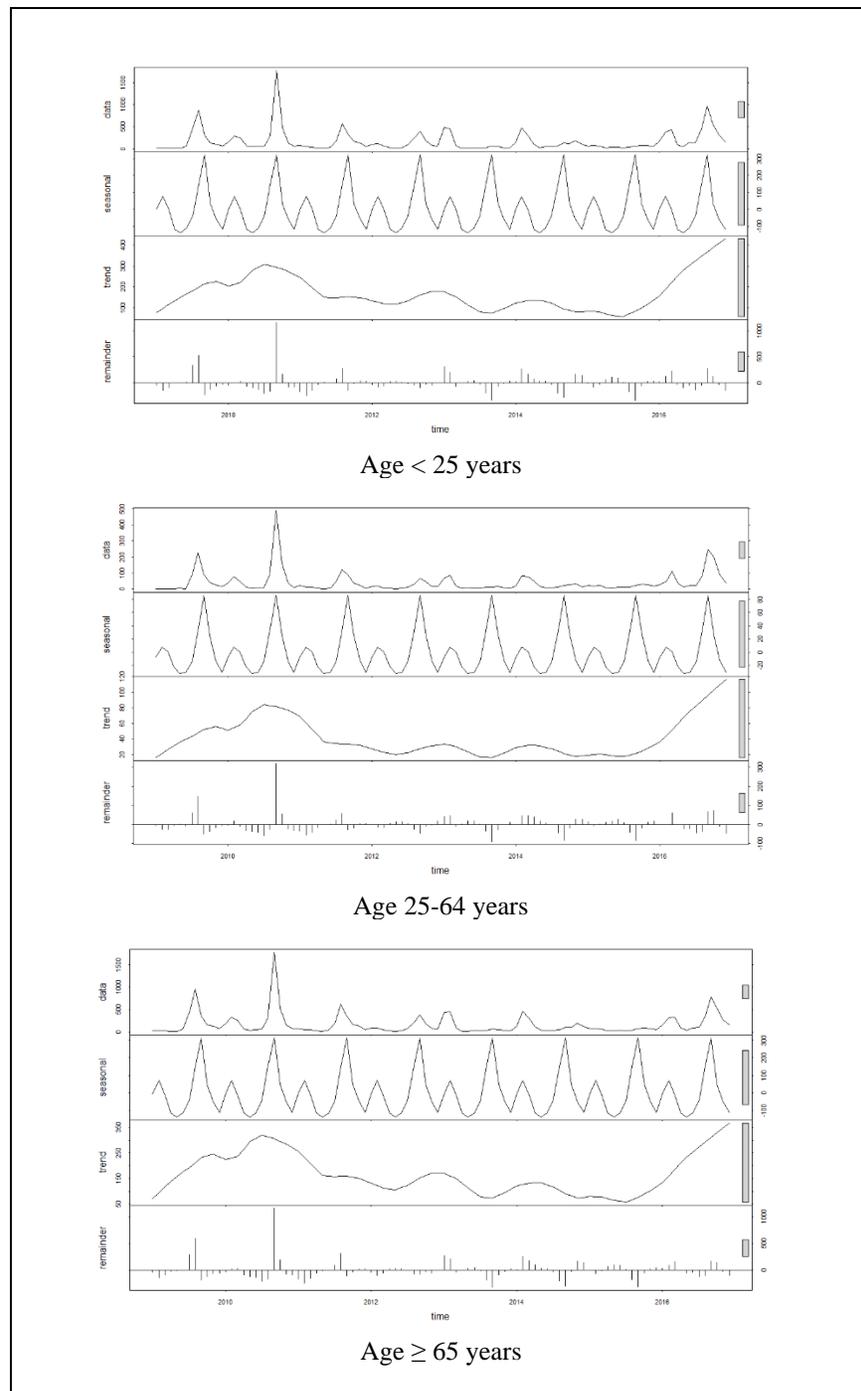


Figure 1. Influenza cases, seasonality and trend of age < 25 year (top), age 25-64 years (middle) and age ≥ 65 years (bottom) in Phitsanulok province, Northern Thailand

