ORIGINAL ARTICLE

Climate Interactions and Respiratory Diseases in Children

Margarida Ramalho[1], Nuno Amaro[2], Ricardo Deus[3], Paulo Jorge Nogueira[4,5,6,7,8], Teresa Bandeira[9,10]

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Abstract

Introduction: Temperature and relative humidity affect health, particularly the respiratory system. Children represent a risk group, due to immature systems and continual development. The present study aimed to analyze the effects of temperature and relative humidity on hospitalizations of children due to asthma exacerbations and respiratory infections.
Methods: This retrospective study analyzed administrative data from patients with respiratory infections and/or asthma exacerbations who were admitted to the pediatric service in a central hospital from 2018 to 2020. Pearson and Spearman correlations, Student *t* test, analysis of variance, and the equivalent non-parametric tests were used to describe the association between environmental factors, such as temperature and relative humidity, on children hospitalizations due to asthma exacerbations and acute respiratory infections. Negative binomial regression was used to model the daily expected hospitalizations.
Results: This study was conducted on a total of 369 clinical records of primary and secondary discharge diagnoses related to 338 children. In 2020, there was a decline in admissions, due to the COVID-19 pandemic. The viral lower respiratory infections, asthma, upper respiratory infections, and non-viral lower respiratory infections accounted for 51.2%, 17.9%, 16.3%, and 14.6% of recorded diagnoses, respectively. The mean ± standard deviation of daily temperature and relative humidity was 14.8ºC ± 4.0ºC and 77.7% ± 12.7%, respectively. A negative correlation was found with maximum temperature ($p = 0.012$), and a positive correlation was observed with mean relative humidity ($p = 0.045$). There was a significant association between viral lower respiratory infections and hospitalizations, which increased with the mean temperatures < 10.0ºC and relative humidity > 86.67%. Finally, our best model showed a negative correlation between daily mean temperature and hospitalizations (incidence rate ratio = 0.989).
Conclusion: Cold and humidity were associated with hospitalizations for asthma and respiratory infections. Further studies with other variables (*eg* pollutants) may identify other factors more precisely and advocate prevention and health planning.

Keywords: Adolescent; Asthma/epidemiology; Asthma/etiology; Child; Climate; Humidity; Infant; Meteorological Concepts; Patient Admission/trends; Portugal; Respiratory Tract Infections/epidemiology; Respiratory Tract Infections/etiology; Temperature; Weather

Keypoints

What is known:
- Meteorology influences the seasonality of respiratory infections and asthma triggers.
- Respiratory infections are very prevalent diseases with social and economic impacts.

What is added:
- This was the first study to determine the impact of meteorological variables on pediatric asthma exacerbations and respiratory infections in Lisbon.

Introduction

Environmental conditions and pollution impact the health and development of children, contributing to death, disease, and disability.[1] Children are more sensitive to environmental hazards due to their physiological, metabolic, and behavioral characteristics. There is growing evidence of the influence of ambient temperature on the occurrence of acute asthma exacerbations through activation of inflammatory

1. Faculdade de Medicina, Universidade de Lisboa, Lisboa, Portugal
2. Planning and Management Information Office, Centro Hospitalar Universitário Lisboa Norte, Lisboa, Portugal
3. Climate and Climate Change Division, Instituto Português do Mar e da Atmosfera, Lisboa, Portugal
4. Biomathematics Laboratory, Instituto de Medicina Preventiva, Faculdade de Medicina, Universidade de Lisboa, Lisboa, Portugal
5. Environmental Health Institute, Instituto de Medicina Preventiva, Faculdade de Medicina, Universidade de Lisboa, Lisboa, Portugal
6. Centro de Investigação, Inovação e Desenvolvimento em Enfermagem de Lisboa, Escola Superior de Enfermagem de Lisboa, Lisboa, Portugal
7. Public Health Research Centre, NOVA National School of Public Health, Universidade Nova de Lisboa, Lisboa, Portugal
8. Comprehensive Health Research Center, Lisboa, Portugal
9. Unidade de Pneumologia Pediátrica, Serviço de Pediatria Médica, Departamento de Pediatria, Centro Hospitalar Universitário Lisboa Norte, Lisboa, Portugal
10. Clínica Universitária de Pediatria, Faculdade de Medicina da Universidade de Lisboa, Lisboa, Portugal
Corresponding Author
Margarida Ramalho | E-mail: margaridaramalho@campus.ul.pt
Address: Unidade de Pneumologia Pediátrica, Hospital de Santa Maria, Avenida Professor Egas Moniz, 1649-035 Lisboa, Portugal
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pathways, which result in hyperactivity of bronchi, remodeling, and airway narrowing. Furthermore, higher temperatures and lower relative humidity can increase pollen release to the atmosphere and thus intensify allergen exposure, which leads to asthma flares.[2] Humid environments are responsible for the rise of other asthma triggering factors, such as fungal spores[3] and the growth of house dust mites.[4] Moreover, the survival and infectivity of respiratory viruses, as another major cause of asthma exacerbations, are strongly dependent both on temperature and relative humidity.[5] Air pollutants must also be considered a trigger factor for asthma, and warm environments[6] have repercussions on the spread, dilution, and accumulation of pollutants.[7]

