Analysis of Appropriate Index for Heat-related morbidity

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Background

Due to climate change and urbanization, thermal problems in urban areas are becoming serious. The frequency and intensity of heat waves are expected to intensify due to the deterioration of the thermal environment in urban areas, and heat waves become a great threat to the health of urban residents. In 2003, 35,000 people died in a heat wave of over 40 degrees Celsius in Europe. It shows heat waves greatly affects the occurrence and death of heat-related diseases in urban residents. Various studies have been conducted to understand the correlation between heat waves and heat-related diseases. Most studies focus on the correlation between heat waves and deaths, and evaluate the heat-related risk by deriving thresholds related to the increase in the number of deaths. However, it is hard to understand heat-related risk appropriately because previous studies use different indicators for heat waves and set different thresholds. Also, these thresholds are derived from heat mortality data, not morbidity. So it can not be used to evaluate heat-related risk about the occurrence of heat-related diseases. Therefore, in this study, the threshold for the heat morbidity is derived from and compared with different heat related indicators used in previous studies to select the most appropriate indicators and thresholds.

Data and Study area

The city of Seoul, South Korea, an area of approximately 605 km2 was chosen as a study area. Seoul is a city of more than 9 million people and most urbanized city in South Korea. The average temperature increase rate in Seoul is higher than the global average temperature increase rate, and heat-related problems have recently emerged.

We use a heat-related morbidity data from the Korea Disease Control and Prevention Agency(KDCA). The KDCA has been monitoring the incidences of heat-related illness (HRI) during the heat waves every summer via the HRI Surveillance System since 2011. The data acquired in 2021 and 2022 are used for this study, because the morbidity data is provided in district level since 2021.

The temperature and relative humidity data from S-DoT(Smart Seoul Data of Things) are used in this study. S-DoT is the combined sensor that collects 15 types of data produced by the Seoul Metropolitan Government. There are about total 1,100 sensors in Seoul and they collect meteorological data on hourly

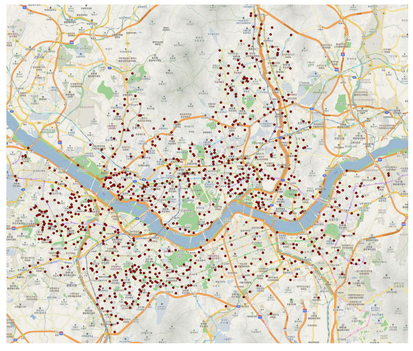

Fig 1. Study sites and the location of sensors (Adapted from : https://www.vw-lab.com/97)

Methodology

Data Pre-processing

There are total 167,232 data in the meteorological data of S-DoT. But there are some outliers due to troubles with sensors. So we select the 5 sensors that working normally and calculate the average gap between the hourly data. Then drop the data that hourly gap exceeds more than two time of the average.
After dropping the outliers, we calculate four different indices. (the daily mean temperature, the daily mean WBGT, the daily maximum temperature and the daily maximum WBGT.
Then we calculate the mean number of patients at intervals of 0.2 Celsius from 20 to 40 Celsius in each indices. The 0.2 interval was chosen by considering the sensor's accuracy.

WBGT Estimation

$$WBGT = -0.2442 + 0.55399T_w + 0.45535T_a - 0.0022T_w^2 + 0.00278T_wT_a$$

$$T_w = T_a \tan^{-1}[0.151977(RH + 8.313659)]^{1/2} + \tan^{-1}(T_a + RH) - \tan^{-1}(RH - 1.67633) + 0.00391838RH^{3/2}\tan^{-1}(0.023131RH) - 4.686035$$

Eq 1. WBGT estimation of the KMA2006 model (Ta : air temperature, RH : relative humidity)

We use the KMA 2006 model that developed by the Korea Meteorological Administration. This model use only two meteorological variables, so it can also be used for observation instruments that can not measure solar radiation such as AWS(Automatic Weather Station). Although the model use only two variables, it's accuracy has been verified through previous studies(Lee et al., 2019). S-DoT sensors can measure the black-bulb temperature but there are a lot of missing values, so we choose KMA2006 model for estimating hourly WBGT.