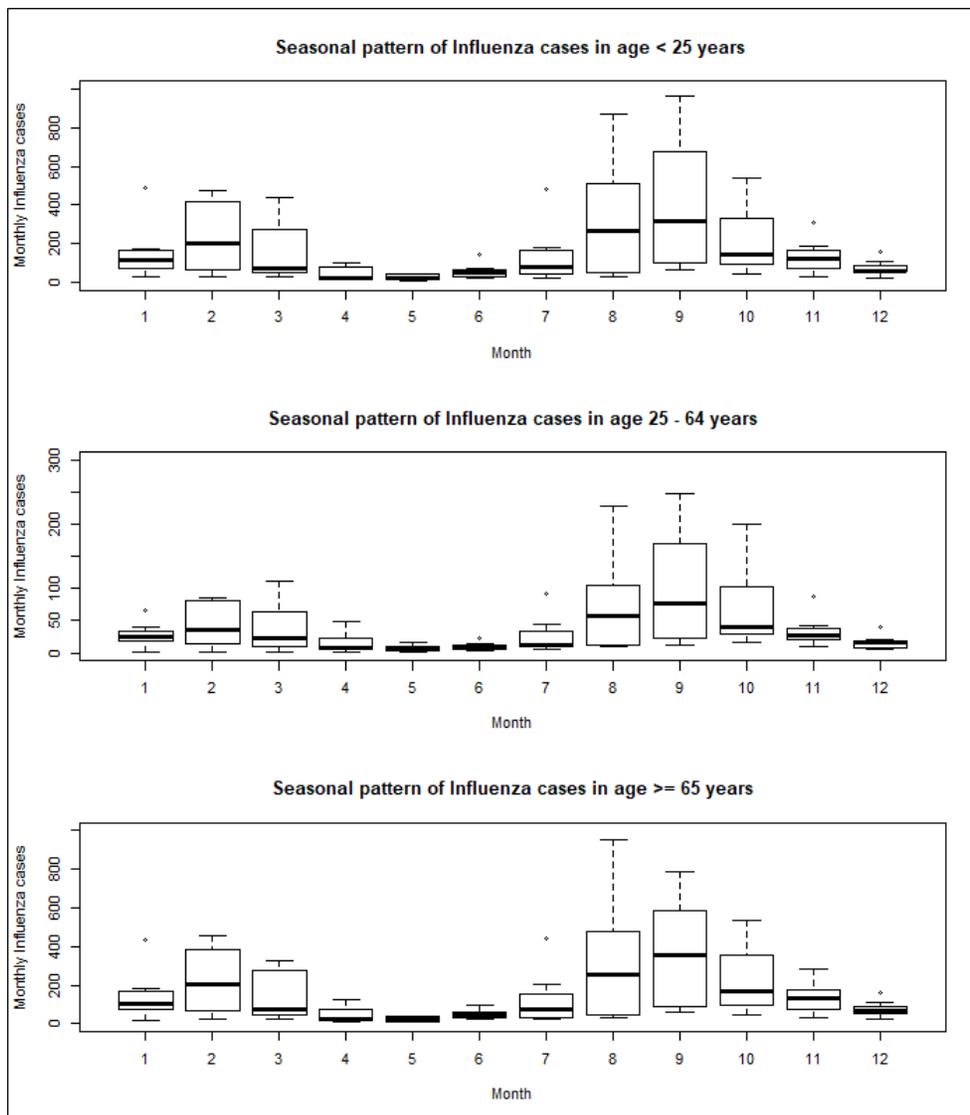


Figure 2. Box plot of Influenza cases (maximum, average, minimum) by month from 2009 to 2016 in age < 25 year (top), age 25-64 years (middle), and age \geq 65 years (bottom) in Phitsanulok province, Northern Thailand

3.2 Synchrony of Influenza for different age groups

Measuring synchrony of monthly Influenza cases in Phitsanulok province for all pairs of data series by age group, the results showed strong correlation ($r = 0.97$ to 0.99) in all pairs of the data series. Considering season, the strong correlation was also observed in all pairs of data series by age group during summer, rainy and winter seasons. This indicated that Influenza cases in the three age groups co-varied or consistently fluctuated over time (Table 1).

