Enthalpy as an environmental parameter for healthy management decisions

Firmo Sousa Campos[1], Carla dos Santos Riccardi[2], Valéria Cristina Rodrigues Sarnighausen[3]

[1]Graduando do curso de Bacharelado em Física da UNESP, Campus de Bauru, SP. E-mail: firmocamp@fca.unesp.br
[2]Professora assistente doutora do Departamento de Bioprocessos e Biotecnologia, Faculdade de Ciências Agronômicas da UNESP, Campus de Botucatu, SP. E-mail: carla_riccardi@fca.unesp.br
[3]Professora assistente doutora do Departamento de Bioprocessos e Biotecnologia, Faculdade de Ciências Agronômicas da UNESP, Campus de Botucatu, SP. E-mail: valeriacrs@fca.unesp.br

Abstract: Climatic changes have potential effects on human health, specifically effects related to the respiratory and the cardiac systems. The enthalpy can be an auxiliary to identify medical care in short time. This parameter can be used for management decisions and take preventive measurements in time, as hospital logistics. This study aimed to use the enthalpy as environmental parameter to evaluate the effect of seasonality on respiratory and cardiac symptoms in Botucatu, a Brazilian city with a tropical altitude climate. Results show that the air enthalpy profile through the year is situated within estimated thermal comfort levels, and reported hospitalizations have been more frequent during the cold season months. Through simple correlation analysis it was possible to identify that symptoms occur when the air enthalpy variation is smaller. Being a preliminary study, a deeper analysis is needed, taking other factors into consideration, such as thermal sensation indexes and hospitalization report dates.

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ntroduction

There are a variety of different indexes that can be used to determine the level of thermal comfort on a given location. While some consider dry bulb temperature and relative air humidity as indicators of possible heat stress in an environment (Monteiro and Alucci, 2007), other authors take a different approach at profiling, such as air enthalpy. Enthalpy is a thermodynamic property that establishes the amount of heat available in any given substance or mixture. Since atmospheric air is a mixture of different gasses, it is possible to use enthalpy to identify the amount of sensible and latent heat available in an environment, enabling its use to establish thermal comfort levels for animals, humans and plants (Rodrigues et al. 2010). For humans, the use of such an index, calculated from the relation between dry bulb temperature, relative air humidity and barometric pressure, allows for an analysis of the climate conditions and its effect on the population, not only in relation to thermal comfort levels, but also as a health indicator. Dry bulb temperatures between 18 and 30 ºC and relative humidity between 30 and 80% are considered parameters of thermal comfort for humans (INMET, 2009), and values that are outside of these limits are considered as a situation of stress. Using an enthalpy equation elaborated directly as an index (Rodrigues et al. 2010), the calculated enthalpy values are between 31,02 kJ/kg of dry air, for minimum temperature and relative humidity levels, and 68,12 kJ/kg of dry air for maximum temperature and relative humidity values, using an estimated barometric pressure of around 760 mmHg for both cases.

These values represent an air enthalpy band where humans can be in a thermal comfort situation. As such, the enthalpy index opens the possibility of analyzing the profile for not only indoor environments, but also as a reliable indicator of thermal comfort for outdoor environments as well, alongside other established indicators, such as black globe temperature (Heidari et al., 2016), and it is also possible to identify situations where climatic conditions can be critical for the occurrence and aggravation of some diseases and health issues, such as respiratory and cardiac symptoms (Silva Júnior et al., 2011). It is known that some respiratory diseases are more common in drier situations, with less precipitation and when relative air humidity levels are low (Alves et al., 2015). Similarly, some cardiac problems and diseases can occur or get aggravated in hot and very humid days (Murara et al., 2010). It should be said, though, that the occurrence of these issues also depends on a variety of other factors, such as wind speed and air pollution (Nascimento et al., 2006). This way, the analysis of outdoor public environments becomes important due to the ever-expanding nature of cities and the fact that the heavily circulated urban locations are prone to absorb and trap heat due to the amount of buildings and paved roads present, creating heat islands and leading to situations of heat stress, which leads to public health issues, especially with those who work outdoors most of their time (Heidari et al., 2015).

Therefore, the aim of this work is to establish enthalpy as an outdoor thermal index for the city of Botucatu and cross-reference these enthalpy profiles with reported hospitalizations, with the objective of finding correlation between them.

