Meteorologically favourable zones for seasonal influenza A and B in Hong Kong: abridged secondary publication

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KEY MESSAGES

1. An accurate risk alert system for influenza epidemics may promote public awareness of the risk of influenza infection. We used a supervised discretisation approach to establish meteorologically favourable zones for influenza epidemics in Hong Kong.
2. Using laboratory-confirmed data from four hospitals in Hong Kong for the period 2004 to 2019, we demonstrated satisfactory classification performance of meteorologically favourable zones based on ambient temperature and relative humidity. The performance was validated by the use of influenza-like illness plus, which is a combined metric comprising clinical diagnosis and laboratory data.
3. Favourable zones for influenza A involved either high temperatures and high humidity in the hot season, or low temperatures in the cold season, whereas favourable zones for influenza B simply required cold conditions.
4. Our findings may help public health and meteorology officials to establish a meteorology-based warning system for increased influenza activity.

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Introduction

Seasonal influenza causes a substantial disease burden each year. Influenza seasonality differs across climate zones. In temperate regions, influenza seasonality exhibits a consistent unimodal peak in winter. In tropical and subtropical regions, influenza seasonality exhibits a more diverse pattern. Influenza A and B are associated with different meteorological parameters.[1] In Hong Kong, influenza exhibits a bimodal seasonality, with one peak in winter and spring and another peak in summer. Some meteorological zones are more favourable for influenza activity.[2] This study was conducted to identify meteorologically favourable zones for influenza A and B, which would facilitate preparation for periods of increased demand for healthcare facilities.

Methods

We collected the weekly detection rates of laboratory-confirmed influenza A and B among inpatients admitted to four public hospitals in Hong Kong (Prince of Wales Hospital, Queen Elizabeth Hospital, Kwong Wah Hospital, and United Christian Hospital) between 1 January 2004 and 31 December 2019. We also performed an analysis of influenza-like illness plus (ILI+), which is a metric comprising the weekly viral detection rate and ILI+ count to validate our findings. We included data regarding inpatients admitted for upper respiratory tract infections, based on International Classification of Diseases (version 9) codes 460 to 487.

An influenza epidemic was defined as a period when influenza activity was above the 50th percentile in a year (ie, from week 44 to week 43 in the following year). To reduce stochastic variation in case detection, we included the two adjacent weeks (1 week before and 1 week after) in each epidemic period. Meteorologically favourable zones were defined as intervals in which meteorological variables had optimal performance in predicting influenza epidemics.

Meteorology records for the included hospitals were collected from their nearest weather stations. Meteorological data including weekly mean ambient temperature, relative humidity, and total rainfall were matched to the time periods covered by influenza data. Actual vapour pressure was used as a proxy for absolute humidity. Additionally, weekly mean concentrations of air pollutants (carbon monoxide, nitrogen dioxide, ozone, sulphur dioxide, and fine particulate matter) were collected from the website of the Environmental Protection Department. The locations of air quality monitoring stations were matched to the locations of the corresponding hospitals. Because school closures are commonly used as public health interventions to interrupt influenza transmission within a community, records of school closures were collected from school calendars for the study period; the school closure variable was regarded as an indicator in the analysis.

We used classification and regression trees as a supervised discretisation approach to discretise continuous variables to intervals that can optimise prediction algorithm performance.[3] Because two influenza peaks were observed in each year, we developed an ensemble model of classification and regression trees stratified by hot season (ie, weeks 13 to 44) and cold season (ie, week 45 to week 12 in the next year); we developed separate models for influenza A and both influenza types. We established a receiver operating characteristic curve to evaluate the discriminating powers of meteorologically favourable zones; we used area under the curve (AUC) as the prediction endpoint for model optimisation. Prediction performance was considered good, excellent, and outstanding when the AUC was 0.7-0.8, 0.8-0.9, and >0.9, respectively. The cut-off point nearest to the top-left portion of the receiver operating characteristic curve was treated as a threshold to maximise the sensitivity and specificity of epidemic prediction. Data were divided into two sets: 2004 to 2014 (for the training model) and 2014 to 2019 (for the validation model). Evaluation statistics were derived for both datasets.

The primary analysis model included the predictors of ambient temperature and relative humidity, with a 3-week lag based on the typical duration of laboratory testing and reporting delay. Absolute humidity was used in the primary model because it is better than relative humidity in indicating influenza seasonality. We also evaluated prediction performance in terms of vulnerable age groups (0-4, 5-9, 10-14, and ≥65 years). To assess the validity of using the laboratory-confirmed rate of influenza as an indicator of influenza activity, the ILI+ rate was used in a separate analysis. Two additional models were established to identify potential improvements in prediction performance: (1) a full model including temperature, relative humidity, total rainfall, and all pollutants; and (2) a model including school closure as an indicator in the primary model using temperature and relative humidity. We also examined whether the results remained robust when the lag was set to 2 weeks and 4 weeks.

