The Potential Benefits of Location Specific Biometeorological Indexes

Ho Ting WONG, Jinfeng WANG, Qian YIN, Si CHEN, Poh Chin LAI

Abstract

It is becoming popular to use biometeorological indexes to study the effects of weather on human health. Most of the biometeorological indexes were developed decades ago and only applicable to certain locations because of different climate types. Merely using standard biometeorological indexes to replace typical weather factors in biometeorological studies of different locations may not be an ideal research direction.

This research is aimed at assessing the difference of statistical power between using standard biometeorological indexes and typical weather factors on describing the effects of extreme weather conditions on daily ambulance demands in Hong Kong. Results showed that Net Effective Temperature and Apparent Temperature did not perform better than typical weather factors in describing daily ambulance demands in this study. The maximum adj-R^2 improvement was only 0.08, whereas the maximum adj-R^2 deterioration was 0.07.

In this study, biometeorological indexes did not perform better than typical weather factors, possibly due to the differences of built environments and lifestyles in different locations and eras. Regarding built environments, the original parameters for calculating the index values may not be applicable to Hong Kong that buildings in Hong Kong are extremely dense and most are equipped with air-conditioners. Regarding lifestyles, the parameters, which were set decades ago, may be outdated and not suitable to modern lifestyles that using hand-held electrical fans on the street to help reduce heat stress are popular. Hence, it is ideal to have tailor-made updated location specific biometeorological indexes to study the effects of weather on human health.

Keywords: ambulance; biometeorological index; health; weather

Introduction

The issue of climate change has long been a popular discussion topic among scholars and the public. Evidence suggests that the effects of global warming are one of the major problems faced by mankind. This inspired many researchers to study the effects of extreme weather conditions on different aspects of health outcomes, such as heat related illnesses (Sugg et al. 2016), suicide (Page et al. 2007), and ambulance demand (Wong et al. 2015a). A majority of the earlier studies used typical weather variables (e.g. average temperature, relative humidity, etc.) to quantify weather conditions (Ohshige et al. 2005; Liang et al. 2009; Wong and Lai 2010; Wong et al. 2015b). Most found that extreme weather conditions have a significant impact on human health. As such studies are very popular, researchers start to use biometeorological indexes such as Net Effective Temperature (NET) (Hentschel 1986) and Apparent Temperature (AT) (Steadman 1984) to conduct further analysis. It is believed that using biometeorological indexes to assess the impacts of extreme weather conditions on human health is better than using typical weather factors. This is because biometeorological indexes are generally developed based on theoretical stands. Moreover, they are composed of more than one weather factor that can better explain non-linear interaction effects between weather factors. For example, during windy and dry days, people may have a higher tolerance for high temperatures, whereas they may feel uncomfortable on wet and windless days. In fact, The World Meteorological Organization and World Health Organization also recommend using biometeorological indexes to evaluate the impacts of heat stress on human health (McGregor et al. 2010).

Studies using biometeorological indexes are now very popular (Chung et al. 2009; Wichmann et al. 2011; Xu et al. 2013). Although many related studies reported that significant relationships between weather and health were found, it is questionable if the relationships obtained by correlating biometeorological indexes and health outcomes can always better reflect the real situations compared to typical weather factors. For the case when biometeorological indexes depend on the factor of air temperature heavily, it is common that index values are usually in the same proportion as air temperature values. Merely adopting biometeorological indexes may result in obtaining a weaker weather-health relationship if the indexes chosen were not suitable. For example, it is common for researchers to use outdoor weather factors measured by weather stations to correlate with health outcomes. However, this approach is questionable as people in metropolitan area generally spend more than 90% of their time indoors, while indoor and outdoor climate are not always strongly correlated (Nguyen et al. 2013). In Hong Kong, the built environments are very different from Western countries as buildings are extremely dense and most are equipped with air-conditioners. Moreover, it is well known that indoor temperature in Hong Kong is commonly maintained at a very low level (e.g. below 20°C). Even in the outdoor environment, it is popular for people to use hand-held electrical fans on the street to help reduce heat stress, which was impossible decades ago. Hence, people in Hong Kong are less likely to be affected by outdoor weather conditions, which implies that standard biometeorological indexes are less useful. In particular, on exceptionally hot days, street sleepers may just move to and stay in shopping malls or McDonald's 24-hour stores to enjoy the air conditioned environment, which sparked the term “McRefugee.” It is questionable if standardized and commonly used biometeorological indexes such as NET and AT are suitable for use in metropolitan regions such as Hong Kong. In this connection, this study seeks to compare the performance of applying typical weather factors and biometeorological indexes to describe daily ambulance demand in Hong Kong.