Acute respiratory infections are the world leading cause of mortality among young children in developing countries[8] and are responsible for the great consumption of health services, mainly during emergency admissions, in Western-style countries.[9] Epidemiological data suggest a significant effect of meteorological factors, such as temperature and relative humidity, in the seasonal variation of acute respiratory infections.[2,10-11] High temperatures are inversely correlated with the respiratory syncytial virus, influenza A, and adenovirus frequency.[10-12] Cold air decreases the functionality of the nasal epithelium and mucociliary defense mechanisms, which makes the lower airways more vulnerable to pathogens.[13] As for relative humidity, its influence depends on the virus infectivity and stability, which behave differently depending on its levels.[11] There are other hypotheses to explain why viruses behave differently depending on meteorological variables, similar to changes in the behavior of the host, that prefers to spend more time indoors, in closed environments when the weather is cold and rainy.[14]

There is a dearth of studies on the association between ambient temperature and relative humidity with the emergence of respiratory diseases in children. Portugal has a temperate climate,[15] and there is a great proportion of inadequately-climatized buildings with high humidity levels due to poor building quality, especially in terms of thermal insulation.[16] These factors along with aeroallergens and pollutants may predispose one to the seasonal burden of respiratory infections and asthma flares that may, in turn, impact health services including children hospitalizations.

Methods

Study design

This retrospective single-center study was conducted in a university hospital in Portugal to investigate the relationship between meteorological parameters (temperature and relative humidity) and the frequency of local acute respiratory infections and acute asthma associated with children hospitalization, using the administrative data recorded from January 2018 to December 2020.

Study population

The collected data included administrative data from January 1, 2018, to December 31, 2020, on the hospitalizations of children (in the age range of 0-17 years) who resided in the municipality of Lisbon, based on the recoded information. Very few 18-year-old patients were included, when the transition to adult care was not completed.

Data related to daily admissions, patient demographics (gender, age in years), and discharge diagnoses were collected from the diagnosis-related group database of the Portuguese Administração Central do Sistema de Saúde (ACSS) and were locally filtered by one of the researchers. Age-restricted codes from the international classification of diseases, 10th revision, clinical modification (ICD-10-CM) were used, and primary and/or secondary discharge diagnosis codes were defined as the condition causing or associated with admission of patients.

The diagnoses considered for this study included tonsilitis, acute tracheitis, acute laryngotracheitis, acute laryngitis, acute upper respiratory infections of multiple and unspecified sites, pneumonia, acute bronchiolitis, unspecified acute respiratory infections, asthma, pleural effusion, nonsuppurative acute otitis (ICD-10-CM codes: J03, J04, J06, J13, J21, J22, J45, J90, and H65, respectively).

For the analysis, diagnoses were classified into four groups:

1. Asthma (ICD-10-CM code J45);
2. Viral lower respiratory infections (viral LRI), including acute bronchiolitis, tracheitis, laryngotracheitis, and laryngitis (ICD-10-CM codes J21, J04);
3. Upper respiratory infections (URI), including tonsilitis, acute upper respiratory infections of multiple and unspecified sites, and non-suppurative acute otitis (ICD-10-CM codes J03, J06, H65);
4. Non-viral lower respiratory infections (non-viral LRI), including pneumonia, pleural effusion, and unspecified acute lower respiratory infections (ICD-10-CM codes J13, J90, J22).