Material and Methods

This work utilizes two different data sets for statistical analysis. The first is a database of meteorological measurements, spanning a period of three years (2014 to 2016), collected from the meteorological station located in the School for Agricultural Sciences, in the city of Botucatu (22º31'S, 48º15' W, 840 m above sea level), which is situated in the state of São Paulo, Brazil. Per the Köppen climatic classification, the city of Botucatu is considered a Cwa type climate, a tropical altitude climate with a dry winter season and hot and humid summer season, with average hotter month temperatures above 22 ºC (CEPAGRI, 2017). The data utilized is comprised of daily measurements of dry bulb temperature (*t*) and relative air humidity (*RH*), along with an average value for the local barometric pressure (p_B). These values were utilized in the equation presented below (Rodrigues et al., 2010) to obtain the atmospheric air enthalpy (*h*) for the location of study.

$$h = 1{,}006.t + \frac{RH}{p_B}.10^{(7{,}5.t/237{,}3+t)}.(71{,}28 + 0{,}052.t) \qquad \text{(I)}$$

The second set of data is comprised of monthly hospitalization records of public and private hospitals for cardiorespiratory diseases (CID-10 chapters 9 and 10), collected from the Health Department's Unified Health System information bank (DATASUS, 2017), from the years of 2014 to 2016. The maximum and minimum air enthalpy values were calculated for each given day and used analyzed along with the monthly hospitalization count. These values were plotted in three graphs, one for each year of study, along with the minimum (*h (Min)*) and maximum (*h (Max)*) thermal comfort air enthalpy, calculated earlier, to establish the thermal comfort band in each graph. For validation purposes, a correlation analysis was performed between the air enthalpy variation and the diseases of study (pneumonia, acute bronchitis, acute myocardial infarction, cardiac insufficiency and other ischemic heart diseases).

Results and Discussion

The meteorological and medical data were organized together in a graph to allow an in-depth analysis of the reported hospitalizations per disease, when compared with the air enthalpy profile for the period of study. Figure 1 shows such graphs, each representing the air enthalpy profile and the hospitalizations occurred for each of the three years studied. Overall, the air enthalpy profiles show a wider range of variation during the hotter periods of the year, from January to March and from September to December, and a smaller differential during the cold season, from April through August. In comparison with the considered thermal comfort levels for humans (31,02 and 68,12 kJ/kg of dry air), the maximum air enthalpy peaks outside of the maximum thermal comfort limit throughout the hotter seasons, while staying near that limit during the colder months. Meanwhile, the minimum air temperature is located just inside or on the minimum thermal comfort limit throughout the year, with peaks during the fall/winter season.