Materials and Methods

Data

The data used in this study is secondary time-series data generated from the study on the relationship between typical weather factors and daily ambulance demands by Wong (2012). The time-series data includes daily ambulance demands in Hong Kong by patients’ age, gender, triage level, hospital admission status, and economic status from May 2006 to April 2009. Although it is worth to know the time spent outdoors to enrich the study, the use of hospital record limited the availability of such information. In addition, hourly temperature, relative humidity, and wind speed values based on a time measurements (e.g. at 12:00, 13:00, 24:00, etc) measured by the Hong Kong Observatory located in the central of Hong Kong were used to calculate the daily average NET and AT values of the same period. Daily average values NET and AT were chosen because they can cater for the analysis of both summer and winter period. Moreover, the choice in this study is also consistent with the choice of Wong (2012) which make the comparison more convenient. As the total area of Hong Kong is only $2755\ \mathrm{km}^2$, the single weather station measurement is representative to the whole Hong Kong territory and adopted by different similar studies (Wong 2012; Wong et al. 2015b).

The equations of NET and AT are listed as below:

$$\mathrm{NET} = 37 - \frac{37 - T}{0.68 - 0.0014\mathrm{RH} + \frac{1}{(1.76 + 1.4v^{0.75})}} - 0.29T(1 - 0.01RH)$$

$$AT = -2.7 + 1.04\mathrm{T} + 2\mathrm{e} - 0.65\mathrm{v}$$

where T is temperature, RH is relative humidity, v is wind speed, and e is water pressure defined as $\mathrm{e} = \left(\frac{RH}{100}\right) \mathrm{x} 6.10 \mathrm{xexp}(17.27\mathrm{x}\frac{\mathrm{T}}{237.7+\mathrm{T}})$. Detailed information about the original dataset can be found in Wong (2012).

Data analysis

Extreme weather conditions may not have immediate effects on daily ambulance demands, so the optimal number of lag days was first being identified through correlating the NET and AT time-series data with the daily ambulance demands of 1) all people in Hong Kong and 2) only people aged above 65. Each ambulance demand time-series data (dependent variable) was then regressed on the NET and AT time-series data (independent variable) respectively with the lag effects being adjusted. The adj-R^2 obtained from the regression models were compared to the adj-R^2 of the model composed of the factors of air temperature (i.e. average temperature, average temperature square, and sum of average temperature difference) obtained in Wong's study (2012) to find out if biometeorological indexes could better describe daily ambulance demands in Hong

Kong. Although Wong's study included models with other weather factors such as relative humidity, pressure, and cloud, they would only be considered if the biometeorological index outperformed the model with air temperature related factors only. All the data preprocessing steps applied in this study were the same as those applied in Wong's study (2012) so that comparison of the regression results can be made.

Results

According to Table 1, the adj-R^2 obtained from biometeorological indexes were similar to those obtained from typical weather factors. Although some of the regression models constructed using biometeorological indexes had a better adj-R^2 value, the improvements were insignificant (maximum adj-R^2 improvement =0.08). In some cases, biometeorological indexes even performed worse than typical weather factors (maximum adj-R^2deterioration =0.07).