Meteorological data

Temperature and relative humidity data were acquired from four meteorological stations of the Instituto Português do Mar e da Atmosfera (IPMA), in Lisbon (Gago Coutinho, Barreiro, Lisboa Geofísico and Tapada

da Ajuda). These data were available for the period from January 2018 through December 2020 and included values of the mean, maximum, and minimum temperatures, and relative humidity for each day, month, and year studied.
Given the unavailability of some weather data, due to malfunctions or measurement errors at the weather stations, we used the average value of the four stations for this study. We associated each hospital admission date with the corresponding mean, maximum, and minimum temperature and relative humidity values of that same day.

Statistical analysis

Statistical analysis of the data was performed using the Statistical Package for the Social Sciences® (IBM SPSS for Apple macOS, Version 27.0). A database was created, containing a total of 369 diagnoses related to 338 patients, as this study considered primary and secondary discharge diagnoses. These were also aggregated per day for additional analysis.
The data were described using descriptive statistics. Pearson and Spearman correlations were employed to relate the meteorological variables and the number of daily hospitalizations. Additionally, the distributions were compared using Student *t* test, analysis of variance (ANOVA), or the equivalent non-parametric tests (Mann-Whitney and Kruskal-Wallis tests). Eventually, negative binomial regression (a generalized linear model) was employed to model the number of hospitalizations.

Results

Out of the total 338 hospitalized children with a mean age of 3.1 ± 5.2 years, 139 (41.1%) and 199 (58.9%) children were female and male, respectively (Table 1). During the three years period of study, boys were more frequently hospitalized with the frequency of 60.7%, 59.2%, and 51.2%, respectively. In 2020, there was a significant reduction in hospitalizations, with only 41 children admitted.
During the study, there was at least one admission per day for 326 days and no permission per day for two-thirds of the days due to respiratory infections or acute asthma exacerbation. From the total of 338 children admissions in the pediatric service, 369 clinical records were obtained, meaning that 31 records corresponded to children with more than one considered diagnosis in the same admission, as primary and secondary discharge diagnoses were considered for this study.

Table 1. Demographic characterization of hospitalized children with acute respiratory tract infections, in the corresponding period

Gender	n (%)	Mean age (SD) (years)	Median age* (min, max) (years)
Female	139 (41.1)	3.4 (5.4)	0.0 (0,18)
Male	199 (58.9)	2.9 (5.0)	0.0 (0,18)
Total	338 (100.0)	3.1 (5.2)	0.0 (0,18)

* 0.0 means under 1-year-old.
max - maximum; min - minimum; SD - standard deviation.

The mean ± standard deviation (SD) values of daily mean, minimum, and maximum temperatures were 14.8ºC ± 4.0ºC, 11.2ºC ± 3.8ºC, and 19.4ºC ± 5.1ºC, respectively. Considering the relative humidity, the mean ± SD values of mean, minimum, and maximum humidity were 77.7% ± 12.7%, 56.1% ± 17.2%, and 92.2% ± 8.2%, respectively. Each civil year had very similar temperature and relative humidity values (Table 2).
Of the 369 clinical records, viral lower respiratory infections were the most frequent (51.2%) diagnosis, followed by asthma (17.9%), upper respiratory infections (16.3%), and non-viral lower respiratory infections (14.6%). The mean ± SD age of cases in viral lower respiratory infections, asthma, upper respiratory infections, and non-viral lower respiratory infections groups was 0.1 ± 0.3, 9.2 ± 5.8, 4.9 ± 5.6, and 2.6 ± 4.1 years, respectively (Table 3).
The association between the hospitalization days for each group of diseases with the mean, maximum, and minimum temperatures, as well as relative humidity, showed that the number of hospital admissions had a negative correlation with maximum temperature ($r = -0.139$) and a positive correlation with mean relative humidity ($r = 0.111$). In our sample, the only group of diagnosis with a statistically significant relation with temperature and relative humidity was viral lower respiratory infections, specifically with a negative correlation for maximum temperature ($r = -0.202$) and a positive correlation with minimum relative humidity ($r = 0.154$) (Table 4).
Considering the mean temperature, an increase was observed in hospital admissions on days with a mean temperature below 10.0ºC, and a decrease was found in hospital admissions on days with higher temperatures (Fig. 1). In terms of relative humidity, a statistically insignificant increase was observed in the number of hospitalizations on days with mean relative humidity above 86.68%.