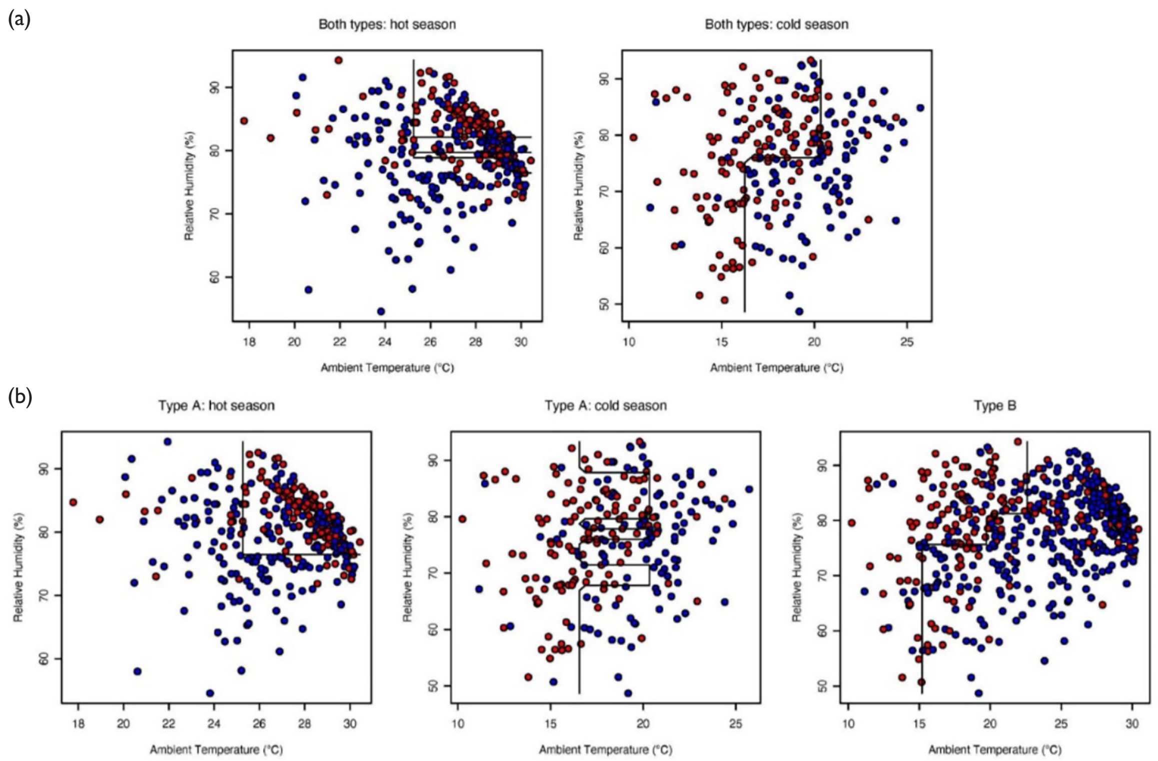

FIG 1. Scatter plots of influenza epidemics in different ambient temperature and relative humidity conditions for (a) both influenza types and (b) influenza A and B. Meteorologically favourable zones are used to classify epidemic weeks (red dots) and non-epidemic weeks (blue dots).

Results

In total, 392 epidemic weeks and 443 non-epidemic weeks were analysed. Using the primary model, meteorologically favourable zones based on mean temperature and relative humidity were established (Fig 1). Generally, temperature >25.1°C and relative humidity >79% were favourable conditions for an influenza epidemic in the hot season, whereas either (temperature <16.4°C) or (temperature <20.4°C with relative humidity >76%) was favourable condition for an influenza epidemic in the cold season. The training model had an AUC of 0.80 (95% confidence interval [CI]=0.76-0.83) with a sensitivity of 0.75 and a specificity of 0.74 for epidemic prediction (Fig 2). The validation model had an AUC of 0.71 (95% CI=0.65-0.77).

The training and validation models demonstrated similar AUCs of meteorologically favourable zones for influenza A in cold and hot seasons (Figs 1 and 2). Meteorologically favourable zones for influenza B were less consistent; the validation model exhibited an AUC of <0.7. The replacement of relative humidity with absolute humidity did not lead to apparent improvements in AUCs.