Table 1. Pearson correlation of monthly Influenza cases for all pairs data series by age group and seasons in Phitsanulok province, northern Thailand

Pairs of data series	Correlation Coefficient (r)											
	All year round January - December			Summer season March – May			Rainy season June – October			Winter season November- February		
	1	2	3	1	2	3	1	2	3	1	2	3
1	1.000	0.971	0.992	1.000	0.899	0.899	1.000	0.959	0.993	1.000	0.965	0.966
2	0.971	1.000	0.985	0.899	1.000	0.985	0.959	1.000	0.934	0.965	1.000	0.969
3	0.992	0.985	1.000	0.899	0.985	1.000	0.993	0.934	1.000	0.966	0.969	1.000

Note: 1=Data series of Influenza cases in age < 25 years, 2=Data series of Influenza cases in age 25 - 64 years and 3=Data series of Influenza cases in age ≥ 65 years

3.3 Identifying the best seasonal ARIMA model for each data series

The best model to forecast Influenza cases for age <25 years, age 25-64 years and age ≥ 65 years was seasonal ARIMA (1,0,1)(0,1,1)₁₂, seasonal ARIMA (1,0,0)(0,1,1)₁₂ and seasonal ARIMA (1,0,1)(1,1,1)₁₂, respectively. The MAPE, which calculated by comparing the predicted cases with reported cases during January to December 2016, were 15.54, 17.27 and 15.61 (Table 2).

Table 2. The best model, AIC and MAPE for each data series

Data series	Seasonal ARIMA model (p,d,q)(P,D,Q) ^s	AIC	MAPE
Age < 25 years	(1,0,1)(0,1,1) ₁₂	155.50	15.54
Age 25 - 64 years	(1,0,0)(0,1,1) ₁₂	209.12	17.27
Age ≥ 65 years	(1,0,1)(1,1,1) ₁₂	148.20	15.61

3.4 Forecast of Influenza cases from January to December 2017

The best model for each data series was fitted to monthly Influenza cases for January 2009 to December 2016 to forecast Influenza cases from January to December 2017. There were 1,698 forecasted cases in age < 25 years, followed by 1478 cases in age ≥ 65 years and 471 cases in age 25-64 years. The major peak in September and minor peak in February were observed in all age groups (Figure 3). Comparison between forecasted cases and reports cases in 2017, the forecasted cases were lower than the reported cases in all data series, except for age ≥ 65 years, which the forecasted cases were higher than the reported cases (Figure 4).