Modelling of the daily number of hospital admissions

The modelling of the daily number of hospital admissions revealed a relation with the daily mean temperature. Model 1 shows the best data fit based on the lowest Akaike information criterion (AIC) and Bayesian information criterion (BIC) values (Table 5).

Table 2. Temperature and relative humidity characterization of the corresponding period

Meteorological variables	Mean	SD	Min	Max
Mean temperature (ºC)	14.8	4.0	6.7	27.9
Minimum temperature (ºC)	11.2	3.8	3.1	21.6
Maximum temperature (ºC)	19.4	5.1	11.1	36.9
Mean relative humidity (%)	77.7	12.7	29.8	98.5
Minimum relative humidity (%)	56.1	17.2	12.8	93.3
Maximum relative humidity (%)	92.2	8.2	55.5	100.0

Max - maximum; Min - minimum; SD - standard deviation.

Table 3. Primary and secondary diagnoses for hospitalizations of children with acute respiratory tract infections, in the corresponding period.

	n (%)	Gender		Mean age (SD) (years)	Median age* (min, max) (years)
		Female, n (%)	Male, n (%)		
Asthma	66 (17.9)	27 (40.9)	39 (59.1)	9.2 (5.8)	8.5 (0,18)
Viral LRI	189 (51.2)	71 (37.6)	118 (62.4)	0.1 (0.3)	0.0 (0,1)
Non-viral LRI	54 (14.6)	21 (38.9)	33 (61.1)	2.6 (4.1)	0.0 (0,16)
URI	60 (16.3)	34 (56.7)	26 (43.3)	4.9 (5.6)	3.0 (0,18)
Total	369 (100.0)	153 (41.5)	216 (58.5)	2.9 (5.0)	0.0 (0,18)

* 0.0 means under 1-year-old.
max - maximum; min - minimum; Non-viral LRI - non-viral lower respiratory infections, including pneumonia, pleural effusion, and unspecified acute lower respiratory infections; SD - standard deviation; URI - upper respiratory infections, including tonsilitis, acute upper respiratory infections of multiple and unspecified sites and acute otitis; Viral LRI - viral lower respiratory infections, including acute bronchiolitis, tracheitis, laryngotracheitis, and laryngitis.

Table 4. Pearson and Spearman correlation for the total days with hospital admissions and each group of diagnoses for hospitalizations of children with acute respiratory tract infections, in the corresponding period

	Statistic	Mean temperature	Max temperature	Min temperature	Mean relative humidity	Max relative humidity	Min relative humidity
		Statistic (*p* value) [n]					
Total admissions	Pearson r	**-0.133 (0.016) [326]**	**-0.139 (0.012) [326]**	**-0.120 (0.030) [326]**	**0.111 (0.045) [326]**	0.090 (0.103) [326]	0.109 (0.050) [326]
	Spearman rho	**-0.118 (0.033) [326]**	**-0.137 (0.014) [326]**	-0.078 (0.159) [326]	0.091 (0.099) [326]	0.080 (0.147) [326]	0.092 (0.097) [326]
Asthma admissions	Pearson r	0.009 (0.947) [62]	-0.001 (0.996) [62]	-0.008 (0.952) [62]	0.116 (0.369) [62]	0.112 (0.387) [62]	0.102 (0.429) [62]
	Spearman rho	-0.007 (0.955) [62]	0.000 (10.000) [62]	-0.007 (0.955) [62]	0.119 (0.356) [62]	0.073 (0.571) [62]	0.132 (0.306) [62]
Viral LRI admissions	Pearson r	**-0.190 (0.019) [152]**	**-0.202 (0.012) [152]**	**-0.163 (0.045) [152]**	0.152 (0.061) [152]	0.113 (0.164) [152]	**0.154 (0.058) [152]**
	Spearman rho	-0.143 (0.079) [152]	**-0.179 (0.027) [152]**	-0.084 (0.302) [152]	0.121 (0.138) [152]	0.088 (0.283) [152]	0.108 (0.185) [152]
URI admissions	Pearson r	0.160 (0.229) [58]	0.196 (0.140) [58]	0.119 (0.374) [58]	-0.042 (0.752) [58]	0.037 (0.784) [58]	-0.143 (0.283) [58]
	Spearman rho	0.124 (0.353) [58]	0.175 (0.189) [58]	0.062 (0.643) [58]	-0.093 (0.487) [58]	0.020 (0.883) [58]	-0.181 (0.175) [58]