Meteorologically favourable zones were established for epidemic prediction in vulnerable age groups (Fig 3). Epidemic prediction performance varied among models, although the training model had an AUC >0.7. The classification of meteorologically favourable zones generally demonstrated good performance for prediction of influenza epidemics among individuals aged 0 to 4 years; the AUCs for both influenza types were 0.76 (95% CI=0.72-0.80) in the training model and 0.75 (95% CI=0.69-0.81) in the validation model. Decreased AUCs for epidemic prediction were observed when only influenza A or influenza B was considered. The classification of meteorologically favourable zones did not demonstrate good performance for age groups of 5 to 9 years, 10 to 14 years, and ≥65 years.

Our results remained robust when the outcome was modified to ILI+. A full model was developed using temperature, relative humidity, total rainfall, and pollutants; however, the validation model showed that AUCs of epidemic prediction were unsatisfactory, presumably because of increased complexity or model over-fitting. Inclusion of the school closure indicator did not improve epidemic prediction performance, compared with the primary model using temperature and relative humidity. Finally, epidemic prediction performance was not affected by 1-week changes in lag.

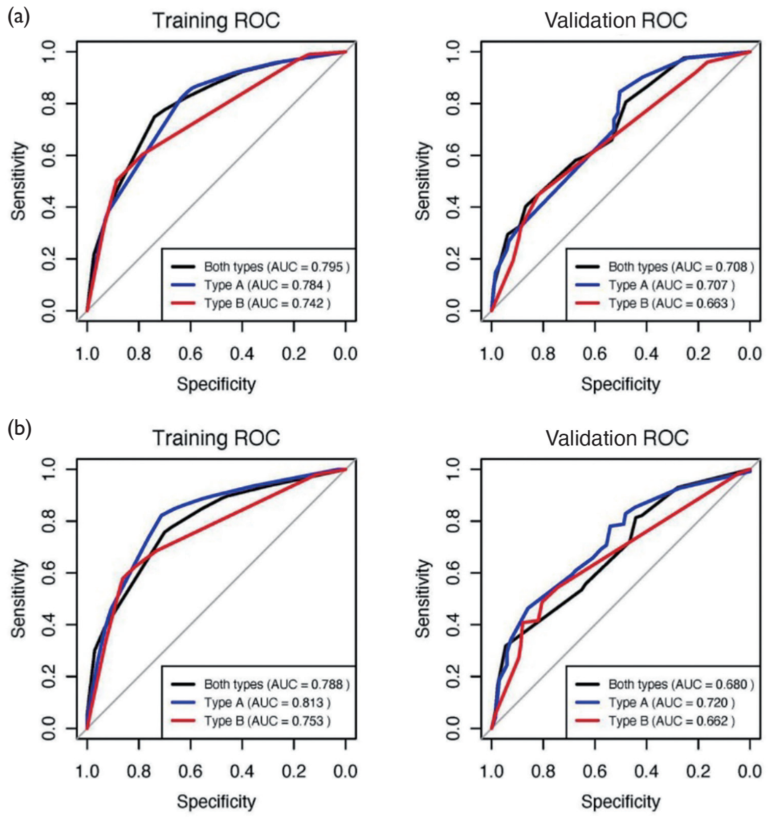

FIG 2. Receiver operating characteristic (ROC) curves established using training and validation data for (a) temperature and relative humidity and (b) temperature and absolute humidity.

Discussion

In the present study, we used a supervised discretisation approach to establish meteorologically favourable zones for influenza epidemics in Hong Kong. Using laboratory-confirmed data for the period 2004 to 2019, we showed that the classification performance of meteorologically favourable zones based on ambient temperature and relative humidity was excellent in the training model and good in the validation model. Compared with the results of a single-centre study conducted in Hong Kong in 2009,[2] our findings are generally consistent: favourable zones for influenza A involved either high temperatures and high humidity in the hot season or low temperatures in the cold season, whereas the favourable zone for influenza B simply required cold conditions. Our findings were supported by external validation (ie, ILI+ data); they could facilitate the establishment of an alert system for increased influenza activity.