Regression and Set Threshold

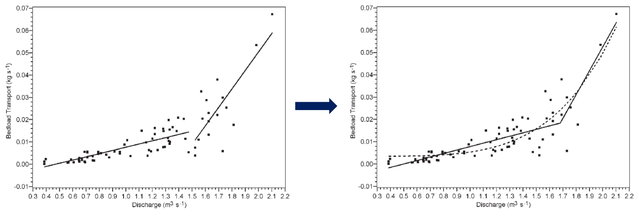

Fig 2. An example of the piece wise regression

The piecewise regression is a form of regression that allows multiple linear models to be fitted to a data for different ranges of x values. We assumed that the heat-related morbidity will be increased when the heat indices exceed the threshold. So we think that the piecewise regression will be fitted better than linear or polynomial regression that we commonly use.
We set only one breakpoint to figure out the starting point of increasing heat morbidity and this breakpoint is a threshold of heat-related morbidity

Results & Discussions

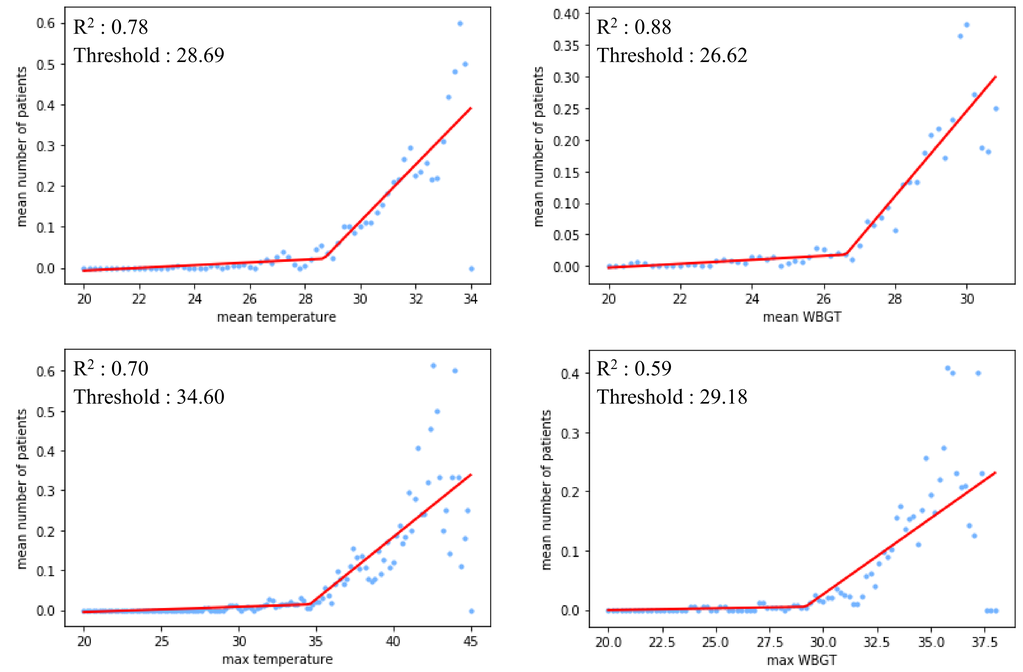

Fig 3. The results of piecewise regression about 4 different indices

All four indices were correlated with the mean number of patients. The index with the highest correlation was the daily mean WBGT, with 26.62 degrees as the threshold and the lowest one was the daily maximum WBGT. Both temperature and WBGT showed a higher correlation in the daily mean value than the daily maximum value. It is estimated that the installation location of measurement sensors such as residential areas, parks, and construction sites has increased volatility in the maximum temperature, which has reduced accuracy compared to the mean value.
Out of a total 6726 data, (1) 1266 data exceeded the daily mean temperature threshold and (2) 1532 data exceeded the daily mean WBGT threshold. There were many overlapping data between the two results, but the daily mean WBGT captures extra 10 more patient than the other one.

	A	B	A-B	B-A
number of data	1266	1532	60	326
number of patients	181	191	0	10

Table 1. The results of comparing daily mean temperature and daily mean WBGT as a index for heat morbidity (A : Above the threshold of daily mean temperature, B : Above the threshold of daily mean WBGT)

Conclusions

This study provides an insight for appropriate index for heat-related morbidity. The daily mean WBGT shows the highest correlation with heat-related morbidity. It can explain more about the heat-related morbidity than the other three indices that we commonly use. It can be helpful to policy makers or heat-related researchers to evaluate the heat-related risk and find appropriate threshold.

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