Should public health systems use simple thermohygrometric indices into urban environment?

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Messeri A [1.2], Morabito M [1.2], Petralli M [1.2]*, Orlandini S [1.2]

CIBIC, Interdepartmental Centre of Bioclimatology, University of Florence, Florence, Italy[1]*
alessandro.messeri@unifi.it
DIPSA, Department of Plant, Soil and Environmental Sciences , University of Florence, Florence, Italy[2]

Abstract

Outdoor human heat perception is not only related to ambient temperature and humidity, as described in most direct biometeorological indices, but also to wind speed and solar radiation. Numerous biometeorological indices are used in Heat-Health Warning System and hot weather response plans to describe the discomfort conditions during the summer. This topic is of great interest because heat wave frequency and intensity is expected to increase due to climate change. The aim of this study was to compare the performance of the most frequently used direct indices in order to assess the thermal discomfort condition during the summer period (2007 - 2010) in several cities of Tuscany (Italy). In each city, one of the interlard and one of the costal plans, characterized by different climatic and geographical conditions, data from two different weather stations were collected (one in the city center and one in the suburb) in order to describe the intra-urban difference of thermal perception. Results showed a very similar trends between all direct thermohygrometric indices even if apparent temperature index seems to be more appropriate to describe the perceived thermal conditions in suburban areas where the wind speed might also be 6-7 times stronger than in the city center. According to these results, the choice and the consequent use of an appropriate thermal index appears a very important step to implement specific preventive measures for health and to set up a reliable heat warning system for the elderly and for the entire population.

Keywords: biometeorological indices, discomfort condition, heat warning system,

1. Introduction

In recent years, because of climate change, the number and the frequency of heat waves during summer in temperate regions has increased with a major impact on public health, especially for elderly people and children [1]. Moreover, in large urban centers, the heat island phenomenon makes thermal conditions even more critical during the hottest days of the year due to the high presence of buildings and impervious surfaces [2]. This is caused by the influences of urban characteristics on meteorological parameters, in particular wind, air temperature and humidity, which determines much difference of temperature perception between the city center and the suburbs. The habitual parameters used to calculate the biometeorological indices are air temperature and relative humidity, but some indices also consider other variables, such as wind speed, atmospheric pressure and solar radiation [3]. Nowadays, also in Italy some of these indices are used in heat warning system, particularly useful for elderly people but also for the entire population, especially if outdoor activities are performed. The main constraint, however, consists in the lack of uniformity of indices application, because each Region and each Institution use different indices. For this reason is crucial to understand the differences and the main limitations of each index [4,5]. Differences between two cities located in different geographical and climatic conditions (inland plains and coastal city) have been also assessed. This study focused on the possibility of using an index with a great potential use such as the Apparent Temperature Index (AT), which is able to evaluate the effect of the wind, coupled with temperature and humidity. Moreover, the choice and the consequent use of an appropriate index is a very important step to prevent the impact of heat on public health.

2. Materials and methods

2.1 Meteorological data

The meteorological data of the Tuscan city centres examined during the period 2007-2010 were obtained from GSM meteorological stations (Teckna model) installed by the Interdepartmental Centre of Bioclimatology of the University of Florence. These stations are located in the city centre of an inland plain city, Florence (Lat 43 ° 46 '44", Long 11 ° 15' 40", re altitude 50m) and in a coastal town, Leghorn (Lat 43 ° 33 '10", Long 10 ° 19' 18", Height 9m). These stations provide air temperature (°C), wind speed (ms-1), solar radiation (Wm-2), relative humidity (%), barometric pressure (hPa) and precipitation (mm) every thirty minutes. The meteorological data of

the suburb areas were achieved by the meteorological stations of the "Centro Funzionale della Regione Toscana". All stations are installed in accordance with the rules of the World Meteorological Organization (WMO-World Meteorology Society) [6].
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2.2 Biometeorological indices

Amongst the numerous biometeorological indices available, the most commonly used for physiological thermal-discomfort during the summer season purposes in Italy were selected (i.e. Apparent Temperature Index with and without wind, Humidex, Discomfort Index). The Apparent Temperature Index (AT), developed in 1979, was the first index of heat being used operationally by the U.S. National Weather Service to predict heat thermal discomfort conditions in a large geographical area [7]. In this study two versions of AT were calculated:

a) ATp : calculation of the apparent temperature considering the effect of air temperature (Ta,°C) and vapor pressure (Pa, kPa) [3]:

$$ATp = 0{,}89\ Ta + 3{,}83\ Pa - 2{,}56$$

b) ATw: calculation of the apparent temperature considering also the effect of the wind (ms-1, measured at 10 m above the ground) when the vapor pressure is 1.6 kPa [3]:

$$ATw = Ta + 3{,}30\ Pa - 0{,}70\ V10 - 4$$

The "Humidex Index" (H) (Masterson & Richardson) developed in Canada in 1979 [8] and still used during summer season, was also considered. This index allows to take into account the combined effect of air temperature (Ta,°C) and vapor pressure (Pa, hPa).