Cold conditions were favourable for the activities of both influenza types. Indeed, cold weather is a common meteorological determinant of influenza seasonality in epidemiological and laboratory investigations[1,2,4] because it affects the frequency of indoor activity and the environmental stability for viral survival. However, the effect of relative humidity on influenza seasonality was less consistent. In the present study, the favourable zone

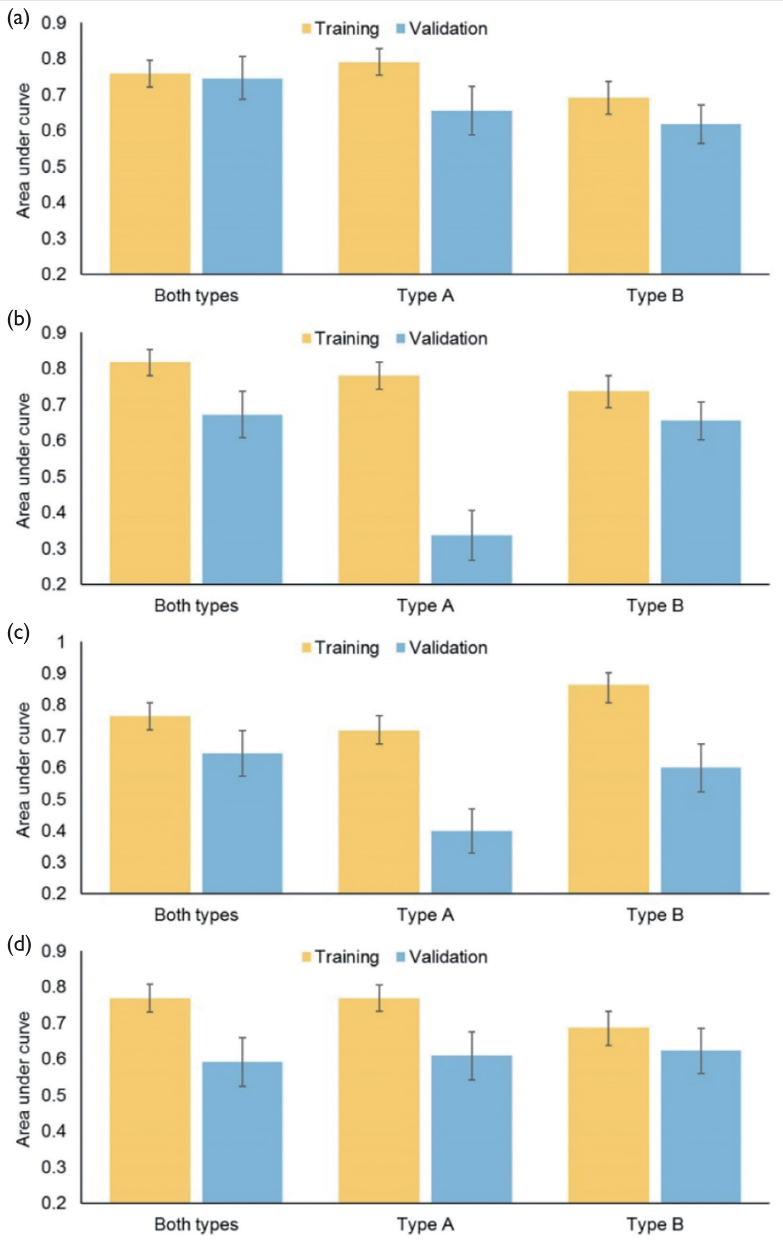

FIG 3. Areas under the curve of meteorologically favourable zones for both influenza types and influenza A and B, established using training and validation data, for epidemic prediction among age groups of (a) 0-4, (b) 5-9, (c) 10-14, and (d) ≥65 years.

of relative humidity differed according to influenza type, and the seasonal effect was affected by the dominant type of influenza in a particular year. In fact, relative humidity is not reliable to infer biological aspects of many organisms. For influenza viruses, absolute humidity has a stronger effect on transmission and survival. The effect of absolute humidity on influenza seasonality is more prominent in temperate settings but is attenuated in warmer climate settings (eg, subtropical regions).[5]

Despite satisfactory prediction performance overall, meteorologically favourable zones did not demonstrate good performance for age groups of 5 to 9 years, 10 to 14 years, and ≥65 years. We speculate that school children tend to have more social contacts than people in other age groups. Differences in contact patterns may influence the effect of meteorological conditions on viral transmission. Similarly, other covariates (eg, influenza-mediated exacerbation of chronic conditions) may affect influenza activity in older adults.

Conclusion

The classification performance of meteorologically favourable zones, established using ambient temperature and relative humidity, was satisfactory in Hong Kong. The performance was validated by the use of ILI+, which is a combined metric comprising clinical diagnosis and laboratory data. Our findings were supported by external validation, suggesting that meteorologically favourable zones could be used to establish an alert system for increased influenza activity. The system may promote infection risk awareness in the general public and ensure early preparation by healthcare officials for influenza season.

Funding

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Disclosure

The results of this research have been previously published in:
1. Chong KC, Chan PKS, Lee TC, et al. Determining meteorologically-favorable zones for seasonal influenza activity in Hong Kong. Int J Biometeorol 2023;67:609-19.

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