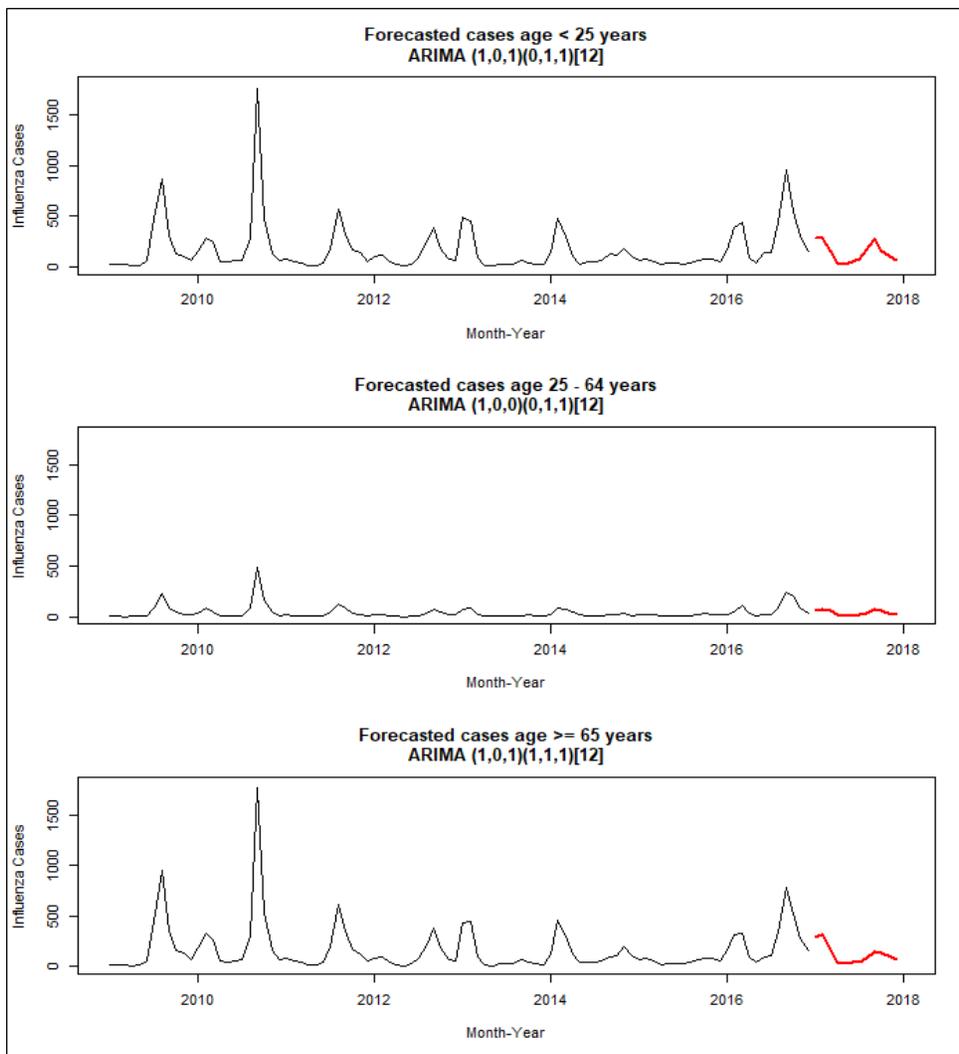


Figure 3. Monthly forecasted Influenza cases from January to December 2017 for each data series: age < 25 years (top), age 25-64 years (middle), and age \geq 65 years (bottom) in Phitsanulok province, Northern Thailand

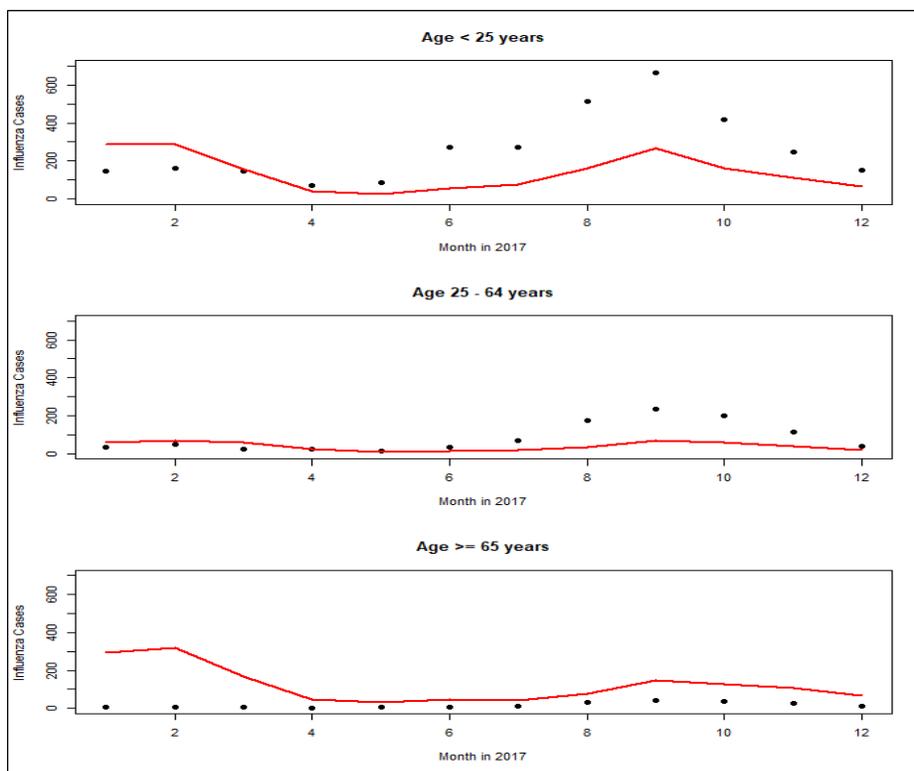


Figure 4. Monthly forecasted Influenza cases (line) for each data series compared with reported cases (dot) from January to December 2017: age < 25 years (top), age 25-64 years (middle) and age \geq 65 years (bottom) in Phitsanulok province, Northern Thailand