$$H = Ta + (0{,}5555 \times (Pa - 10))$$

In Italy, the Humidex index is usually considered as a benchmark for the "National System of Surveillance, since dives an efficient forecast and warning for the prevention of the effects of heat waves on health. Finally, Discomfort Index (DI) was calculated [9], which takes account both wet bulb temperature (Tw,°C) and dry bulb temperature (Ta, ° C).

$$DI = 0{,}4 \times (Ta + Tw) + 4{,}8$$

This index is currently used by the Meteorological Service of Emilia-Romagna Region during summer season [10].

2.3 Statistical analysis

Meteorological and biometeorological data was analyzed by means of ANOVA statistical analysis and Tukey's test was applied to compare the averages.

3. Results

3.1 Meteorological analysis

Regarding air temperature and humidity, meteorological data analysis did not show any significant differences between the center and suburb for the inland city (Florence) as regards (Tab.1).

Table 1: Average values of meteorological parameters (temperature, humidity and wind speed) in Florence city center and suburbs during the summer.

Florence				
Parameter	**Zone**	**June**	**July**	**August**
Temp.(°C)	center	21.8	25.3	24.3
	suburb	22.4	25.8	24.8
Sign.		n.s	n.s	n.s
Humidity(%)	center	64.2	52.4	57.8
	suburb	64.5	53.9	57.9
Sign.		n.s	n.s	n.s
Wind(m/s)	center	0.3	0.4	0.4
	suburb	2.5	2.5	2.4
Sign.		0.001	0.001	0.001

On the opposite, wind speed presents the average values considerably higher in the suburb. The coastal town of Leghorn, however, shows differences not only in wind but also in temperature (Tab.2)

Table 2: Average values of meteorological parameters (temperature, humidity and wind speed) in Leghorn city center and suburbs during the summer.

Leghorn				
Parameter	**Zone**	**June**	**July**	**August**
Temp.(°C)	center	22.1	25.1	25.2
	suburb	20.6	23.4	23.0
Sign.		0.0001	0.001	0.001
Humidity(%)	center	72.2	67.3	69.7
	suburb	74.8	72.7	73.7
Sign.		n.s	0.01	n.s
Wind(m/s)	center	0.3	0.3	0.3
	suburb	2.1	2.2	2.0
Sign.		0.001	0.001	0.001

In Florence, the higher homogeneity in temperature distribution between center and suburb is probably due to the increased influence of the urban heat island effect of the city which is larger and extensive than the coastal city. In fact, according to what reported in scientific literature, big cities are usually characterized by more developed heat islands [11]. On the opposite, the wind speed show higher values in the suburbs than in the downtown in both the analysed cities, likely due, to a minor density of urban buildings and streets [6].

3.2 Biometeorological analysis

Fig.1 shows the most important biometeorological direct indices widely applied in literature and in the specific Apparent Temperature Index with and without the contribution of the wind (ATp and ATw, respectively), Humidex (H) and Discomfort Index (DI) for the center (A) and suburb (B) of Florence city.

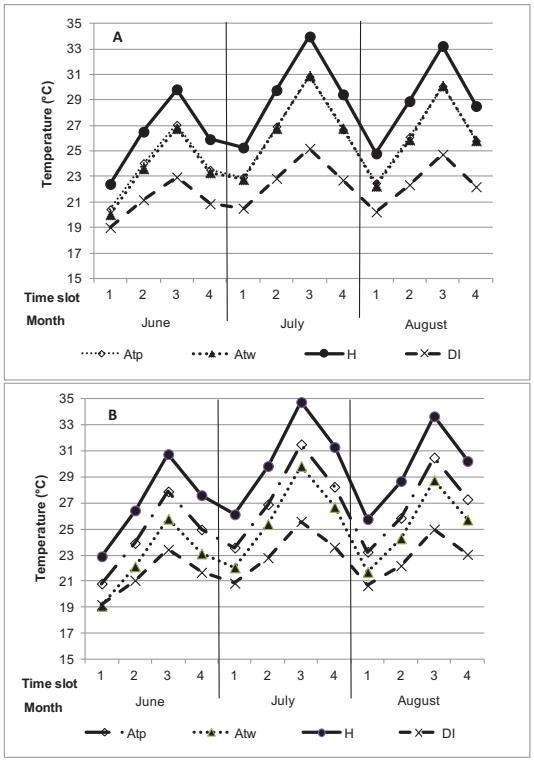

Fig 1. Average perceived temperatures of time slots (night 0-5;morning 6-11, afternoon 12-17, evening 18-23) during the summer in the center (A) and in suburb (B) of Florence.