Max - maximum; Min - minimum; URI - upper respiratory infections, including tonsilitis, acute upper respiratory infections of multiple and unspecified sites and acute otitis; Viral LRI - viral lower respiratory infections, including acute bronchiolitis, tracheitis, laryngotracheitis, and laryngitis.

This model revealed that the daily number of hospital admissions for children in our context had an inverse relation to the daily mean average temperature. The estimated incidence rate ratio (IRR) of 0.989 (below one) indicated a negative correlation between the daily mean temperature and the number of hospital admissions.

Although without statistically significant parameters, model 3 was revealed to be our second-best model (Table 5). This model indicated to have a potentially more complex relationship with the climatic variables. When moderated by daily mean average relative humidity, the relation between average mean temperature and hospital admissions could not be fully explained. Nevertheless, the inverse association was maintained. Although not statistically significant, the relative humidity tended to have a positive association with hospital admissions of children after control for temperature (*ie*, hospital admissions tended to increase with the increase of relative humidity).

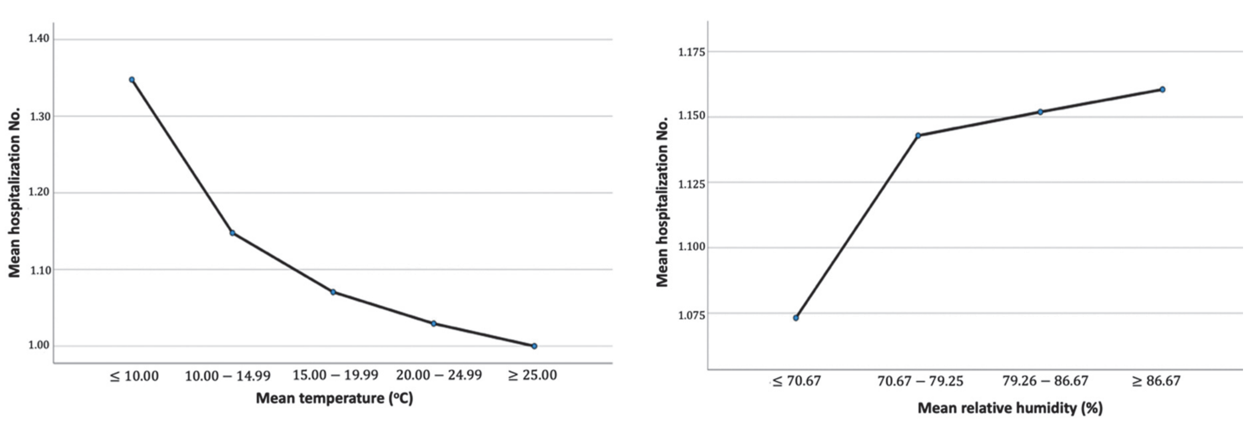
Discussion

The present study analyzed the association of daily monitored temperatures and relative humidity with children hospitalizations. Based on the obtained results,

Table 5. Negative binomial regression of the number of daily hospital admissions for children with acute respiratory tract infections