The trend of Influenza cases for the three age groups; less than 25 years, 25-64 years and 65 years and older; had increased from 2009 to 2011, thereafter the trend was slightly decreased and increased in 2016. This was in accordance with the cyclic pattern which likely showed major peak in two consecutive years for every five years (2009-2010 and 2016-2017). However, due to only eight years of data series, it may not be clear to see the cyclic pattern of the disease. Various cyclic patterns of Influenza have been observed, such as every 1, 2-3, 5-6, 8, 10.6-11.3, 13 and 18-19 years. The cyclic patterns were associated with the cycle of natural environment related to Physico-chemical processes and irradiations of cosmic or terrestrial origin, called as space weather [9-12]. Some previous researches reported that Influenza epidemic changes had been 1.3 times more frequent in the years of the sudden increase in solar activity. Moreover, the cyclic variations of Influenza every 2-4 years can be associated with the frequency of such sudden changes [9, 10].

Seasonality, the major peak occurred in September and minor peak most likely occurred in February. The major peak in September may cause by rainfall, which increases humidity and precipitation. This corresponds with the highest cumulative rainfall in Phitsanulok province which was reported from August to September (247 mm) [13]. Those factors are related to increased Influenza activities [14]. In fact, year-round Influenza activity is more common in tropical countries [15, 16] including Thailand with the peak during rainy season between July and September [17, 18], and a seasonal pattern of Influenza in non-epidemic year caused by circulation of Influenza A [19]. The minor peak in February, during winter, may be due to the low

temperature which increases virus stability. This is in line with the minimum temperature in Phitsanulok province, which was 18.6°C in December to 25.4 °C in April [13]. The low temperatures and humidity enhance the temperate countries typically experience Influenza during winter season [20-23].

Temporal patterns of Influenza among the three age groups were not different. This corresponded with the results of synchronicity which found that Influenza occurrence of the three age groups co-varied or consistently fluctuated over time, both in year-round and each season. This reflects the disease occurrence are more likely affected by common factors rather than specific host factors in different age groups. The common factors can be an exogenous factor such as meteorological factors (temperature, rainfall, humidity) [20-23] and solar activity [10] or it can be some host factors found in all age groups, such as contact pattern [24, 25] and personal hygiene; hand washing, wearing a protective mask when illness [26]. Those factors concomitantly enhance the etiologic agent and spread of Influenza in all age groups. However, some previous studies reported the differences among age groups due to pre-existing specific immunity, accessibility to health services and physiological factors [27, 28].

The reported cases in age less than 25 and age 24-64 years were higher than the forecasted cases. This is in line with the nationwide epidemic of Influenza in 2017 which showed that there were 61 event-based surveillance of Influenza outbreaks in 2017, compared to 34 and 24 events in 2016 and 2018, respectively [29]. On the contrary, the reported cases in age ≥ 65 years were lower than the forecasted cases. It may be due to the reason that in 2017 Phitsanulok province has supported free vaccination for the four high risk groups which included elderly older than 65 years. It was found that the coverage of the vaccination in the elderly was quite high, which may be due to the campaign and accessibility to government services [30, 31]. Therefore, the reported cases were lower than the forecasted cases.

4. Conclusions

Trend of Influenza cases for the three age groups in Phitsanulok province slightly decreased from 2011 to 2015 and dramatically increased in 2016. The two peaks were observed; major peak in September and minor peak in February. The cyclic pattern likely observed major peak in two consecutive years for every five years. All pairs of data series co-varied over time. The forecasted cases of the three age groups were less than cases in 2016. The major peak in February and minor peak in September were observed in all data series. Age less than 25 years had the highest forecasted cases, followed by age 65 years and older and age 25-64 years. The forecasted cases in 2017 were lower than the reported cases in all data series, except for age ≥ 65 years. Prevention and control of Influenza should be strengthened before September (rainy season) and February (winter), focusing on the common factors enhancing the disease occurrence in all age, such as hygiene, hand washing, wearing a protective mask when illness. In order to get more accurate forecast, meteorological factors (temperature, rainfall, humidity), environment, space weather, and solar activity should be included in the forecasting model. The variables in surveillance system should be utilized to guide more specific for Influenza prevention and control.

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