Significant strong correlations were observed between all biometeorological indices applied both in the historical center and in the suburb. However, comparing two different areas of the city, a greater difference between the mean values, calculated with different indices in the suburbs, is observed. This result suggests the importance in the selection of the index that can be used: the one (ATw) which takes into account also wind and humidity is more reliable, index shows the most extreme values of physiological discomfort from heat amongst all the analysed indices. Mean differences with others appear to be highest during the afternoon, with about 3-5 ° C higher compared to the AT with and without wind, and 9-10 °C compared to the DI. However, the major differences between centers and suburbs are highlighted in the comparison of ATp and ATw. In the center, the trends of the two indices are virtually superimposed during the day and in every summer month. This is likely due to wind influence which is minimized (in terms of speed and intensity) by the higher density of buildings than in suburbs [12]. This is even more evident in the suburb of Leghorn, located along the sea shire (fig. 2). In this area, the presence of sea breezes determines relevant differences reaching the maximum value of about 2°C during the time slot 3 between ATp and ATw.

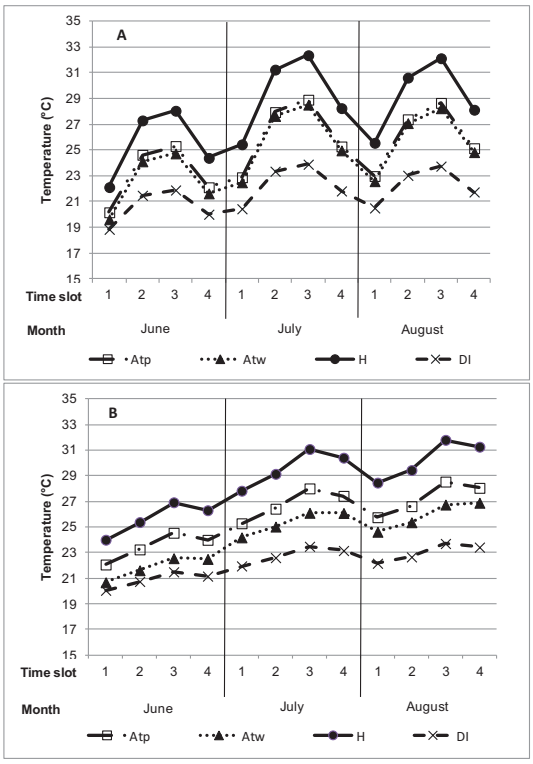

Fig 2. Average perceived temperatures of time slots (night 0-5;morning 6-11, afternoon 12-17, evening 18-23) during the summer in the center (A) and in suburb (B) of Leghorn.

Compared to Florence, however, in this case, the higher temperature values are achieved in the center and not in the suburban zone where a more mitigation effect of the sea occurs.

4. Discussion

In this study a strong correlation between all biometeorological indices applied was observed. However, relevant differences between stations located in highly urbanized areas and stations located in the suburb zones were observed both in Florence and Leghorn. This is particularly evident during the afternoon and in days characterized by high humidity and wind speed values. The Apparent Temperature Index, which takes into consideration also the contribution of the wind, revealed to be the most efficient biometeorological index to describe thermal conditions in the urban environment. Moreover, wind plays a key role in this context, especially in the suburban areas where ATw showed revelant differences comparing to the Apparent Temperature Index without the consideration of wind (ATp). ATw index provided therefore the greatest performance in evaluating thermo-physiological conditions of heat discomfort inside large urban centers and in any geographical areas particularly affected by wind, such as coastal cities or suburb areas.

5. Conclusion

The use of a biometeorological index which takes into consideration also the effect of wind seems to be more effective in describing the comfort or discomfort conditions during summer season. ATw is used in the Tuscany Region Heat health Warning System for safeguarding the health of the greatest risk groups, particularly the elderly.

6. Acknowledgements

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