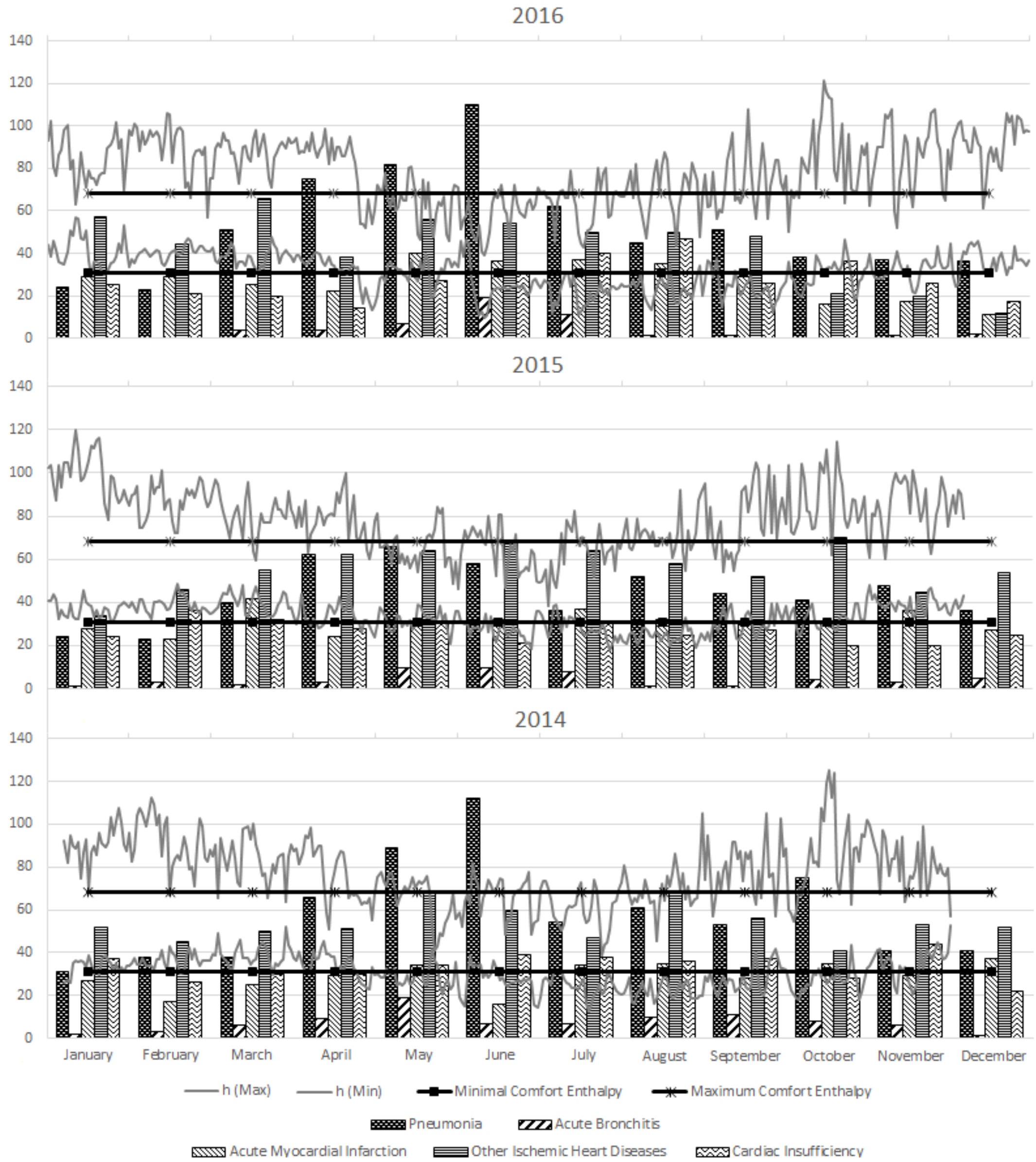

Figure 1. Time series of air enthalpy and number of reported disease symptoms for the city of Botucatu (2014-2016).

The graphs show that the number of reported hospitalizations increases during the cold season, between April and August. During these months, the air enthalpy index has minimal variation between minimum and maximum values, and even though such values are situated within the considered thermal comfort levels for humans, making so that hypothermia (cold stress) and hyperthermia (heat stress) are not factors during this period, the increase in cardiac and respiratory symptoms is significant when compared with the rest of the year. In 2014, number of reports of pneumonia symptoms increased 194,7 % from March, which marks the end of summer, to June, the beginning of winter. In 2015, reports increased 45 % during the same period; in 2016, the increase was 119,6 %.

During the cold season, the low temperatures and relative air humidity cause the blood vessels to suffer constriction, making it difficult for the blood to flow through the body, favoring the occurrence of arterial hypertension, cardiac insufficiency and heart attacks (Murara et al., 2010). This is even further complicated by air pollution, since the air is drier and there is less precipitation to dissipate the particulates suspended in the atmosphere. These particulates enter the blood stream through respiration and cause the blood to thicken, thus further complicating blood flow through veins and arteries.

Air pollution and lower temperatures are also complicating factors in respiratory problems, where air, dry and saturated with particulates, enters the lungs and cause various symptoms, from allergic reactions to pulmonary infections (Silva Junior et al., 2011).

The air enthalpy index shows that the smaller the enthalpy variation during a day, the worse the climatic conditions are, favoring the occurrence of such symptoms. This is further corroborated after realizing a simple correlation analysis, located in Table 1, between the air enthalpy variation and the increase in the number of reported hospitalizations.

Table 1. Simple correlation for maximum/minimum air enthalpy variation and reported hospitalizations.

Variables **Δh (kJ/kg dry air)**	**Pneumonia**	**Acute Bronchitis**	**Acute Myocardial Infarction**	**Other Ischemic Heart Diseases**	**Cardiac Insufficiency**
2014	0,08	0,24	-0,31	-0,11	0,10
2015	-0,2	-0,42	0,00	-0,26	0,12
2016	-0,60	-0,60	-0,77	-0,61	-0,23

There are indications of some dependence between the air enthalpy variation and the number of reported hospitalizations. In 2016, strong inverse correlation was obtained for acute myocardial infarction (-0,77), other ischemic heart diseases (-0,61) and acute bronchitis and pneumonia (-0,6), meaning that the smaller the variation in the air enthalpy index, the higher the occurrence of such symptoms.

The lack of correlation in the years of 2014 and 2015 can be attributed to the possibility that the hospitalizations were reported in time periods differing from the actual climatic situations where these symptoms would be favored of occurring. That way, the hospitalization data would not align properly with the air enthalpy profile, leading to inconsistencies. Even so, some symptoms did show some correlation, such as acute bronchitis (-0,42) for the year of 2015.

Conclusions

There are indications that the climatic analysis through the air enthalpy index can identify possible microclimatic situations that can favor the occurrence or aggravation of symptoms for the cardiorespiratory diseases studied (pneumonia, acute bronchitis, acute myocardial infarction, other ischemic heart diseases and cardiac insufficiency), leading to hospitalizations. However, since this is a preliminary study, further, more precise analysis needs to be done, taking into consideration thermal sensation variables, like the wind chill index and the heat stress index, and the period where hospitalizations are reported.

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