				95% CI						95% CI		
	Parameter	**B**	**s.e.**	**Lower limit**	**Upper limit**	**Waldchi-square**	**df**	***p***	**IRR**	**Lower limit**	**Upper limit**	**Model diagnostics**
Model 1	(Intercept)	0.29	0.07	0.154	0.427	17.326	1	**< 0.001**	**1.34**	1.166	1.533	AIC = 964.459 AICC = 964.496 BIC = 972.033 CAIC = 974.033
	Mean average temperature	-0.01	0.005	-0.02	-0.002	6.115	1	**0.013**	**0.99**	0.98	0.998	
	(Scale)	-0.058										
Model 2	(Intercept)	0.119	0.074	-0.03	0.264	2.536	1	0.111	**1.13**	0.973	1.303	AIC = 969.106 AICC = 969.293 BIC = 988.040 CAIC = 993.040
	Mean average temperature	-0.01	0.004	-0.02	5.92	3.788	1	0.052	**0.99**	0.983	1	
	Asthma	0.087	0.06	-0.03	0.204	2.142	1	0.143	**1.09**	0.971	1.226	
	Viral LRI	0.219	0.049	-123	0.315	19.83	1	**< 0.001**	**1.25**	1.13	1.371	
	URI	0.05	0.06	-0.07	0.167	0.691	1	0.406	**1.05**	0.935	1.182	
	Non-Viral LRI	.	.	.	.	.	.	.	**1**	.	.	
	(Scale)	0.049										
Model 3	(Intercept)	0.116	0.167	-0.21	0.444	0.486	1	0.486	**1.12**	0.81	1.558	AIC = 966.383 AICC = 966.458 BIC = 977.744 CAIC = 980.744
	Mean average temperature	-0.01	0.005	-0.02	0.001	3.139	1	0.076	**0.99**	0.982	1.001	
	Mean average relative humidity	0.002	0.002	0	0.005	1.312	1	0.252	**1**	0.999	1.005	
	(Scale)	0.057										
Model 4	(Intercept)	-0.82	0.162	-0.4	0.236	0.255	1	0.614	**0.92**	0.671	1.266	AIC = 971.011 AICC = 971.275 BIC = 993.733 CAIC = 999.733
	Mean average temperature	-0.01	0.005	-0.02	0.004	1.394	1	0.238	**0.99**	0.985	1.004	
	Mean average relative humidity	0.002	0.002	0	0.005	1.932	1	0.165	**1**	0.999	1.005	
	Asthma	0.081	0.059	-0.04	0.197	1.876	1	0.171	**1.09**	0.966	1.218	
	Viral LRI	0.221	0.049	0.125	0.317	20.429	1	**< 0.001**	**1.25**	1.134	1.373	
	URI	0.056	0.06	-0.06	0.173	0.878	1	0.349	**1.06**	0.941	1.189	
	Non-Viral LRI	.	.	.	.	.	.	.	**1**	.	.	
	(Scale)	0.049										

AIC - Akaike information criterion; AICC - Akaike information criterion corrected; B - regression coefficient; BIC - Bayesian information criterion; CAIC - consistent Akaike information criterion; CI - confidence interval; df - degrees of freedom; IRR - incidence rate ratio; Non-viral LRI - non-viral lower respiratory infections, including pneumonia, pleural effusion, and unspecified acute lower respiratory infections; s.e. - standard error; URI - upper respiratory infections, including tonsilitis, acute upper respiratory infections of multiple and unspecified sites and acute otitis; Viral LRI - viral lower respiratory infections, including acute bronchiolitis, tracheitis, laryngotracheitis, and laryngitis.
Dependent variable - daily number of children hospital admissions.



No - number.

Figure 1. Number of days with hospital admissions and the correspondent mean temperature (ºC) (A) and relative humidity (%) (B).

in our clinical local setting, the number of hospitalizations due to asthma and respiratory tract infections, especially the infections most probably caused by a virus (in the viral lower respiratory infections group), increased with cold temperatures and humid environments. Although not all the variables were statistically significative in this study, the trends were aligned with the literature.