<please insert Table 1 here>

Discussion

In this study, biometeorological indexes did not perform significantly better than typical weather factors, and sometimes performed slightly worse. This is consistent with the results of an Australian, which also showed that the capability of modeling outcomes of heat-related mortality using average temperature and different biometeorological indexes were similar (Vaneckova et al. 2011). Although biometeorological indexes have the advantage of having a single numerical value to describe different weather conditions, which is useful when a threshold value is required to develop a warning system, they may not have enough power to describe different health outcomes even if the outcome is sensitive to extreme weather conditions. For this study, it is possible that the biometeorological indexes were lowered because their parameters might not be suitable for the situation in Hong Kong. In fact, Effective Temperature (ET) was first introduced by Houghton and Yaglou (1923), and Missenard (1933) further developed the mathematical formula. NET was named by Li and Chan (2000) through adapting the Missenard formula (Blazejczyk et al. 2012),while AT was created in 1984 (Steadman 1984). We mentioned earlier, the modern built environments are quite different from that of decades ago, the changes may affect street air ventilation and resulted in lower wind speed and higher air temperature. As in metropolitan areas, outdoor weather data were typically measured on building roof top and people typically spend 90% of the time indoor, outdoor weather measurements may not be able to reflect the environmental conditions that people is facing. Hence, it was not surprising that the biometeorological indexes did not outperform typical weather factors, it is also questionable if biometeorological indexes can be applied in different places of the world without recalibrating their parameters or redefining threshold values for issuing location specific warning signals. Ideally, it is better for each location to have its own biometeorological index calculated using tailor made formula based on specific health outcomes. For this reason, the Hong Kong Observatory has already attempted to develop the Hong Kong Heat Index (HKHI) for use in Hong Kong based on hospitalization rate (Lee et al. 2016), although a significant number of weather and health studies chose to use standard biometeorological indexes without any adjustment.

To conclude, it is ideal to redevelop location specific biometeorological indexes or recalibrate NET and AT so that the new indexes can be applied in different regions and the distinctive built environments and lifestyles can be accounted for. One of the ways to achieve this is through regressing important health outcomes on different weather factors and let the data to decide the optimum factors with the help of corresponding subject knowledge. In fact, the development of HKHI is already a good example on developing a tailor made biometeorological index for local use, although indoor climate was not considered

When such a recalibrated or tailor-made biometeorological index is not available, it is suggested to include typical weather factors as a control in studies so the performance of biometeorological indexes can be assessed.

Acknowledgments

We are grateful to the following government departments of the Hong Kong Special Administrative Region for access to data records used in the present study: Hospital Authority and Hong Kong Observatory.

Conflict of Interest

The authors declare that they have no conflict of interest.

References

Blazejczyk K, Epstein Y, Jendritzky G, Staiger H, Tinz B (2012) Comparison of UTCI to selected thermal indices. Int J Biometeorol 56(3):515-535.

Chung JY, Honda Y, Hong YC, Pan XC, Guo YL, Kim H (2009) Ambient temperature and mortality: an international study in four capital cities of East Asia. Sci Total Environ 408(2): 390-396.

Hentschel G (1986) A human biometeorology classification of climate for large and local scales. Proc. WMO/HMO/UNEP Symposium on Climate and Human Health.

Houghton FC, Yaglou CP (1923) Determination of the comfort zone. ASHVE Trans 29:515-536.

Lee KL, Chan YH, Lee TC, Goggins WB, Chan EYY (2016) The development of the Hong Kong Heat Index for enhancing the heat stress information service of the Hong Kong Observatory. Int J Biometeorol 60(7): 1029-1039.

Li PW, Chan ST. (2000) Application of a weather stress index for alerting the public to stressful weather in Hong Kong. Meteorol Appl 7(4):369-375.

Liang WM, Liu WP, Kuo HW (2009) Diurnal temperature range and emergency room admissions for chronic obstructive pulmonary disease in Taiwan. Int J Biometeorol 53(1): 17-23.

McGregor G, Bessemoulin P, Ebi K, Menne B (2010) Heat waves and health: guidance on warning system development. World Meteorological Organization, 14, 15.