Concerning hospitalizations due to acute respiratory infections, studies found a significant inverse association with temperature in Germany[10] and Mexico.[17] The same pattern has been observed in outpatient visits due to upper respiratory infections in Taiwan, which indicated a positive association with average temperatures lower than 15.0ºC.[18]

These findings can be explained by the stability and pathogenesis of most viruses in environments with lower temperatures and relative humidity. Moreover, cold weather can make changes in the host defense mechanisms, for instance by diminishing the secretion function of the respiratory mucosa membrane, impairing mucociliary clearance, and vasoconstriction in the respiratory mucosa. In addition, the decrease in immune function reduces the phagocytic activity of leucocytes with inhalation of cold and dry air, leading to increased susceptibility to infections.[11]

As for relative humidity, the association with acute respiratory infections is not linear since viruses behave differently according to their environment. For instance, influenza and parainfluenza viruses are more stable at low relative humidity, but adenovirus,[11] respiratory syncytial virus, and rhinovirus survive longer in humid environments.[10] In this study, we did not specifically describe the microorganisms involved in the infections. Nevertheless, our sample was mostly (51.2%) composed of cases from the viral lower respiratory infections group, including respiratory syncytial virus-caused acute bronchiolitis,[19] and rhinovirus was very frequent in upper respiratory infections (16.3% of total).[20] These results seem to be in line with the literature since these viruses tend to survive in high relative humidity.

Although more significant results were obtained for the viral lower respiratory infections group in this study, asthma admissions tended to increase in the temperature range of 10.0ºC-14.9ºC and relative humidity of 79.26%-86.67%. Results are conflicting in the literature, with some studies suggesting that cold temperatures increase the risk of asthma attacks, and others referring to hot temperatures in this regard.[21] A study in Australia even suggests that higher temperatures are associated with worse pulmonary function, probably due to the higher allergen exposure and airway drying, as common triggers of bronchoconstriction.[22]

Several authors advocate that the impact of meteorological factors in determining diseases is mainly due to exposure in the days immediately before hospitalization, rather than on the day of admission itself, particularly changes in temperature on consecutive days as well as extreme decreases in temperature.[23] Dealing with administrative data in this retrospective study made it impossible to evaluate this finding precisely. However, reports on higher admissions for acute respiratory infections three to five days after temperature variations indicate that this finding can be studied more relevantly with different study designs.[24]

It is important to note that factors other than temperature and relative humidity might as well influence the risk of hospitalizations in children. Although not studied here, it is known that air pollution, such as fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), and others, have a significant impact on hospital admissions for respiratory diseases, especially asthma and infections, due to factors such as the oxidizing effect, increasing bronchial responsiveness, wheezing, asthma exacerbations, and susceptibility to infections.[25] Studies suggest an important interaction between air pollution and hot temperatures, resulting in higher emergency room visits and mortality rates.[26]

In this regard, social factors, such as attending kindergarten, may also play an important role and influence the results since these children can be exposed to the impact of temperature variations, compared to home-care children. Moreover, children attending school are more exposed to outdoor air temperature[27] as well as pathogens that can be transferred through contact with other kids.[28,29]

A lockdown in Portugal was implemented from March 16, 2020[30] after the official announcement of the coronavirus disease 2019 (COVID-19) pandemic by the Director-General of the World Health Organization on March 11, 2020.[31] This made 2020 a peculiar year in many ways, including the significant reduction in the number of hospitalizations, which is quite evident in our study, regarding the admission of only 41 children (12% of the total), since COVID-19 is a disease with little impact on children.[32] The decrease in the incidence of respiratory infections and asthma exacerbations could have been caused by such factors as improved outdoor air quality, reduced exposure to outdoor seasonal aeroallergens,[33] as well as lower viral exposure due to the closure of schools and daycares,[34] and less participation in sports and exercises.[35]

Regarding asthma exacerbations, rather than a gradual drop, which would have been more in favor of improved therapeutic adherence, the decline was abrupt and suggestive of a sudden change in exposure to trigger factors, coinciding with the beginning of lockdown.[33,35] Furthermore, avoidance of healthcare setting due to fear of contracting COVID-19 is another factor that cannot be ignored.[35]

This study has some limitations that should be considered in the interpretation of the results. Firstly, although the data were taken from a large central hospital in Lisbon, the findings may not be directly extrapolated to other locations. Secondly, for the meteorological data, the average values were calculated from four weather stations. Therefore, probably the values are inaccurate for specific localizations. Eventually, this study did not take into account other confounding factors such as aeroallergens, pollutants, indoor environment, or even temperature variation in the days close to hospitalization. Further studies are recommended to be conducted on a bigger population in the various hospitals in the municipality of Lisbon using the meteorological data from the closest stations. In addition, the study of milder cases who presented to the emergency room and did not need hospitalization could be useful for further understanding of the meteorological influence.

In summary, the results of our study show that lower temperatures and higher humidity levels are responsible for a rise in pediatric hospitalizations caused by asthma exacerbations and acute respiratory tract infections, being more evident in respiratory infections of probable viral etiology. We have found cut-off values affecting hospital admissions.

However, meteorological factors do not act in isolation and interact with other variables such as pollutants, allergens, and the presence of microorganisms. Indeed, as beheld in this study, especially in the atypical year 2020, pathogens are essential for asthma flares and hospitalizations due to respiratory infections. This underscores the need for further studies that consider all these factors and their interactions.

This study can help the doctors to teach parents and children about the importance of paying more attention to weather forecasts and adopting preventive measures, mainly during the high-risk periods. Furthermore, pediatric services could be kept informed about atmospheric conditions which might result in their better preparation for respiratory illness overload. In a perfect world, this information could reduce childhood hospitalizations and emergency room visits, which would have tremendous psychological, organic, and economic consequences due to a reduction in school and labor absenteeism and health care costs.

Author Contribuitions

MR, PN and TB participated in the study conception or design. MR, NA, RD and TB participated in acquisition of data. MR, PN and TB participated in the analysis or interpretation of data. MR, PN and TB participated in the drafting of the manuscript. MR, NA, RD, PN and TB participated in the critical revision of the manuscript. All authors approved the final manuscript and are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Conflicts of Interest

The authors declare that there were no conflicts of interest in conducting this study.

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Protection of human and animal subjects

The authors declare that the procedures followed were in accordance with the regulations of the relevant clinical research ethics committee and with those of the Code of Ethics of the World Medical Association (Declaration of Helsinki 2013).

Provenance and peer review

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Confidentiality of data

The authors declare that they have followed the protocols of their work center on the publication of patient data.

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Interações Climáticas e Doenças Respiratórias em Crianças

Introdução: A temperatura e humidade relativa podem afetar a saúde, particularmente respiratória. As crianças representam um grupo de risco, pela sua imaturidade e desenvolvimento contínuos. Os objetivos deste estudo foram analisar os efeitos da temperatura e humidade relativa nos internamentos por exacerbações de asma e infeções respiratórias.

Métodos: Este estudo retrospetivo analisou dados administrativos entre 2018 e 2020, de internamentos no serviço de pediatria de um hospital central. Correlações de Pearson e Spearman, teste *t* de *Student,* análise de variância e correspondentes não paramétricos foram usados para determinar associações entre variáveis climáticas e internamentos. Fizeram-se modelos do número diário de internamentos previstos usando a regressão binominal negativa.

Resultados: Registaram-se 338 crianças e 369 registos clínicos de diagnósticos de alta primários e secundários. Em 2020 verificou-se uma redução de internamentos pela pandemia COVID-19. Dos diagnósticos, 51,2% eram infeções respiratórias baixas virais, 17,9% asma, 16,3% infeções respiratórias altas e 14,6% infeções respiratórias baixas não-virais. As médias diárias de temperatura média foram 14,8 ºC ± 4,0ºC e humidade relativa 77,7% ± 12,7%. Verificou-se correlação negativa com temperatura máxima (p = 0,012) e positiva com humidade relativa média (p = 0,045). No grupo infeções respiratórias baixas virais o número de internamentos aumenta quando as temperaturas médias são < 10,0ºC e humidade relativa > 86,67%. O melhor modelo mostra que quando a temperatura média diária aumenta, os internamentos diminuem (relação taxa incidência = 0,989).

Conclusão: O frio e humidade estão associados a internamentos por asma e infeções respiratórias. O estudo de outras variáveis (por exemplo poluentes) pode identificar outros fatores e promover a prevenção e planeamento em saúde.

Palavras-chave: Internamento de doentes/tendências; Adolescente; Asma/epidemiologia; Asma/etiologia; Criança; Clima; Conceitos Meteorológicos; Humidade; Infeções Respiratórias/epidemiologia; Infeções Respiratórias/etiologia; Lactente; Portugal; Temperatura; Tempo