Missenard FA (1933) Température effective d'une atmosphere Généralisation température résultante d'un milieu. In: Encyclopédie Industrielle et Commerciale, Etude physiologique et technique de la ventilation. Librerie de l'Enseignement Technique, Paris, pp 131-85.

Nguyen JL, Schwartz J, Dockery DW (2014) The relationship between indoor and outdoor temperature, apparent temperature, relative humidity, and absolute humidity. Indoor Air. 24(1):103-112.

Ohshige K, Hori Y, Tochikubo O, Sugiyama M (2005) Influence of weather on emergency transport events coded as stroke: population-based study in Japan. Int J Biometeorol 50(5): 305.

Page LA, Hajat S, Kovats RS (2007) Relationship between daily suicide counts and temperature in England and Wales. Br J Psychiatry 191(2): 106-112.

Steadman RG (1984) A universal scale of apparent temperature. JCAM 23(12): 1674-1687.

Sugg MM, Konrad CE, Fuhrmann CM (2016) Relationships between maximum temperature and heat-related illness across North Carolina, USA. Int J Biometeorol 60(5): 663-675.

Vaneckova P, Neville G, Tippett V, Aitken P, FitzGerald G, Tong S (2011) Do biometeorological indices improve modeling outcomes of heat-related mortality? JCAM

50(6): 1165-1176.

Wichmann J, Andersen Z, Ketzel M, Ellermann T, Loft S (2011) Apparent temperature and cause-specific emergency hospital admissions in Greater Copenhagen, Denmark. PLoS One 6(7): e22904.

Wong HT, Lai PC (2010) Weather inference and daily demand for emergency ambulance services. Emerg Med J 29(1): 60-4.

Wong HT (2012) Biometeorological Modelling and Forecasting of Ambulance Demand for Hong Kong: A Spatio-Temporal Approach. Dissertation, The University of Hong Kong.

Wong HT, Yin Q, Guo YQ, Murray K, Zhou DH, Slade D (2015a) Big data as a new approach in emergency medicine research. J Acute Dis 4(3): 178-179.

Wong HT, Chiu MYL, Wu CST, Lee TC, SCHSA (2015b) The influence of weather on health-related help-seeking behavior of senior citizens in Hong Kong. Int J Biometeorol 59(3): 373-376.

Xu W, Thach TQ, Chau YK, Lai HK, Lam TH, Chan WM, Lee RS, Hedley AJ, Wong CM (2013) Thermal stress associated mortality risk and effect modification by sex and obesity in an elderly cohort of Chinese in Hong Kong. Environ Pollut 178: 288-293.

Table 1 The difference between using biometeorological indexes and typical weather factors*** in describing daily ambulance demand

		Typical weather factor*	NET*		AT*	
		adj-R^2	adj-R^2	improvement	adj-R^2	improvement
Age	0-14	n.a.	n.a.	n.a.	n.a.	n.a.
	15-34	0.15	0.15	0.00	0.16	0.01
	35-64	0.24	0.25	0.01	0.30	0.06
	65+	0.74	0.69	-0.05	0.67	-0.07
gender	Male	0.46	0.40	-0.06	0.42	-0.04
	Female	0.42	0.43	0.01	0.44	0.02
Triage Level	1	0.62	0.57	-0.05	0.56	-0.06
	2	0.50	0.46	-0.04	0.47	-0.03
	3	0.61	0.57	-0.04	0.55	-0.06
	4	0.15	0.17	0.02	0.23	0.08
	5	n.a.	n.a.	n.a.	n.a.	n.a.
Hospitalization status	Admit	0.70	0.66	-0.04	0.63	-0.07
	Not admit	0.14	0.14	0.00	0.21	0.07
Economic Status	CSSA**	0.51	0.48	-0.04	0.47	-0.04
	Non-CSSA	0.40	0.38	-0.02	0.40	0.00
Overall		0.49	0.46	-0.03	0.48	-0.01

*4-day time-lag data; **CSSA: Comprehensive Social Security Assistance;*** Typical weather factors includes temperature, average temperature square, and sum of average temperature difference (Wong 2012).